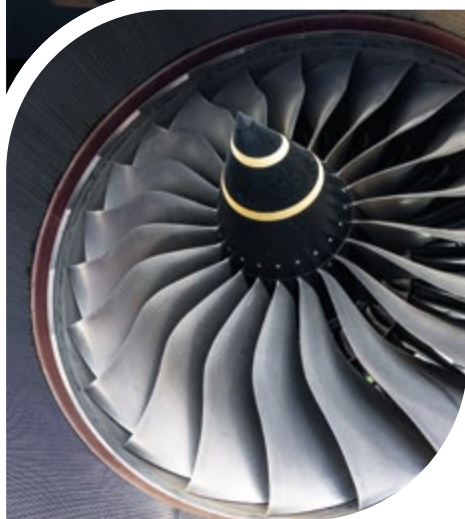


9th edition

of the International conference on fatigue design

PARTNER COUNTRY: GERMANY



17 & 18
November 2021
Senlis - France

fatiguedesign.org

ABSTRACTS BOOK





Prenscia

DATA ANALYTICS AND CAE SIMULATION

Delivering insights
into the performance,
durability, and reliability
of electric systems

ABSTRACTS BOOK

9th edition

of the International conference
on fatigue design

PARTNER COUNTRY: GERMANY

Sponsors



Organizer





Fabien Lefebvre



Pascal Souquet

Introduction Message

On behalf of the Fatigue Design 2021 International Scientific Committee and Organizing Committee, we would like to welcome you all to the 9th edition of Fatigue Design 2021 taking place at Cetim, Senlis, France on November 17 & 18 2021.

Since 2005, and every two years, the conference takes place at Senlis, the City of culture and history, located at 45km from Paris with more than 2000 years of history. The Notre-Dame Cathedral of 12th century, Saint-Pierre church, Medieval ramparts of 13th - 16th century, the château royal and 4 museums are among the most attractive places to be visited.

Organized by Cetim and his partners, the 9th Fatigue Design 2021 International Conference aims to present the most innovative approaches, scientific and technological progress in design methodologies, testing methods and tools to evaluate and extend the fatigue lifetime of the industrial equipment. The papers are mostly focusing on the industrial applications.

Germany is the “partner country” for Fatigue design 2021 in respect to the German advance research works in the area of fatigue and fracture mechanics in the last decade and by means of our strong relationship with the DVM association. More than 30% of conference speakers are coming from Germany including 2 plenary key speakers.

This edition will introduce the first concepts of Big Data and Artificial Intelligence contribution to the fatigue design world through 2 keynotes and 3 presentations.

The following scientific and technical topics are covered:

- additive manufacturing,
- big data and Artificial Intelligence,
- complex loading
- composite and elastomers,
- contact fatigue, fretting and vibration fatigue behavior
- damage tolerance and fatigue life,
- experimental and numerical design and validation methods,
- fatigue of assemblies (mechanical, welded, adhesive-bonding, multimaterial...),
- reliability-based approaches and probabilistic methods,
- influence of manufacturing process in fatigue analysis (effect of microstructure, welding, stress relief techniques...).

The presentations will focus on the latest development and most recent experimental, numerical simulation techniques and the associated engineering tools applied to the large domain of the industrial applications.

The 9th edition of the Fatigue Design International conference is organized in close collaboration with Elsevier editor for the proceedings’ publication through Structural Integrity Procedia. The papers are published online on ScienceDirect, which makes available worldwide for a better dissemination and maximum exposure. In this respect the selection and peer review of the papers have been done in collaboration with the International Scientific and Organizing Committees.

“Fatigue Design” became the reference conference to address the concerns of industrials on fatigue design of structures and components. It is also considered as the trade crossroads between industry and academia: 84 oral presentations are performed with 50% by industry.

We hope that the speakers and the delegates would have a fruitful exchange and discussions on technical and scientific developments and issues during the conferences. The poster sessions and exhibition stands are the complementary opportunities to facilitate the exchanges between the Scientists, industry participants, PhD students and the solution providers. We hope also that the digital platform realised due to the covid situation will allow to welcome people who cannot physically join and promote worldwide the conference.

We would like to thank members of the International Scientific and Organizing Committees for their valuable scientific support for the selection and paper reviews, the authors, delegates for their contributions, exhibitors, and sponsors, SF2M and DVM, and the colleagues of Cetim for the organization and to make this conference successful one.

We wish you all a most pleasant stay in Senlis and hope that you will enjoy the conference.

Fabien Lefebvre
Chairman
Organizing Committee
Fatigue Design 2021

Pascal Souquet
Co-Chairman
Organizing Committee
Fatigue Design 2021

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ENERFAST TESTING	EIKOSIM	HBK	
SONATS-EUROPE TECH.	3R TESTING MACHINES	METAL AM IN FRANCE	
RUMUL AG SUISSE	CETIM	MTS	

Poster Award 2021

The poster session of the 9th edition of the Fatigue Design conference includes more than 20 posters. This session will offer the opportunities for the technical exchanges between the scientists, industry participants, PhD students.

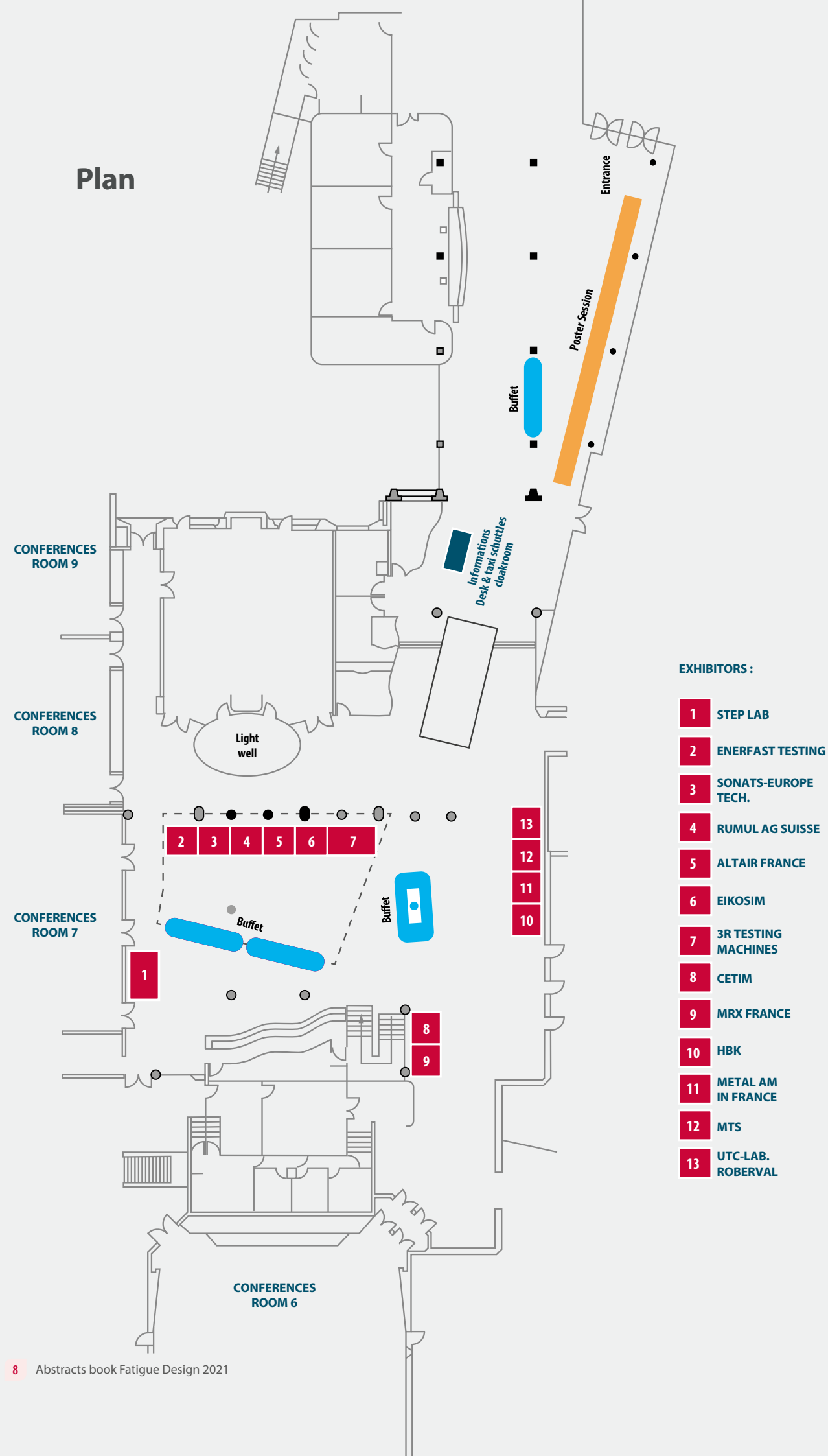
To acknowledge and promote outstanding research and to encourage the young researchers/scientists and PhD students, an award for the best poster has been set.

The best poster will be chosen by the Poster Award Committee members with scientific and technical criteria. The Poster Award winner will receive a Certificate of Recognition and an I-Pad©.

During the 8th Fatigue Design 2019 conference, the Poster Award has been dedicated to Vincent Laflé from Roberval Mechanics Laboratory, UTC, Compiègne, France for his work on “Microstructure evolution of pearlitic steel at early states of wear under rolling contact fatigue”.



Plan



Content

Plenary session

- FD21-11** 23
Artificial neural network approach integrated with finite element analysis for residual stress simulation of direct metal deposition process
Farshid Hajjalizadeh, [Ayhan Ince](#)
- FD21-50** 24
Experimental-numerical analysis microstructure-property linkages for additively manufactured materials
Alexander Raßloff¹, Paul Schulz², Robert Kühne³, André T. Zeuner³, Marreddy Ambati¹, Ilja Koch^{2,4}, Maik Guda², Martina Zimmermann³, [Markus Kästner](#)^{1,4,5}
- FD21-61** 25
Fatigue damage estimation in vehicle thermal subsystems from minimal instrumentation thanks to a mixed engineering / Data science approach
Tudor Miu¹, Marco Bonato², [Frédéric Kihm](#)³
- FD21-99** 26
Definition of simplified fatigue tests using numerical fatigue simulation methods
[Ronald Schrank](#)

S01 Additive manufacturing

- FD21-8** 29
Fatigue property-performance relationship of additively manufactured Ti-6Al-4V bracket for aero-engine application: An experimental study
[Alok Gupta](#)^{1,2}, Chris J. Bennett², Wei Sun²
- FD21-16** 30
Image-based and in-situ measurement techniques for the characterization of the damage behavior of additively manufactured lattice structures under fatigue loading
[Wiebke Radlof](#), Manuela Sander
- FD21-27** 31
Comparison of different approaches to model fatigue for SLM specimens considering production-related characteristics
[Michaela Zeißig](#)¹, Frank Jablonski²

FD21-28	32
Estimating the fatigue thresholds of wrought and additively manufactured metallic materials with consideration of defects	
<u>Daniele Rigon</u> , Giovanni Meneghetti	
FD21-31	33
Correlation between quasistatic and fatigue properties of additively manufactured AISi10Mg using laser powder bed fusion	
<u>Andreas Kempf</u> ^{1,2} , Julius Kruse ³ , Mauro Madia ³ , Kai Hilgenberg ^{2,4}	
FD21-40	34
Effects of the modification of standard powder particle size on fatigue performance of laser powder-bed fused Ti-6Al-4V	
Arash Soltani-Tehrani ¹ , Mohammad Salman Yasin ¹ , Shuai Shao ¹ , <u>Meysam Haghshenas</u> ² , Nima Shamsaei ²	
FD21-45	35
Influence of post-processing treatments on the fatigue behavior of notched additive manufactured TA6V: Rapid fatigue characterization using staircase procedure and infrared techniques	
<u>Théo Dusautoir</u> ¹ , Bruno Berthel ¹ , Siegfried Fouvry ¹ , Paul Matzen ² , Klaus-Dieter Meck ²	
FD21-52	38
Room temperature mechanical properties of additively manufactured ni-base superalloys: A comparative study	
<u>Seyed Ghiaasiaan</u> ^{1,2} , Muztahid Muhammad ^{1,2} , Arash Tehrani ^{1,2} , Shuai Shao ^{1,2} , Nima Shamsaei ^{1,2}	
FD21-66	39
Fatigue behaviour assessment of an industrial component produced by additive manufacturing processes: The hydraulic block	
<u>Christophe Grosjean</u> ¹ , Philippe Amuzuga ² , Etienne Camus ² , Fabien Lefebvre ² , Thomas Munch ³	
FD21-73	40
State of the art of fatigue strength of materials & structures from additive manufacturing – The pivot, A CETIM development	
Benaouda Abdellaoui ¹ , Robin Hauteville ² , Alexian Juin ¹ , Philippe Amuzuga ¹	
FD21-94	41
Experimental and numerical study of fatigue behavior of Ti6Al-4V architected materials obtained by additive manufacturing »	
<u>Marie Pirotais</u> , Nicolas Saintier, Charles Brugger	
FD21-98	42
Contribution of the introduction of artificial defects by additive manufacturing to the determination of the Kitagawa diagram of Al-Si alloys	
<u>Matthieu Bonneric</u> ¹ , Charles Brugger ¹ , Nicolas Saintier ¹ , Antonio Castro-Moreno ² , Benoît Tranchand ²	

FD21-102	43
Influence of microstructure on fatigue behaviour of 316L stainless steel manufactured by laser powder bed fusion (LPBF)	
<u>Hugo Roirand</u> ^{1,2,3} , Benoit Malard ³ , Anis Hor ² , Nicolas Saintier ¹	
FD21-105	44
The effect of surface state on the crack initiation mechanisms of additively manufactured titanium components for aeronautical applications	
<u>David Mellé</u> ^{1,2} , Etienne Pessard ² , René Billardon ³ , Franck Morel ² , Daniel Bellett ² , Martine Monin ¹ , Sandy Blanc ⁴	

S02 Big data and artificial intelligence

FD21-7	47
How fraud detection technologies can help to detect damages in aircraft structures	
<u>Arnaud Cugniere</u> , Olaf Tusch, Andreas Mösenbacher	
FD21-9	48
Prediction of fatigue failure in small-scale butt-welded joints with explainable machine learning	
<u>Moritz Braun</u> , Leon Kellner, Sören Ehlers	
FD21-48	49
A data-driven approach for approximating nonlinear dynamic systems using LSTM networks	
<u>Leonhard Heindel</u> ¹ , Peter Hantschke ^{1,2} , Markus Kästner ^{1,2}	
FD21-95	50
Smart testing: IoT applied to fatigue test monitoring	
<u>Xavier Hermite</u> , Fabien Lefebvre, Matthieu Cronnier	

S03 Complex loadings

FD21-10	53
Local prestressing of cold forging tools by reinforcements with adapted interference	
<u>Martin Killmann</u> , Marion Merklein	
FD21-46	54
Multiaxial variable amplitude loading for automotive parts fatigue life assessment: A loading classification-based approach proposal	
<u>Enora Bellec</u> ^{1,2} , Matteo Luca Facchinetti ¹ , Cédric Doudard ² , Sylvain Calloch ² , Sylvain Moyne ²	

FD21-47	55
A systematic experimental study on the impact of multiaxiality and non-proportionality on fatigue life of cast steels at high temperature	
<u>Karl Michael Kraemer</u> , Alexander Erbe, Fabian Conrad, Christian Kontermann, Matthias Oechsner	
FD21-58	56
Fracture fatigue life calculations with the local strain approach	
<u>Melanie Fiedler</u> ¹ , Michael Vormwald ²	
FD21-91	57
Nonlinear modal time history analysis: allowing for quick stress determination taking nonlinear phenomena into account	
<u>Romain Duval</u>	
FD21-120	58
Methodology for evaluating the probability of failure of a mechanical component in multiaxial fatigue	
<u>Guillaume Causse</u> ¹ , Thierry Yalamas ²	

S04

Composites, elastomers and adhesive bonding

FD21-5	63
Joint strengths and fatigue properties of Al/steel dissimilar adhesive joints	
<u>Yoshihiko Uematsu</u>	
FD21-18	64
An investigation of the residual stiffness and strength of a glass fibre reinforced composite in high cycle fatigue experiments	
<u>Stephan Häusler</u> , Richard Fink, Christopher Benz, Manuela Sander	
FD21-19	65
Fatigue and damage assessment of CFRP material using digital image correlation	
<u>Sara Eliasson</u> ^{1,2,3} , Lars Berg ^{1,2,3} , Per Wennhage ^{1,2} , Zuheir Barsoum ¹	
FD21-79	66
Fatigue of adhesive bonding: world first fatigue s-n curve for fpso application	
<u>Hamza Abbad El Andaloussi</u> ¹ , Luc Mouton ²	
FD21-80	67
Towards a methodology to estimate the experimental fatigue limit for thermoplastic elastomer materials: A mechanical behaviour modelling with hysteresis loops	
<u>Laurent Gornet</u> ¹ , Pierre Robard ¹ , Patrick Rozycki ¹ , Gilles Marckmann ¹ , Jean Charles Guldner ² , Frédéric Maitay ²	

FD21-86	68
Numerical calculation of homogenized effective material properties of the single ply for arbitrary fiber distributions	
<u>Sebastian Spanke</u> , Jan Scholten, Henning Haensel, Jochen Höhbusch	
FD21-88	69
Stress-related structural durability engineering of mounting parts subjected to inertia forces with multi-axial dynamic excitations	
<u>Sébastien Chéreau</u> , Felix Bilger, Kurt Poetter	
FD21-90	70
Ply scale modelling of the fatigue behaviour of a glass fibre / acrylic matrix composite material covering the service temperature range of wind turbine blades	
Eileen Boissin ¹ , <u>Christophe Bois</u> ¹ , Jean-Christophe Wahl ¹ , Thierry Palin-Luc ² , Damien Caous ³	
FD21-104	71
Fatigue strength of adhesively bonded tube-tube specimens under multiaxial loading with constant and variable amplitudes	
<u>Matthias Hecht</u> ¹ , Jörg Baumgartner ^{1,2}	

S05

Contact fatigue, fretting and vibration

FD21-37	77
Effects of inappropriate sampling on counting algorithms in vibration fatigue	
<u>Arvid Trapp</u> , Quirin Hösch, Peter Wolfsteiner	
FD21-68	78
Fretting cracking behaviour of an Al/SiC composite: influence of the anisotropy of the reinforcing particles orientation	
<u>Jean Balmon</u> ¹ , Julien Said ¹ , Siegfried Fouvry ¹ , Patrick Villechaise ² , Jean-Yves Buffière ³ , Josselin Paturaud ⁴ , Julien Feraille ⁵ , Nicolas Guillemot ⁵	
FD21-72	80
Multi-scale modelling and testing of overhead conductors under vibrating loadings	
<u>Julien Said</u> ¹ , <u>Siegfried Fouvry</u> ¹ , Marc Coulangeon ² , Jerome Brocard ² , Georges Caillaud ³ , Christine Yang ⁴ , Fikri Hafid ⁴	
FD21-112	81
Wear resistance under fretting conditions, an alternative to hard chrome plating by using thermal spraying	
<u>C.Trevisiol</u> ¹ , D. Dublanche ² , S. Beauvais ³ , E. Aubignat ³ , P. Spiller ⁴ , YM. Chen ¹ , C. Luh-Minh ¹ , A. Govaere ¹ , R. Jacques ¹ , K. Leclerc ¹ , D. Cazé ¹	

S06 Damage tolerance and fatigue life

FD21-13	85
3D FEA based surrogate modeling in fatigue crack growth life assessment	
Adrian Loghin ¹ , Shakhrukh Ismonov ²	
FD21-20	86
Experimental study of a CoCrMo alloy treated by SMAT under rotating bending fatigue	
Lucas Brasileiro ¹ , Zhidan Sun ¹ , Catherine Mabru ² , Rémy Chieragatti ² , Gwénaëlle Proust ³ , Delphine Retraint ¹	
FD21-21	87
The effect of the environmental conditions on the threshold against fatigue crack propagation	
Larissa Duarte, Mauro Madia, Uwe Zerbst	
FD21-22	88
Determination of fatigue crack propagation thresholds using small-scale specimens	
Tiago Werner ¹ , Sergio Blasón ¹ , Mauro Madia ¹ , Julius Kruse ¹ , Matteo Benedetti ²	
FD21-25	89
Estimation of the Kitagawa-Takahashi diagram by cyclic R-curve analysis	
Mauro Madia, Uwe Zerbst, Tiago Werner	
FD21-34	90
Fatigue strength of autofrettaged component-like specimens made of ultra high strength steel	
Carl Fällgren, Heinz Thomas Beier, Michael Vormwald	
FD21-53	91
Assessment of fatigue crack growth based on 3D finite element modeling approach	
Paul Ilie ¹ , Ayhan Ince ¹ , Adrian Loghin ²	
FD21-54	92
The REX-model: a phenomenological approach for crack growth evolution description under fatigue loading	
Sergio Blasón ¹ , Alfonso Fernández-Canteli ² , Cristina Rodríguez ² , Enrique Castillo ^{3,4}	
FD21-65	93
Crack propagation analysis using XFEMand following evaluation of deck repair projects at rib-to-deck weldingfor steel orthotropic bridge decks	
Jacques Berthellemey ¹ , Morteza AhmadiVala ²	

FD21-87	94
Residual Life Assessment (RLA) of structures and equipment	
Bruno Depale, Mohamed Bennebach	
FD21-100	95
Instrumented fatigue tests on 316L and TA6V samples producedby wire arc additive manufacturing	
Hacquard Christophe, Deschaux-Beaume Frédéric, Wattrisse Bertrand, Muracciole Jean-Michel, Soulié Fabien	

S07 Experimental and numerical design and validation methods

FD21-6	99
Structural integrity proof of automotive safety parts	
Matteo Facchinetti	
FD21-30	100
Identification method of vehicle loads using a multi body vehicle model, real sensors and an extended Kalman filter	
Debarbouillé Alexandre ^{1,2} , Dion Jean-Luc ² , Renaud Franck ² , Dimitrijevic Zoran ¹ , Chojnacki Denis ¹	
FD21-32	101
Optimized vehicle durability testing by means of an intelligent test driver guidance system	
Florian Grober ¹ , Andreas Janßen ¹ , Ferit Küçükay ²	
FD21-36	102
Towards a better understanding of mechanical stress applied by passenger vehicle customers with optimized instrumentation and relevant data post-processing méthodologies	
Denis Chojnacki	
FD21-49	103
Phase-field model, fatigue, residual stresses, local strain approach, Paris law	
Martha Seiler ¹ , Marreddy Ambati ¹ , S. Keller ² , N. Kashaev ² , B. Klusemann ^{2,3} and Markus Kästner ^{1,4}	
FD21-59	105
Advanced fatigue assessment - The future of wind turbine towers	
Hendrik Bissing ¹ , Marion Rauch ² , Markus Knobloch ¹	
FD21-62	106
Digital twin for fatigue analysis	
Amaury Chabod	

FD21-75	107
Fatigue strength of laser-dressed non-load-carrying fillet weld joints made of ultra-high-strength steel	
Tuomas Skriko, Antti Ahola , Ilkka Poutiainen, Timo Björk	
FD21-93	108
On the evaluation of overload effects on the fatigue performance of engineering materials	
Kimiya Hemmesi ¹ , Franz Ellmer ² , Majid Farajian ³ , Michael Luke ¹	

S08

Fatigue of assemblies (mechanical, welded, adhesive-bonding, multimaterials,...)

FD21-2	111
Life-cycle energy analysis of a high strength steel heavy vehicle component subjected to fatigue loading	
Nitish Shetye, Mathilda Hagnell Karlsson, Per Wennhage, Zuheir Barsoum	
FD21-3	112
Fatigue and ultimate strength assessment of post weld treatedstrenx 1100 plus butt welds	
Tobias Jonsson ¹ , Torbjörn Narström ² , Zuheir Barsoum ¹	
FD21-14	113
The peak stress method applied to fatigue lifetime estimation of welded steel joints under variable amplitude multiaxial local stresses	
Luca Vecchiato, Alberto Campagnolo, Beatrice Besa, Giovanni Meneghetti	
FD21-17	114
Fatigue assessment of welded joints including the effect of residual stresses	
Andrea Chiocca , Francesco Frendo, Leonardo Bertini	
FD21-64	115
Fatigue evaluation of beam cope holes in the web coinciding with thickness transition in the flange (study commissioned by ASF-Vinci and French Road Directorate)	
Jacques Berthelley	
FD21-67	116
Overview on the fatigue strength of single-sided transverse and longitudinal fillet weld joints	
Antti Ahola ¹ , Tuomas Skriko ² , Timo Björk ¹	

FD21-69	117
Influence of overload on fatigue behaviour of longitudinal non-load-carrying welded joints	
Isabel Huther ¹ , Fabien Lefebvre ¹ , Benaouda Abdellaoui ¹ , Vincent Leray ²	
FD21-78	118
Influence of out-of-plane deformation on fatigue strength of web gusset welded joints	
Yuki Takahashi ¹ , Masahiro Sakano ¹ , Taiga Teranishi ¹ , Yoshihiko Takada ²	
FD21-81	119
Investigation of fatigue performance for structural steels and their weldments in VHCF domain	
Yevgen Gorash ¹ , Tugrul Comlekci ¹ , Gary Styger ²	
FD21-83	120
Parametric calculations of service fatigue life of welded t-joints	
Miloslav Kepka, Miloslav Kepka Jr.	
FD21-89	121
Fatigue design of mild and high-strength steel cruciform joints in as-welded and HFMI-treated condition by nominal and effective notch stress approach	
Peter Brunnhofer , Christian Buzzi, Tobias Pertoll, Martin Rieger, Martin Leitner	
FD21-101	122
Fatigue testing and analysis of aluminum welds in highway bridge decks	
Mahmoud Trimech ¹ , Charles-Darwin Annan ¹ , Scott Walbridge ²	
FD21-111	123
A stochastic modeling of fatigue behavior on welding joints in automotive structures	
H. Guo ^{1,3} , P. Feissel ¹ , F. Druesne ¹ , N. Limnios ² , S. Bouzebda ² , A. Patigniez ³ , S. Bouyaux ³	

S09

Reliability–based approaches and probabilistic methods

FD21-33	127
Fatigue characterization of car loading histories using equivalent load approaches	
Emilien Baroux ^{1,2,3} , Benoit Delattre ¹ , Ida Raoult ¹ , Patrick Pamphile ³ , Andrei Constantinescu ²	
FD21-55	128
A methodology for the probabilistic analysis of fatigue cumulative damage cases	
Enrique Castillo ¹ , Sergio Blasón ² , Miguel Muniz-Calvente ³ , Alfonso Fernández-Canteli ⁴	

FD21-70 129

A new generic method to analyze fatigue results

[Robin Hauteville](#), Xavier Hermite

FD21-97 130

Scatter and size effect in high cycle fatigue strength due to the effects of porosity in cast aluminum-silicon alloys: Probabilistic modelling

[Driss El Khoukhi](#)^{1,2}, Franck Morel¹, Nicolas Saintier³, Daniel Bellett¹, Pierre Osmond², Viet-Duc Le¹

S10 Taking into account manufacturing process in fatigue analysis (effect of microstructure, welding, residual stresses,...)

FD21-24 133

Design of microstructural gradient for fatigue properties of pearlitic steels

[Lais Avila de Oliveira Silva](#)¹, Christophe Mesplont², Jérémie Bouquerel¹, Jean-Bernard Vogt¹

FD21-35 134

Estimation of fatigue life for clinched joints with the local strain approach

[Boris Spak](#)¹, Markus Kästner², Melanie Fiedler¹

FD21-41 135

A comparative study on fatigue performance of various additive manufactured titanium alloys

Mohammad Salman Yasin¹, Arash Arash Soltani-Tehrani¹, Shuai Shao¹, [Meysam Haghshenas](#)², Nima Shamsaei¹

FD21-56 136

Fatigue software smart use to calculate by FEA a complete map of the damage due to a duty cycle, regarding thermo-mechanical fatigue failure modeApplication to a truck cylinder head lifetime assessment

[Barthoux Kamilia](#)¹, Blondet Hubert²

FD21-82 137

Effect of machining, heat and surface treatment process on gear fatigue performance (bending and pitting)

[Victorien Gautheron](#)¹, Simon Jolivet¹, Hind Orkhis², Marion Risbet³, Julie Marteau³, Fabien Lefebvre¹, Hervé Rognon¹

FD21-103 138

High cycle fatigue behaviour of high-pressure die-cast aluminium alloy AlSi9Cu3: Role of defects and loading conditions

[Thomas Landron](#)^{1,2,3}, Franck Morel¹, Nicolas Saintier², Viet Duc Le¹, Daniel Bellett¹, Pierre Osmond³

Poster session

FD21-2 141

Life-cycle energy analysis of a high strength steel heavy vehicle component subjected to fatigue loading

Nitish Shetye, Mathilda Hagnell Karlsson, Per Wennhage, [Zuheir Barsoum](#)

FD21-12 142

The cyclic strain evolution and the fatigue prediction in non-proportional multiaxial loadings of NiTi SMAs

[Di Song](#)^{1,2,3}, Chao Yu⁴

FD21-23 143

Comparison of the fatigue behavior of wrought and additively manufactured AISI 316L

[Tiago Werner](#), Mauro Madia, Uwe Zerbst

FD21-26 144

Investigation of residual stresses and microstructure effects on the fatigue behavior of a L-PBF AlSi10Mg alloy

[Ilaria Roveda](#), Itziar Serrano-Munoz, Mauro Madia

FD21-35 145

Estimation of fatigue life for clinched joints with the local strain approach

[Boris Spak](#)¹, Markus Kästner², Melanie Fiedler¹

FD21-51 146

High temperature tensile and fatigue behaviors of additively manufactured IN625 and IN718

[Sugrib Shaha](#)^{1,2}, Seyed Ghiaasiaan^{1,2}, Arun Poudel^{1,2}, Nabeel Ahmed^{1,2}, Shuai Shao^{1,2}, Nima Shamsaei^{1,2}

FD21-57 147

Planning and assessment of dental implant fatigue tests using a specific software program

Marta García-González¹, [Sergio Blasón](#)², Ismael García-García³, María Jesús Lamela-Rey³, Alfonso Fernández-Canteli³, Ángel Álvarez-Arenal¹

FD21-60 148

Fatigue assesment of the wind induced vibrations of a cableat St Nazaire cable stayed bridge

[Jacques Berthelley](#)¹, Dominique Siegert², Edouard Berton³, Pierre Quentin⁴

FD21-71 149

Fretting fatigue of shrink fitted assembly under rotating bending loading: A numerical and experimental study to compare Crossland fatigue stress analysis and Ruiz contact stress approach

[Benjamin Dieu](#)^{1,2}, Siegfried Fouvry¹, Florent Bridier³, Christian Ménard³

FD21-76	151
Fretting fatigue of lug-bush connection members with interference fit: Comparison between a multiaxial fatigue stress analysis and “tribological” Ruiz surface stress approach	
<i>Mélody Le Falher^{1,2}, Siegfried Fouvry¹, Clément Defaisse², Nicolas Hervé²</i>	
FD21-77	152
Proposal and verification of countermeasure against fatigue cracking from welded joints between trough ribs and cross ribs in orthotropic steel decks	
<i>Yuichi Shiraishi¹, Masahiro Sakano¹, Chihiro Sakamoto², Hideyuki Konishi³, Koichi Omori⁴</i>	
FD21-82	153
Effect of machining, heat and surface treatment process on gear fatigue performance (bending and pitting)	
<i>Victorien Gautheron¹, Simon Jolivet¹, Hind Orkhis², Marion Risbet³, Julie Marteau³, Fabien Lefebvre¹, Hervé Rognon¹</i>	
FD21-84	154
Fatigue life of welded junction by electron beam in Ti-6Al-4V	
<i>Natan Bodlet¹, Yves Nadot², Rémi Amargier³</i>	
FD21-85	155
Interaction hydrogen/microstructure of a nickel base superalloy: Impact on low-cycle fatigue behavior and fatigue crack initiation	
<i>Achraf Radi¹, Marion Risbet¹, Jérôme Favergeon¹, Gilbert Hénaff², Abdelali Oudriss³, Xavier Feaugas³</i>	
FD21-92	156
Designing very high-cycle fatigue specimens of additively manufactured Ti-6Al-4V with different porosities and microstructures	
<i>Grégoire Brot^{1,2}, Véronique Favier¹, Imade Koutiri¹, Vincent Bonnard², Corinne Dupuy¹, Nicolas Ranc¹, Fabien Lefebvre³</i>	
FD21-96	157
Scatter and size effect in high cycle fatigue of cast aluminum-silicon alloys: A comprehensive experimental investigation	
<i>Driss El Khoukhi^{1,2}, Franck Morel¹, Nicolas Saintier³, Daniel Bellett⁴, Pierre Osmond², Viet-Duc Le¹</i>	
FD21-120	158
Methodology for evaluating the probability of failure of a mechanical component in multiaxial fatigue	
<i>Guillaume Causse¹, Thierry Yalamas²</i>	

Plenary session

Chairmen:

F. Lefebvre & F. Morel

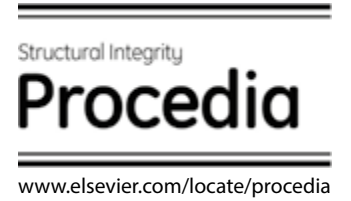
F. Lefebvre & P. Souquet



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FATIGUE DESIGN 2021

FD21-11

Artificial neural network approach integrated with finite element analysis for residual stress simulation of direct metal deposition process

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Additive manufacturing (AM) based on direct metal deposition (DMD) has been attracted great attention in both academia and industry. AM is known as progressively deposition of material onto a substrate by implementing a thermal source. Although AM provides significant improvements in terms of reducing production cost and time, the generation of residual stresses inside the fabricated part, as the result of heating and cooling cycles, is inevitable. Finite elements (FE) analysis has been used to predict the residual stress distribution in AM products. However, computational time of FE models remains as a challenging problem in practical applications. Machine learning methods e.g. artificial neural networks (ANN) have shown great potential for modeling of complex mechanical behavior. A novel artificial neural network-based modelling approach integrated with finite element analysis is proposed to address shortcomings of conventional thermo-mechanical FE-based models for predicting residual stresses of DMD parts. Predicted results showed that the novel approach is capable of accurate and efficient prediction of residual stress distributions of three different AISI 304L structures e.g. a plane wall shape, L-shape wall, and rectangular box structures. Furthermore, the computational time of predicting the residual stresses for three structures is significantly improved with respect to the classical FE thermo-mechanical analysis. The proposed approach shows great potential for prediction of residual stress and distortion of real complex components built on the basis of the DMD process.



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FATIGUE DESIGN 2021

FD21-50

Experimental-numerical analysis microstructure-property linkages for additively manufactured materials

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The innovation of new or improved products fabricated from additive manufacturing processes with desired properties and its reliable utilization depends on a multitude of trials. Therefore, a systematic approach is essential to accelerate materials development. This can be realized by developing systematic materials knowledge in the form of process-structure-property (PSP) linkages.

In this envisioned framework, the present work aims to derive the SP linkages of additively manufactured Ti-6Al-4V alloy. The main focus is to investigate the influence of potential defects (pores) inherited from the fabrication process on the fatigue properties. The polycrystalline structure geometry, including the porosity at a microscale, is obtained by processing the Light Microscopy (LM) Electron Back-Scatter Diffraction (EBSD) and Computed Tomography (CT) measurements. A detailed statistical analysis is performed to obtain a low-dimensional representation of the structure (inputs). Based on these statistical measurements, a suitable reconstruction algorithm is developed to create pore distributions that are incorporated into synthetic Statistically Similar Volume Elements (SSVEs). Using these SSVEs, microscale crystal plasticity simulations in DAMASK are performed to obtain the material properties (outputs) such as yield strength and Fatigue Indicator Parameters (FIP).

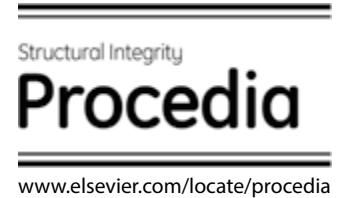
The linkages of inputs and outputs are established through regression techniques using datasets generated by simulations. A detailed numerical analysis is carried out to study the influence of pore statistics such as spatial distribution, size distribution or porosity fraction. Data analysis is carried out to rank-order the SSVEs based on FIPs. Furthermore, a comparison with the empirical Murakami's square root area concept is made.



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FATIGUE DESIGN 2021

FD21-61

Fatigue damage estimation in vehicle thermal subsystems from minimal instrumentation thanks to a mixed engineering / Data science approach

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Monitoring damage and its potential causes in lab-tested structures requires extensive instrumentation that cannot be feasibly replicated in production assets. Since strain gauge instrumentation at a large scale is impractical, other proxy measurements for damage such as pressure, temperature or acceleration can be monitored and damage can be inferred from them. There is considerable difficulty in understanding not only which events lead to significant damage accumulation, but also in suitably and economically instrumenting assets in order to capture these data.

We propose a general framework for exploring data which is inspired from the field of data science. Using a combination of engineering calculation packages and open-source data science tools, we show how engineers can further their understanding of the problem domain. We present a case study involving an automotive Valeo thermal subsystem that is extensively instrumented with strain gauges, temperature and pressure sensors and accelerometers. We evaluate absolute damage from the strain data and, by using engineering indicators, data reduction, visualisations, correlations and outlier detection, we show how a minimal instrumentation subset can be identified for the purpose of damage approximation.



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FATIGUE DESIGN 2021

FD21-99

Definition of simplified fatigue tests using numerical fatigue simulation methods

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“Virtual prototyping” has been established as an important part of the development process for technical components and technical systems. Fatigue simulation is a main discipline in virtual prototyping, but it is a quite complex field, especially for structures being exposed to time-varying multi-channel loads. Thus, at the end of the development process, the series approval for technical components is often based on extensive fatigue tests, particularly with regard to automotive chassis parts.

Currently, test-based fatigue qualification gathers interest in other process phases, for instance

- to assure fatigue safety just for non-series / prototype parts
- to make quality checks during series parts production on the supplier’s site
- to validate fatigue simulation methods just within the first phases of the development process

Main requirements concerning these fatigue tests are a simplified test set-up as well as a short test duration. These requirements are interpretable as an objective function of a kind of “fatigue test optimization”. Reproduction of the results of the “full” fatigue test is the main constraint of this optimization task.

A typical process of simplified fatigue definition will be clarified using the main structural part of a double wishbone wheel suspension as a typical example. First, basics of simulation-based fatigue analysis will be summarized. Next, some strategies of fatigue test simplification will be discussed. Results are presented in terms of a comparison of the “full” fatigue test and the simplified fatigue test. Finally, the utilization of an in-house developed optimization tool for future applications will be outlined.

S01

Additive manufacturing

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FATIGUE DESIGN 2021

FD21-8

Fatigue property-performance relationship of additively manufactured Ti-6Al-4V bracket for aero-engine application: An experimental study

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Selective Laser Melting (SLM) is a promising Additive Manufacturing (AM) technology which offers exciting opportunities to make weight sensitive complex shape parts in Ti-6Al-4V material for safety critical and weight sensitive parts for aerospace applications. Porosity and lack of fusion voids, which are inherent to the AM process, can cause significant debits in the fatigue performance of the SLM parts [1]. SLM parts operating in vibration environment on an aeroengine require an in-depth analysis and validation using the test results before the parts can be certified for a safe flight of the engine [2]. There exist several studies depicting fatigue strength of the SLM Ti-6Al-4V alloy, but studies on fatigue performance of an SLM part are very limited [3].

In this study, the X-Ray CT scan and fracture surface examinations results are used to describe the morphology, density and distribution of defects in the SLM Ti-6Al-4V alloy samples. Results of high cycle fatigue data obtained from the laboratory testing are used to establish; (1) endurance limit of the SLM Ti-6Al-4V alloy and (2) its relationship with fatigue performance of the SLM bracket tested on the shaker table (Fig. 1). Finite Element Analysis (FE) predictions are used in conjunctions with the endurance limit of Ti-6Al-4V alloy to establish high cycle fatigue performance of the bracket in an engine vibration environment. A 3-way relationship of 'defect size - property - part performance' is described to prepare the substantiation needed to qualify the SLM bracket for use on an aero-engine.



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FD21-16

Image-based and in-situ measurement techniques for the characterization of the damage behavior of additively manufactured lattice structures under fatigue loading

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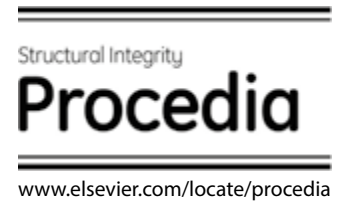
Additively manufactured structures have a great potential to be applied in load-bearing porous implant structures. Due to the flexibility of the manufacturing process the porous structure design can be adjusted to achieve desired mechanical properties, e.g. to match the elastic modulus of human bone or to obtain desired ultimate limit and fatigue strength. For a safe application in load-bearing implants knowledge of the material and damage behavior as well as failure mechanisms is essential. In this paper, different designs of Ti-6Al-4V lattice structures with cubic unit cells were fabricated by electron beam melting. To investigate the mechanical response as well as damage behavior under compression, bending and torsional loading conditions the lattice structures were tested in cyclic tests. The influence of the structure-determining parameters, such as porosity and strut thickness on the mechanical response was highlighted and power law expressions were proposed. To characterize the damage behavior and failure mechanisms different image-based and in-situ measurement techniques, e.g. digital image correlation technique, temperature field measurement and potential drop method, were implemented into the test rigs. X-ray tomography and microstructural analyses were used to distinguish the failure behavior in dependence of manufacturing related imperfections. Therefore, the experiments were interrupted, scanned and examined at defined points. The successful application of the measurement techniques allows an insight into the damage behavior as well as underlying failure mechanisms of 3D printed lattice structures under fatigue loading. Moreover, the identified results provide the basis for the validation of subsequent numerical simulations using local damage approach.



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FD21-27

Comparison of different approaches to model fatigue for SLM specimens considering production-related characteristics

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Additive manufacturing processes such as selective laser melting (SLM) gain more and more importance and are already applied in various industries ranging e.g. from aerospace to automotive. However, in order to further spread their distribution among the common manufacturing technologies, reliable material data is required. While static material data for various materials is available in literature, fatigue data is comparably scarce.

Due to the manufacturing process, the parts show especially high surface roughness, isolated pores at overall low porosity and significant macroscopic residual stresses in the unprocessed state. As it is not always possible to alter these features, it seems advisable to incorporate them in a fatigue model for SLM specimens. Furthermore, the part's properties can vary depending on the building direction and the building parameters, hence a non-isotropic approach should also be considered depending on the degree of anisotropy.

Different fatigue models incorporating the aforementioned aspects will be applied and compared. These include models primarily focussing on the aspects of stress raisers such as pores, considering the factors like stress triaxiality as part of the underlying mechanism of failure, and damage mechanics approaches. Some approaches especially for the aspect of defects can be taken from other areas such as casting. As input data, experimental results are supplemented by results generated via Finite Element Method (FEM) e.g. for residual stresses.



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FD21-28

Estimating the fatigue thresholds of wrought and additively manufactured metallic materials with consideration of defects

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The fatigue limits of defective alloys can be estimated by using classical models which require the experimental evaluation of some material properties. In the case of the El-Haddad model (E-H), the experimental fatigue limit of the “defect-free” material, $\Delta\sigma_0$, and the threshold stress intensity factor for long cracks $\Delta K_{th,LC}$ are required to evaluate the transition of the Kitagawa-Takahashi diagram, i.e. the fatigue limits of small defects. Recently, by using data taken from the literature we have calibrated an empirical model for evaluating the $\Delta K_{th,LC}$ of several wrought as well as additively manufactured (AM) alloys for a load ratio $R=-1$, where the sole required parameters are the hardness (HV) and defined microstructural lengths [1]. Then, since $\Delta\sigma_0$ is approximately $3.2 \cdot HV$, it was possible to draw the E-H curve and comparing it with short cracks/small defects fatigue tests results taken from the literature. Given the encouraging results obtained, we wanted to extend the same calibration for determining $\Delta K_{th,LC}$ by using I and HV also for different load ratios (i.e. 0.1 and 0.5) on data taken from the literature. The second material parameter, i.e. the $\Delta\sigma_0(R)$, was evaluated by using the $\Delta\sigma_0(R=-1)=f(HV)$ corrected by using a classical mean-stress-based model. Finally, fatigue tests results related to small defects of some AM materials found in the literature demonstrated a good agreement with the predicted E-H model.

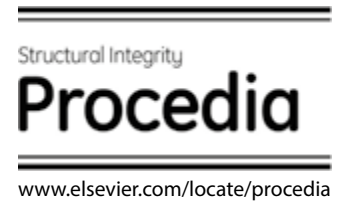
[1] Rigon and Meneghetti. An engineering estimation of fatigue thresholds from ..., IJF, 139 (2020), 105796



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FATIGUE DESIGN 2021

FD21-31

Correlation between quasistatic and fatigue properties of additively manufactured AlSi10Mg using laser powder bed fusion

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Qualification of additively manufactured (AM) components is still challenging and requires an understanding of the relationship among technological parameters, microstructure and resulting mechanical performance. Especially for the perspective use of AM structures as safety-critical, cyclic loaded components, conventional approval processes need costly and time-consuming test series and are, thus, in contradiction with the high production flexibility achievable with those technologies. It is well known that the fatigue resistance of parts produced with laser powder bed fusion (L-PBF) strongly depends on surface quality and material defects. In this context, the objective of the present contribution is to identify the relation between quasistatic and fatigue properties of AlSi10Mg specimens manufactured with L-PBF in order to find a resource efficient approach for the fatigue lifetime prediction. Overall, nearly 200 rotating bending tests have been performed and related to the microstructural characteristics and properties from tensile tests. The examination included different heat treatment conditions, surface finishes and L-PBF machines.

The test results showed that the high attainable tensile strength properties after the manufacturing process are not beneficial in the high cycle fatigue (HCF) regime. In contrast, post process heat treatment improved dramatically the fatigue behavior and lead to higher ductility. Furthermore, different surface roughness induced by the applied L-PBF machines influenced HCF performance. A clear correlation between the elongation at fracture and HCF resistance of machined samples has been found. This empiric relationship provides an estimation of the fatigue resistance in presence of defects and can be implemented in part qualification processes.

Effects of the modification of standard powder particle size on fatigue performance of laser powder-bed fused Ti-6Al-4V

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In powder-based metal additive manufacturing, one key specification that needs to be precisely optimized is the particle shape and size distribution of metallic powders. Particle shape and size distribution influences the flowability of the powder and the uniformity of powder bed density (i.e. packing state of the powder). These eventually affect the porosity, which ultimately influences the fatigue performance of the fabricated parts. Therefore, it is essential to understand the effect of powder characteristics on the fatigue behavior before additively manufactured parts can be used in load-bearing, safety-critical applications. The current study aims at modification of the standard recommended particle size distribution of 15-53 μm on mechanical properties and fatigue response of laser beam powder bed fused (LB-PBF) Ti-6Al-4V; an alpha-beta workhorse alloy of the titanium family. A modified Ti-6Al-4V powder batch with adjusted D10, D50, and D90 was used to fabricate the parts employing an EOS M290 machine. The processability and associated mechanical properties were compared with the manufactured components with the recommended particle size distribution of 15-53 μm . Powder characteristics, including flowability, size, and shape morphology, are investigated to reveal the differences between the two tested powder batches. Porosity levels and mechanical testing results are compared among specimens fabricated from different powder batches and the differences are explained based on variations in powder characteristics.

Influence of post-processing treatments on the fatigue behavior of notched additive manufactured TA6V: Rapid fatigue characterization using staircase procedure and infrared techniques

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Engineering structures are routinely subjected to cyclic multiaxial stress states, the additive manufacturing (AM) process offers new opportunities for manufacturers to reach designs that perfectly fit to the specific solicitations. The aim of this study is to characterize the High Cycle Fatigue (HCF) behavior of 3D printed Titanium alloy (i.e., TA6V) subjected to cyclic multiaxial stresses involving a stress gradient representative of the loading applied to a mechanical component (coupling). Thus, fatigue tests were conducted on TA6V notched specimens obtained with Selective Laser Mating (SLM) process. In addition to the staircase procedure, a thermographic approach using an infrared camera was applied on this particular material to quickly and easily compare different specimen configurations.

The additive manufacturing process has made significant progress since few years and so the possibilities that it offers as well, i.e., lighter parts, fast build, and optimized designs. John Crane, which is a global leader in the design, development and providing of mechanical seals, filtration systems and power transmission couplings has found an interest to explore the potential of AM by developing couplings prototypes. A flexible coupling is a device used to connect two machines at their shaft ends for the purpose of transmitting torque, it is designed to accommodate misalignment and absorb shock loads

(cf. Fig. 1).

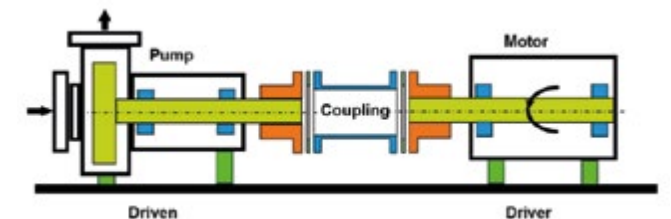


Fig. 1. Power transmission coupling.

In operation, these mechanical parts are subjected to complex multiaxial fatigue loading with stress gradient induced by the geometry and the misalignments. Therefore, it is necessary to characterize properly the behavior of these parts under fatigue loading to ensure a sufficient fatigue life. On the other hand, the layer-built strategy used in additive manufactured process creates defects and microstructures that defer from those seen in conventional metals (DebRoy et al. 2018). The fatigue performances of AM parts are altered by the presence of porosities (Le et al. 2020), residual stresses and high surface roughness (Sanaei and Fatemi 2020). As this technology is used for critical engineering solutions, post-processing treatments are generally used to ensure the requested mechanical properties. In this study the influence of mechanical surface finishing and heat-treatments on

the fatigue properties of TA6V alloy obtained by SLM (Selective Laser Melting) are investigated. The surface roughness and microstructures of different specimen configurations are presented in the next figure. Microblasting using ceramic microbeads supplied by Zirpro permits to highly reduce the surface roughness and results in smoother surface (cf. Fig. 2).

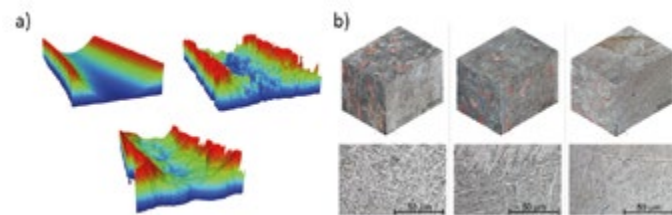


Fig. 2. a) Notch surface texture of reference TA6V, microblast AM TA6V, as built AM TA6V. b) Microstructures at different scales of as built, Sub-transus and super transus heat treated AM TA6V

Although John Crane has all the facilities to test the couplings in industrial conditions, the production of several AM couplings would be too expensive. It has been shown that the bridge between life prediction of conventional laboratory fatigue tests specimen and real life component is even more difficult for AM parts because of the volume effect (Edy et al. 2020). Consequently, a choice has been made to design an equivalent specimen instead of using conventional fatigue test specimen geometry.

Three matters were identified as critical:

- Transcribe the cyclic loading: couplings undergo multiaxial stresses due to the loading and the complex geometry, result of the AM, as well. As a result, the cyclic loading will be reduced to an equivalent cyclic scalar value calculating using the Crossland multiaxial fatigue criterion.

- Take into account the stress gradient effect: The geometry obtained from topology optimization generates high localized stresses that introduces stress gradient, it is characterized by the hydrostatic stress gradient which is known to influence the fatigue life (Papadopoulos and Panoskaltis 1996).
- Consider the volume effect: It is known that the fatigue performance of a part can be influenced by its size because of the probability to encounter a material defect.

Following this strategy, we came up with a double semicircular notch rectangular bar design.

For this work, an alternative method to the staircase has been used to rapidly compare different material configurations, i.e., infrared thermographic technique. This technique rests on the assumption that the specimen temperature evolution during a fatigue test can be related to microplasticity mechanism and thus the fatigue limit (Luong 1998). From a single thermal signal the heat sources causing the heating; thermoelasticity and dissipation (microplasticity) can be separately estimated by an overall thermal drift θ and two periodic signals at f_s and f_c where f_s is the loading frequency (Berthel et al. 2014).

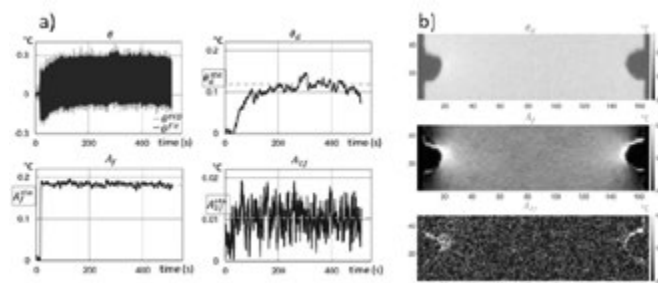


Fig. 3. a) Evolution of θ , θ_{exp} , θ_{fit} , θ_A , A_r and A_{2r} during one bloc load. $\sigma_{max} = 530 \text{ MPa}$, $R = -1$, $f_s = 30 \text{ Hz}$ and $f_c = 19 \text{ Hz}$. b) θ_A , A_r and A_{2r} 2D maps from a notch to another extracted during a bloc load of 15000 cycles, $\sigma_{max} = 650 \text{ MPa}$ and $R = -1$ of Shot peened AM TA6V

The fully reversed uniaxial fatigue tests () are conducted on an MTS servo-hydraulic testing machine at a frequency of 40 Hz. The Wöhler curves and the evolution of the stabilized amplitude and (result from the infrared thermographic technique) of different tests specimen configurations are displayed on the Fig. 4. Note that the results are normalized according to the reference material fatigue limit. The AM as built material got the lowest fatigue limit, it is 50% lower than the reference material. Regarding evolution, it increases faster than others at 40% meaning that microplasticity is appearing much sooner. This result is not surprising, it is principally explained by the surface roughness of the AM parts that generates localized stresses facilitating crack initiation. The fatigue limit is increased by 50 % when the specimens have been microblasted, this enhancement is observed as well on evolution as the slope change occurs later at a stress close to 60%. As a result, the infrared thermographic technique allows us to compare rapidly the fatigue response of different specimen configurations (i.e. with different surface finishing treatment and microstructures).

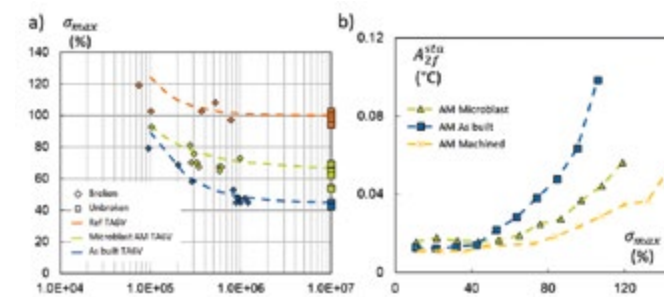


Fig. 4. a) Wöhler curves of TA6V notched specimen for $R = -1$, $f_s = 40 \text{ Hz}$. b) Evolution of the stabilized second amplitude according to the stress for different surface finish treatment

References

- Berthel B, Moustafa AR, Charkaluk E, Fouvry S (2014) Crack nucleation threshold under fretting loading by a thermal method. Tribol Int 76:35–44. <https://doi.org/10.1016/j.triboint.2013.10.008>
- DebRoy T, Wei HL, Zuback JS, et al (2018) Additive manufacturing of metallic components – Process, structure and properties. Prog Mater Sci 92:112–224. <https://doi.org/10.1016/j.pmatsci.2017.10.001>
- Edy F, LE V-D, BIERE C, et al (2020) From the fatigue properties of Ti6Al4V produced by ALM selective laser melting process to the mechanical design of an aeronautical part. MATEC Web Conf 321:03032. <https://doi.org/10.1051/mateconf/202032103032>
- Le VD, Pessard E, Morel F, Prigent S (2020) Fatigue behaviour of additively manufactured Ti-6Al-4V alloy: The role of defects on scatter and statistical size effect. Int J Fatigue 140:. <https://doi.org/10.1016/j.ijfatigue.2020.105811>
- Luong MP (1998) Fatigue limit evaluation of metals using an infrared thermographic technique. Mech Mater 28:155–163. [https://doi.org/10.1016/S0167-6636\(97\)00047-1](https://doi.org/10.1016/S0167-6636(97)00047-1)
- Sanaei N, Fatemi A (2020) Analysis of the effect of surface roughness on fatigue performance of powder bed fusion additive manufactured metals. Theor Appl Fract Mech



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FATIGUE DESIGN 2021

FD21-52

Room temperature mechanical properties of additively manufactured ni-base superalloys: A comparative study

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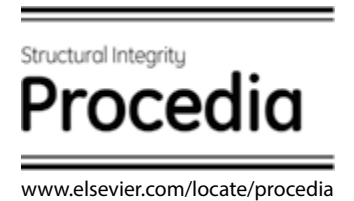
The unique layer-by-layer manufacturing strategy and near-net shaping capability of Additive Manufacturing (AM) make it a promising technology for Ni-superalloys components, where their typical service conditions demand complex shapes and impose significant production costs due to the alloys' poor machinability. In this work, the room temperature mechanical behavior of several Ni-superalloy series, including Hastelloy, Inconel, and Haynes, are investigated and their properties/performances compared. The test specimens were produced using various AM processes such as laser/electron beam powder bed fusion (LB/EB-PBF) and/or direct energy deposition (LB/EB-DED). Thorough microstructural analyses have been performed on test specimens along with their mechanical response under both static and cyclic axial loads. This study aimed to provide a better understanding of process-structure-property relationship for the AM processed Ni-superalloys in two steps. In the process-structure step: the microstructural evolution as the result of thermal cycles has been studied comprehensively by quantitative metallography based on scanning electron microscopy (SEM). In the structure-property step: both monotonic and cyclic deformation mechanisms of these alloys are carefully examined by both SEM and scanning transmission electron microscopy in hope to correlate the measured fatigue and tensile properties with microstructure.



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FATIGUE DESIGN 2021

FD21-66

Fatigue behaviour assessment of an industrial component produced by additive manufacturing processes: The hydraulic block

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In this study, hydraulic blocks commonly used on large machines (earthmoving, mining, agriculture...) were produced by three different additive manufacturing processes: laser powder bed fusion (L-PBF), metal binder jetting (MBJ) and lost-wax casting. For this third process, it is the wax model which is processed by an additive manufacturing method. The material retained is a martensitic precipitation-hardening stainless steel that provides good corrosion resistance and high mechanical properties. After a redesign phase aimed at reducing the weight of the historical component, static pressurization tests enabled very high pressures to be reached, exceeding expectations for each of the technological solutions selected.

A second phase enabled fatigue tests to be carried out, again with performance in line with the initial specifications (several hundred bars).

A correlation between the crack initiation sites and modelling was carried out in order to better understand their locations. Some non-usual aspects such as non-uniform roughness coming from the process were integrated.



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FATIGUE DESIGN 2021

FD21-73

State of the art of fatigue strength of materials & structures from additive manufacturing – The pivot, A CETIM development

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Additive manufacturing is a subject at the heart of innovation in many fields of mechanics. It allows, through different techniques, to produce increasingly complex parts. It also offers greater design freedom, often with shorter times than conventional manufacturing. These techniques having a multitude of parameters and finishing methods, Cetim wishes to study their influence on fatigue resistance through tests on standardized samples and on mechanical parts.

The pivot is an example of study part developed at CETIM. It is at the crossroads of technical art and technological developments. This part, resulting from a mechanical assembly of cable reels for industry, has been specially developed for additive manufacturing. It incorporates all the constraints and advantages of current technology. This part is stressed in fatigue during operation in combined rotations. It is subjected to alternating loads linked to centrifugal forces.

The design optimizes the constraints and design opportunities linked to additive manufacturing (topological optimization, supports optimizations). It also integrates metallurgical considerations and geometric constraints necessary for the finish. A specific range of surface finishes was produced for this part, driven by the reduction of two key roughness values, the Ra and Rz of the surfaces.

The validation of the mechanical properties was carried out on several production batches characterize the alloy behavior (metallurgically, mechanically and in fatigue). The parameters obtained during the first test phase (static and Manson-coffin) were incorporated into the simulations and dimensioning of the fatigue tests of the part. The pivot had several metrological checks with no-contact methods (tomography, scan, CMM, etc.) to check the dimensions and whether any defect was present. Then, the part was placed under a test bench to validate its mechanical performance and industrial expectations.

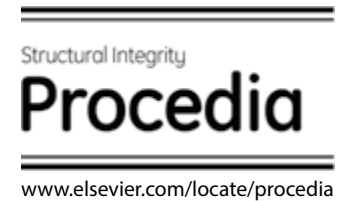
This study therefore proposes a direct correlation between the difficulties linked to the development of parts of additive manufacturing structures. The various technical problems from the microstructure to the structure of the part were removed step by step.



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FATIGUE DESIGN 2021

FD21-94

Experimental and numerical study of fatigue behavior of Ti6Al-4V architected materials obtained by additive manufacturing »

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Architectural structures are attracting increasing interest since a few years, achieving numerous excellent specific properties compared to fully dense materials. The transport industry sector sees periodic assemblies of elementary cells, called lattices, as a solution to lighten structures. This is made possible by the development of Additive manufacturing technologies (AM). AM allows to create a wide range of porous cell topologies, and to tailor their complex geometry with the desired property. However, understanding their fatigue properties is essential to validate their long-term use in load-bearing parts. Recent studies have recognized thin-walls TPMS (Triply Periodic Minimal Surfaces) structures as the most promising structures for fatigue resistance, especially the gyroid geometry, compared to conventional strut-lattices. The FA process plays an important role in fatigue life, as it systemically generates a heterogeneous microstructure, as well as surface and volume defects, which are preferred sites for fatigue crack initiation. The fatigue life of these structures also depends strongly on their geometry, which, due to their complexity, induces scale and stress gradient effects. This work investigates the study of the high cycle fatigue behaviour of Ti-6Al-4V gyroid thin-wall TPMS structure, manufactured by Selective Laser Melting, and post-treated by Hot Isostatic Pressing (HIP). The evolution of the damage and the underlying mechanisms are evaluated. As the HIP treatment eliminates all volume defects, the effect of surface defects will be quantified by testing chemically polished structures. A FEM numerical approach is developed to predict the gyroid multiaxial stress field of the structure under loading, considering high strain gradient in the wall thickness. A fatigue post-computation of these results allows to predict fatigue critical areas using a non-local multi-axial fatigue criterion.



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FATIGUE DESIGN 2021

FD21-98

Contribution of the introduction of artificial defects by additive manufacturing to the determination of the Kitagawa diagram of Al-Si alloys

**Matthieu Bonneric¹, Charles Brugger¹, Nicolas Saintier¹, Antonio Castro-Moreno²,
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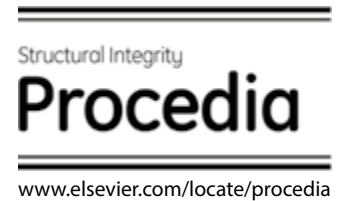
Despite a continuous improvement in the additive manufacturing (AM) technologies to enhance the quality of the produced parts, some process defects cannot be fully avoided and remain a critical issue for the design of industrial components regarding fatigue damage. More precisely, it is well known that volume defects (lack-of-fusion defects or gas pores) and surface roughness are the main cause for fatigue failure in AM components. In this context, the present work is focused on the influence of defect features (size, position and morphology) on the fatigue behavior of AlSi7Mg0.6 alloys produced by laser powder bed fusion technology (L-PBF). To this purpose, various artificial defects were introduced in fatigue specimens, either by milling or by placing holes directly into the CAD files. In both cases, the specimens were machined before test in order to avoid the influence of surface roughness. The influence of the as-built surface was separately investigated with defect-free vertical specimens. All results will indicate whether surface defects (i.e. defects associated to the surface roughness) have a greater impact on the fatigue life than the volume defects, as well as the most critical configurations among the volume defects.



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FATIGUE DESIGN 2021

FD21-102

Influence of microstructure on fatigue behaviour of 316L stainless steel manufactured by laser powder bed fusion (LPBF)

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Recent developments in additive manufacturing (AM) technologies allows generating different type of microstructure by modifying the additive manufacturing parameters. Indeed, with the laser powder bed fusion process, the laser power, energy density or laser scan strategies are such of parameters which affect size, morphology and orientations of grains. This allows to build microstructures which were no accessible with conventional processes. Furthermore, the control of AM parameters allows to significantly reducing the size and density of defects inherent to the process (gas pores, lack of fusion). These advances make it possible to study the role of microstructure on fatigue crack initiation behaviour by freeing itself from defect initiation. To do that, two microstructures with low and high energy density, resulting in low and high texture intensity were built. Their fatigue behaviour will be compared thanks to multiaxial (traction, torsion) fatigue test campaign.



FATIGUE DESIGN 2021

FD21-105

The effect of surface state on the crack initiation mechanisms of additively manufactured titanium components for aeronautical applications

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Martine Monin¹, Sandy Blanc⁴**

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⁴Safran Additive Manufacturing, a technology platform of Safran Tech, Magny les hameaux, France

Additive manufacturing processes increasingly cover a wide range of aeronautic parts due to their ability to produce complex designs that allow important weight reductions and fuel savings. As such parts are already flying, the next step is to be able to additively produce structural parts without decreasing the safety and reliability levels.

One of the most studied additive manufacturing processes is Laser Powder Bed Fusion (LPBF). This process induces high surface roughness that is not compatible with a loaded aeronautic component fatigue life requirements. Many studies concerning LPBF produced parts, including on Ti-6Al-4V alloy, are already available but few have studied in details the crack initiation mechanisms and few compare specimen geometries structural behavior influence on the results.

Fatigue tests have been conducted on several geometries and surface states. The resulting Wöhler diagram shows an important abatement due to surface roughness. Differences between specimen geometries with a machined surface state are also enlightened. Then, the crack initiation mechanisms have been studied. To explain the fatigue scatter observed, a comprehensive study has been conducted to determine the influence of several characteristics observed at the initiation sites on the fatigue life.

It is concluded that the microstructural heterogeneities responsible for crack initiation does not follow Linear Elastic Fracture Mechanics predictions. More precisely, considering an alpha colony as a pre-existing crack does not seem an appropriate way to model its impact on fatigue life. Surprisingly, while these heterogeneities sizes exhibit large scatter, the resulting fatigue life scatter is quite low.

S02

Big data and artificial intelligence

Chairmen:

M. Kästner & Q. Chantenet



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FATIGUE DESIGN 2021

FD21-7

How fraud detection technologies can help to detect damages in aircraft structures

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Trying to harvest and analyze data in order to predict certain trends is probably one of the most explored options used nowadays in the industry to generate new profits.

This is widely known as data mining.

Data mining can rely on machine-learning, which, broadly speaking, is a set of statistical tools used by a computer to explore data. It is commonly used in banking systems to automatically detect fraud for instance.

Combining machine-learning techniques with the field of structural analysis can lead to innovative ideas.

Using a rather heuristic approach, this paper presents a practical example of how machine-learning can be used to predict the appearance of damages in an aircraft structure.



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FATIGUE DESIGN 2021

FD21-9

Prediction of fatigue failure in small-scale butt-welded joints with explainable machine learning

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Butt-welded joints are one of the most commonly used welded joints in many industries. Fatigue behaviour of such joints depends on a number of factors, such as load level, macro-geometric misalignment, local weld geometry, but also parent material strength. Due to the complexity of this topic, fatigue assessment of such joints often leads to high deviations between experimental and predicted fatigue life. Thus, advanced fatigue assessment methods are required in order to take the various influencing factors into account. For this purpose, machine learning techniques are used to predict failure locations and number of cycles to failure of fatigue tests performed on small-scale butt-welded specimens.

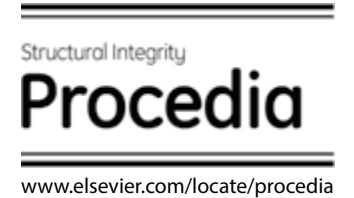
Beyond accurate predictions, an understanding of importance and mutual influence of the factors is desired, e.g. a ranking of the most important factors. However, capturing the influence of several possibly interacting factors usually requires complex nonlinear machine learning models. We use gradient boosted trees and artificial neural networks. Since these are black box models, the SHapley Additive eXplanations (SHAP) method is used to explain the predictions.



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FATIGUE DESIGN 2021

FD21-48

A data-driven approach for approximating nonlinear dynamic systems using LSTM networks

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The analysis of sensor data in nonlinear dynamic systems plays a fundamental role in a variety of modern engineering problems like fatigue analysis and predictive maintenance. In many applications, the accurate approximation of sensor signals supports and complements experimental efforts in order to accelerate the development process and conserve resources.

Forward prediction (FP) estimates the system response for a given drive signal during the commission of component test rigs. Virtual Sensing (VS) techniques aim to replace physical sensors in a system by using the data from available sensors to estimate additional unknown quantities of interest. Data-driven approaches can be convenient tools for FP and VS, as they only require a sufficiently large dataset of the desired input and output quantities for the purpose of model parametrization. The presented approach explores their suitability of Long Short-Term Memory (LSTM) networks for the approximation of dynamic systems with multiple input and output channels.

The proposed method utilizes short subsequences of signals to carry out LSTM training and prediction. Long sequence estimations are generated by combining the individual subsequence predictions using a windowing technique. This general strategy is well suited for hybrid modelling, during which the LSTM network builds upon predictions from different methods.

Our approach is tested on synthetic data and extended to target-response-simulations for commissioning of nonlinear experimental test setups. To enable a comprehensive evaluation of the model quality, various metrics in time and frequency domains, as well as fatigue strength under variable amplitudes are compared using a large dataset.



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FATIGUE DESIGN 2021

FD21-95

Smart testing: IoT applied to fatigue test monitoring

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The Industrial Internet of Things (IIoT) and its technologies are more and more relevant for testing knowledge and know-how management. Starting at data collection on a test machine to the visualization of performance indicators on a dashboard, different specific item are necessary to ensure quality and security of the data, from sensor to work specific treatment algorithms needed to extract relevant information.

If testing is much more suitable to small data management, gathering different data from different tests leaded on similar or equivalent equipment should introduce the big data concept, and also allow more investigations to improve physical models by dealing with more variability of best experimental practices and/or equipment mission profiles.

Hybridization of physics with data has then to be thought from collection to processing, and of course in the definition of efficient IIoT technologies. If time series and test/machine state are very relevant for work specific application, metadata becomes most valuable information to allow big data processing, and are the base of the database to deal with, which needs to be at the highest quality as possible (ensure integrity, quality and validity of the data before storage and further works). Data engineering is then very important in our application to allow data analysts to manage mathematics well, in accordance of course with the work domain (for instance fatigue).

The aim of the study is also to show the data pre-processing needed to ensure the quality of the input of data analysis, and the large possibilities that IIoT offers to improve all activities around testing (Smart Testing: improve reporting, increase just necessary testing ability, improve machine efficiency, etc.), illustrated with fatigue test monitoring.

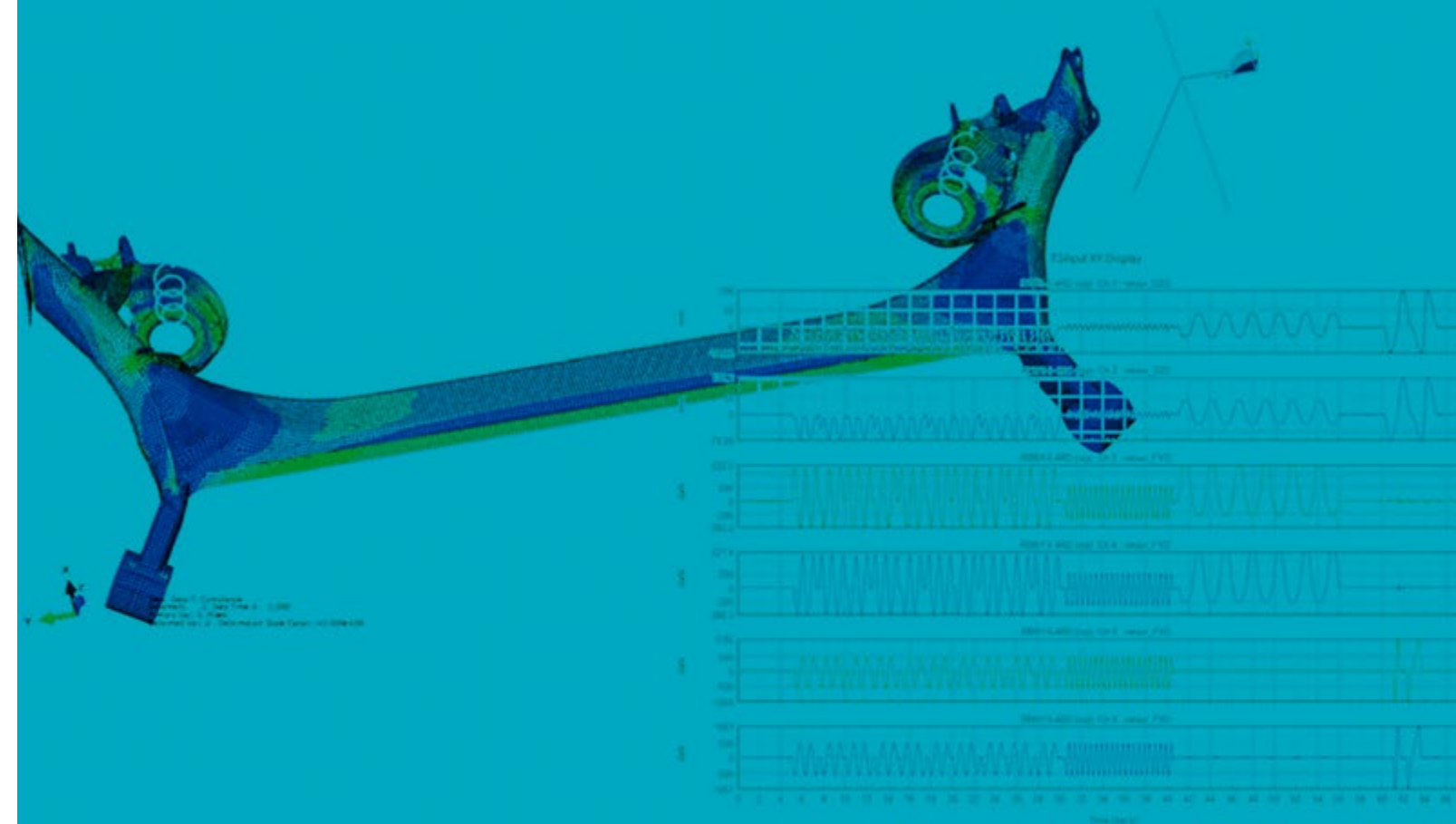
S03

Complex loadings

Chairmen:

E. Pessard & G. Fournel

C. Peyrac & G. Thoquenne





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FATIGUE DESIGN 2021

FD21-10

Local prestressing of cold forging tools by reinforcements with adapted interference

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With contact pressures of more than 3000 MPa cold forging dies belong to the highest loaded components in mechanical engineering. Especially in non-symmetrical dies, this leads to a complex stress state with locally varying stresses. Cyclically occurring tensile stress concentrations lead to crack initiation, which is why fatigue is the most important failure mechanism for complex cold forging tools. To reduce tensile stresses and counteract fatigue failure, dies are conventionally prestressed by inserting them into a reinforcement ring with a uniformly distributed interference. However, the compressive prestress is often not enough to compensate the high local stresses occurring in processes for non-symmetrical parts. Therefore, this paper focuses on using a non-uniformly distributed interference to locally increase prestresses in critical areas. To achieve this, gaps are inserted between die and reinforcement, inducing a bending stress. It is analysed how to design the gaps depending on the interference fit, so that the compressive prestress is used effectively without causing new critical tensile stresses. For this purpose, height and angle of the gaps are varied in a closed-die forging process for elliptical parts and the effect on the local stresses is evaluated in a numerical model. Results show, that high gap heights and angles generally increase the bending effect and the local prestress. For high interferences, they also increase tensile stresses occurring in other areas of the dies. To create a stress state beneficial for tool life, large gaps should be used with small interferences and small gaps with high interferences.



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FATIGUE DESIGN 2021

FD21-46

Multiaxial variable amplitude loading for automotive parts fatigue life assessment: a loading classification-based approach proposal

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This study focuses on variable amplitude loadings applied to automotive chassis parts experiencing carmaker's specific proving ground. They are measured at the wheel centres and composed of the six forces and torques within the standard vehicle reference frame. In the scope of high cycle fatigue, the loadings considered are supposedly acting under the structure yield stress. Among the loadings encountered during the vehicle lifetime, two classes stand out:

- Driven Road: loads measured during the vehicle manoeuvre (cornering, braking).
- Random Road: random loads mainly coming from the road asperity.

To separate both effects, a frequency decomposition method is proposed before applying lifetime assessment methods. The usual rainflow counting method can be applied to the Driven Road signal. Giving some requirements regarding the time signal (stationarity, ergodicity, Gaussian distribution), less time-consuming methods such as spectral ones can be applied to the Random road signal.

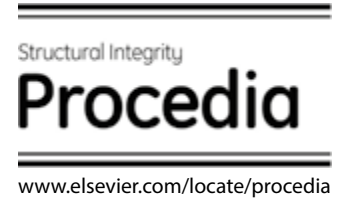
To assess fatigue life, it is essential to determine the local stress tensors inside the structure. These stress states are "multi-input" ones gathering simultaneously the impact of each loading measured at the vehicle wheels. The history stress state complexity depends on whether the input signals are in phase or decorrelated. Yet, the signal partition mentioned enables the loads separation according to this aspect. Thus, the damage indicator calculation is assumed to be the sum of the damage induced by the two groups considered (Driven Road, Random Road). Regarding the latter, a multiaxial approach based on spectral methods is proposed. The process is illustrated using measurements on ground.



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FATIGUE DESIGN 2021

FD21-47

A systematic experimental study on the impact of multiaxiality and non-proportionality on fatigue life of cast steels at high temperature

Karl Michael Kraemer, Alexander Erbe, Fabian Conrad, Christian Kontermann, Matthias Oechsner

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Rising demands on material performance at high temperature in components under complex loading such as gas turbine housings demand an increase in versatility and precision of component life modelling approaches. However, the database to train those models is commonly derived from uniaxial testing. The impact of multiaxial loading, both proportional and non-proportional, is usually addressed theoretically by the use of equivalent stress/strain formulations or reduction ratios derived from selective validation testing.

In this study, the fatigue life of a cast steel is investigated systematically using a servo-hydraulic bi-axial test machine with induction heating. Each experiment is accompanied with finite element simulations before and after the test to parametrize the loading condition and derive hot-spot equivalent loading parameters. The impacts of different load axis ratios are investigated systematically both under displacement and force control as well as the effect of hold times.

The results show that the modelled strain hot spots are coinciding with the observed crack initiation. A reoccurring sequence can be found in the impact of strain axis ratios on specimen life. This order of strain axis ratios is also conserved when switching to primary (force-controlled) loading. An assessment of different fatigue damage parameters from literature shows no capability to unify the life description and resolve this ordering so far. Therefore, an alternative approach utilizing a unified viscoplastic constitutive material model will also be discussed briefly.



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FATIGUE DESIGN 2021

FD21-58

Fracture fatigue life calculations with the local strain approach

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The Research Association of Mechanical Engineering (FKM) has published different guidelines for approximations of the fatigue life for mechanical components of steel or aluminium alloy. One guideline is able to approximate the fatigue life for fracture based on linear-elastic FE calculation, using a local stress approach with linear-elastic material behaviour. Another guideline is able to approximate the fatigue life for crack initiation also based on linear-elastic FE-calculation but considering elastic-plastic material behaviour using the Local Strain Approach. Both guidelines base on the assumptions: defining the local stresses and strains, approximating Woehlercurves from the ultimate tensile strength and using shifting factors for the Woehlercurves to consider component effects. The main difference between the guidelines is the material behaviour. If the material behaviour is assumed to be independent of crack history, it seems possible to use the Local Strain Approach for failure criterion fracture.

Therefore, the application of the Local Strain Approach to failure criterion fracture only needs a new definition of the Woehlercurves. This definition has to consider the crack growing effects leading to differences in the fatigue lives between crack initiation and fracture.

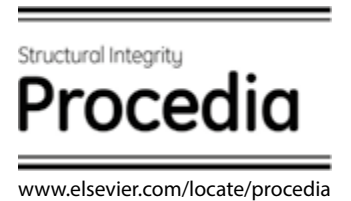
For an identification of the new damage parameter Woehlercurves, a big steel database with more than 1500 experiments under constant and more than 700 experiments under variable amplitude loadings were evaluated. The output is the U-Concept: a constant shifting of the P-Woehlercurve from crack initiation to fracture, a modification of the slope and a function to consider an additional mean stress effect between crack initiation and fracture.



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FATIGUE DESIGN 2021

FD21-91

Nonlinear modal time history analysis: allowing for quick stress determination taking nonlinear phenomena into account

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For many industrial structures, fatigue evaluation by calculation (for design or verification purpose), requires to take into account complex phenomena.

There are several time history analysis methods ; among them modal based time history analysis which is widely used because of its performance (calculation duration is short).

However, the principal limitation of this method is that it can only address linear behaviors.

An approach to enlarge modal based time history to nonlinear phenomena is presented in this paper.

It's indeed possible to apply nonlinear forces at the second member of the equation. This possibility, available in Code-Aster, allow for calculation of time history based on modal analysis involving nonlinearities such as contact.

Cetim uses this method when it's necessary to carry a long time history together with small time increments. For example, a 20 seconds analysis with 1 μ s time increment is performed in a few minutes.

Degrees of freedom depends of modes and nonlinearities rather than on nodes or elements amount.

An other advantage is the possibility to select damping on a modal basis.

The paper describes this methods, its assumptions, and gives example for illustration.

FD21-120

Methodology for evaluating the probability of failure of a mechanical component in multiaxial fatigue

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STATE OF THE ART

The fatigue phenomenon is one of the main causes that leads to the rupture of a mechanical component as the result of random or cyclic loads. Regarding industrial components, it is quite common for the state of stress under loading to be multiaxial. In order to estimate a fatigue lifetime, it is therefore necessary to implement a multiaxial fatigue post-processing. Multiaxial fatigue criteria are criteria distinguish the safe domain and the failure domain (blue curve on Figure 1) for a given number of crack initiation cycles.

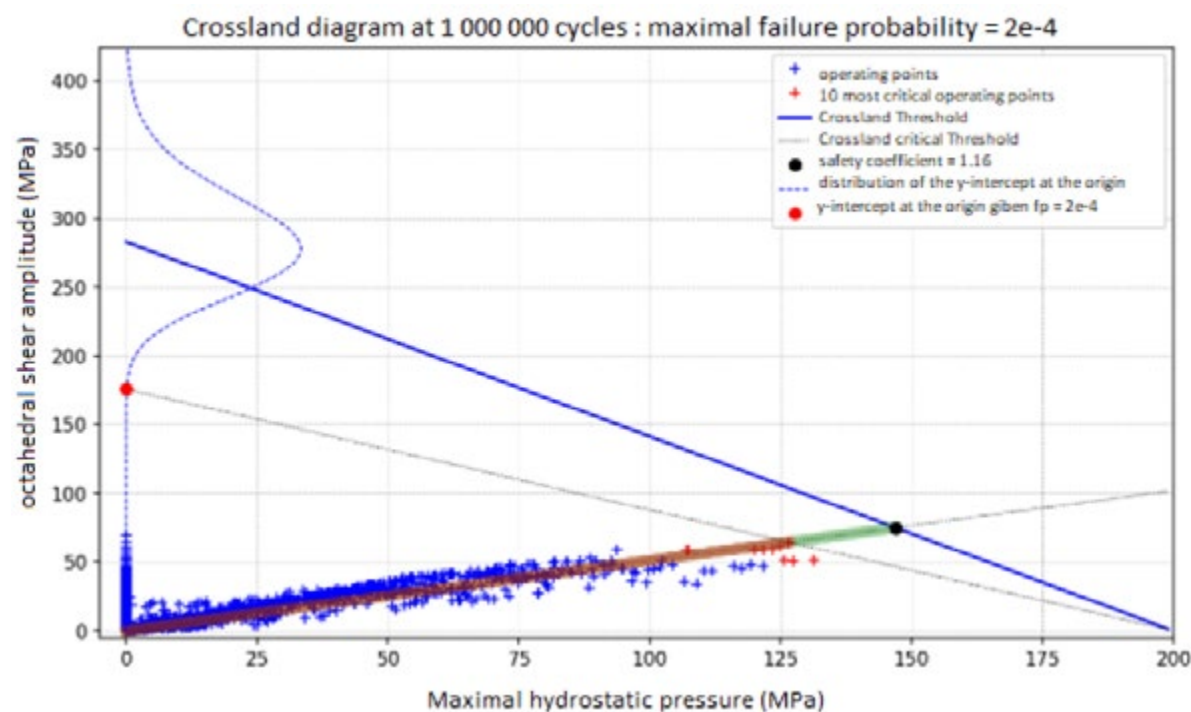


Fig 1 : Operating points and Crossland diagram

NEW APPROACH

Most of the time, a safety coefficient in relation to this boundary is evaluated. The lifetime is therefore evaluated for a fixed probability of failure. Yet, there are several sources of variability that may modify the position of the operating points, but also the position of the threshold associated with the multiaxial fatigue criterion considered:

- Variability of the loading
- Variability of the material characteristics
- Variability intrinsic to the fatigue phenomenon, represented by a dispersion on the S-N curve.

To evaluate the probability of failure, the distribution of the y-intercept at the origin of the threshold is first evaluated by propagation of uncertainties. Then, we evaluate for the most critical operating point (associated with the threshold having the highest y-intercept) the associated probability in this distribution (red y-intercept on the graph). Finally, in order to capitalize on the reliability of this post-processing and to make it easy to use, a graphic interface has been developed.

ADDED VALUE FOR DIMENSIONING IN AN INDUSTRIAL CONTEXT

The safety coefficient usually used with multiaxial fatigue criteria does not allow to precisely quantify the margin. The evaluation of the probability of failure allows to optimize the sizing for a reliability objective, and thus to ensure the durability of the product while minimizing the material costs and the environmental impact.

References:

- Technique de l'ingénieur, M4170 V1, Essais de fatigue, Partie I
- Robert, IFMA, Dimensionnement en fatigue des pièces mécaniques et des structures métalliques, Fatigue sous chargement d'amplitude variable, Fatigue multiaxiale.
- B. Weber, Fatigue multiaxiale des structures industrielles sous chargement quelconque, 1999
- Mines Douai, Critère de fatigue multiaxiale: critère de Crossland/ critère de Dang Van.
- N. Nadjitonon, Contribution à la modélisation de l'endommagement par fatigue, 2010
- K. Dang Van, B. Griveau and O. Message. On a new multiaxial fatigue limit criterion: theory and application, Proc. of the 2nd International Conference on Biaxial and Multiaxial Fatigue, Sheffield, England, 479-496, 1989.
- Paulin-Luc, Introduction au dimensionnement en fatigue des structures sous chargements complexes, Institut de Mécanique et d'Ingénierie, UMR CNRS 5295 Arts et Métiers ParisTech, campus de Bordeaux

S04

Composites, elastomers and adhesive bonding

Chairmen

L. Gornet & R. Chantalat

M. Afzali & B. Abdellaoui

S. Chereau & M. Bennebach





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FATIGUE DESIGN 2021

FD21-5

Joint strengths and fatigue properties of Al/steel dissimilar adhesive joints

Yoshihiko Uematsu

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Aluminum (Al) alloy, A6061-T6, plates were joined to stainless steel, type 304, plate using epoxy adhesive, where the thickness of adhesive was fixed as 150 μm . The thickness of steel plate was fixed as 0.8 mm, while those of the Al plates were varied as 1.0, 1.6 and 3.0 mm. Tensile and fatigue tests were conducted using lap-shear specimens and the effect of Al plate thickness was investigated. The stress distribution at the edge of adhesive was also analyzed by FEM. According to the stress analyses, the stress concentration occurred at the edge of adhesive. In addition, it was found that the edge stress on Al side decreased with increasing Al plate thickness, while the edge stress on steel side increased. Tensile-shear strength increased with increasing Al plate thickness, and cohesive failure of adhesive was dominant. Under fatigue loading condition, fatigue strengths tended to increase with increasing Al plate thickness, where interface failure was dominant. Those test results indicate that the stress state near the interface of Al plate and adhesive was a controlling factor of the static and fatigue tensile-shear strengths of Al/Steel dissimilar adhesive joints.



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FATIGUE DESIGN 2021

FD21-18

An investigation of the residual stiffness and strength of a glass fibre reinforced composite in high cycle fatigue experiments

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A modern wind turbine is designed to operate 20 to 25 years under various loading conditions. In operation, the current degradation and damage states of the turbine's rotor blades are unknown and structural reserves for further years of operation may exist. But, the turbine will be disassembled after reaching its design lifetime.

To approach this issue a deeper insight in the fatigue behaviour of glass fibre reinforced composites is mandatory. For this, comprehensive experimental investigations of the residual stiffness and strength are conducted. The specimens are tested in the high cycle fatigue regime and the stiffness degradations are monitored. Different types of experiments have been performed: Tension, compression and shear. For each type, experiments at different load amplitudes are conducted, while the strains are recorded with a camera and analysed via digital image correlation. In addition, from the rear view a second camera takes pictures of the transmitted light. Thus, the increasing damage can be evaluated due to the decrease of transparency. Based on the number of load cycles until failure from the residual stiffness tests as well as on the defined damage states by the transmitted light analysis, certain life fractions are determined. To measure the residual strength at comparable damage states, further specimens are loaded with a constant amplitude until reaching these predefined life fractions. Then the specimen is tested quasi-statically for determining the residual strength.

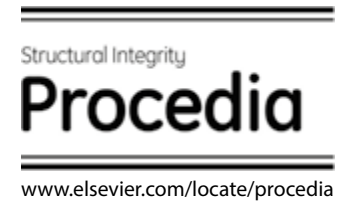
This work is based on the project DynaWind² (funding number: 0325228G) funded by the Federal Ministry for Economic Affairs and Energy.



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FD21-19

Fatigue and damage assessment of CFRP material using digital image correlation

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Carbon Fiber Reinforced Polymer (CFRP) materials are an attractive choice for lightweight design. Increasing the range of applications for CFRP materials, the topic of fatigue and durability is hence becoming more important. Fatigue testing of a CFRP composite in tension-tension fatigue has been conducted. In-situ surface strain measurements were performed to examine the gradual elongation of the specimen as this relates to stiffness loss and fatigue damage. A methodology capturing the peak load have been developed, including a trigger mechanism that activates the camera at the desired cycle count. The material tested is a unidirectional NCF fabric with carbon fiber and epoxy matrix.

The fatigue test results revealed a wide spread scatter in the mid-range of the high cycle fatigue region. By studying the strain in the early fatigue loading cycles and stiffness loss over time, benchmark of the fatigue performance between different material samples could be carried out, which could explain the scatter in the fatigue testing. It could be observed that the fatigue limit of UD material in the fiber direction is in the magnitude of 80% of the material tensile failure strength.



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FD21-79

Fatigue of adhesive bonding: world first fatigue s-n curve for fpso application

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The aging FPSOs (>10 years) induces frequent and costly structural maintenance operations in hazardous environment. The challenge is to perform these offshore structural maintenance operations with no production disruption while maximizing safety even for the most stressed areas such as a mid-ship deck plating.

COLDSHIELD, a co-development between COLD PAD, TOTAL and IFP Energies nouvelles, has been set up to meet this very challenge. This CLASS approved innovative alternative to “crop and renew” stops the corrosion and restores hull strength. Among the steps to be taken to demonstrate that such repair can be considered as permanent, it was mandatory to characterize the fatigue behavior of this reinforcement solution.

For the time being there is – to our knowledge - no S-N curve for structural bonded reinforcements. Full-scale coupon specimen fatigue tests of the structural bonded reinforcements were conducted by COLD PAD, third-partied by Bureau Veritas and in collaboration with two laboratories (private and public) in order to study the adhesive fatigue. Statistical analysis was performed according to international standards. The resulting S-N curve is fit for industrial fatigue design. It demonstrates a comfortable fatigue strength (S-N curve presenting a slope of 9).

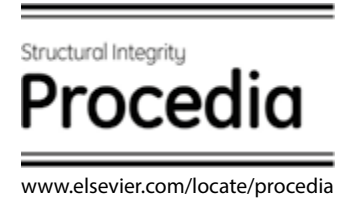
This paper presents the results of a fatigue life assessment campaign of COLDSHIELD including the experimental setup, the fatigue test results, and the numerical analyses. It details the reason why the design is compatible with a stress-based approach. It also explains the conclusions that can be derived in terms of fatigue life for a deck repair campaign



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FATIGUE DESIGN 2021

FD21-80

Towards a methodology to estimate the experimental fatigue limit for thermoplastic elastomer materials: A mechanical behaviour modelling with hysteresis loops

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This work presents the mechanical behaviour of a thermoplastic elastomer copolyester-ether (TPE) under fatigue loadings. Under static or fatigue loadings, these materials exhibit a complex thermomechanical response. The proposed model takes into account the temperature evolution due to rubber-like hyperelasticity with damage process, as well as the effects of viscoelasticity and viscoplasticity. The viscoelastic evolution appears to be part of the short-term material response, whereas the viscoplasticity impacts both short and large time scales. Moreover, a competition between damage and residual strain evolutions is highlighted during experimental tests. The main objective of this paper is to present a robust indicator to determine the fatigue limit of TPE materials based on experimental Self-Heating method. In this study several indicators have been used to obtain an estimation of the limit of fatigue. A novel “hysteresis loop” criteria is finally proposed as the most suitable methodology to determine the fatigue limit of TPE materials. The proposed nonlinear model is based on the multiplicative decomposition of the deformation gradient into elastic and plastic components. The model is written in the thermodynamic framework. Both hyperelastic part and damage parts were first proposed by Gornet et al. in 2012 (ECCMR) for rubber-like materials. For TPE materials this model is extended with viscoelastic and viscoplastic effects. Dissipation mechanisms during a self-heating loading could be computed in order to reproduce heat generation. Simulation shows the capability of the proposed model for predicting self-heating and plastic strain. It is a step towards the prediction of TPE materials Wohler curves.



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FD21-86

Numerical calculation of homogenized effective material properties of the single ply for arbitrary fiber distributions

Sebastian Spanke, Jan Scholten, Henning Haensel, Jochen Höhbusch

AG BMFT, Ruhr-University Bochum, Bochum, Germany

This paper presents research results of the AG BMFT in co-operation with Rheinmetall referring to a fatigue strength assessment workflow for the strength optimized design of highly loaded structures made of fiber reinforced composites in off-road vehicles. The experimental investigations are based on four-point bending tests, using a Zoltek carbon fiber (PX35 50K) with an epoxy resin matrix as the composite material. A subfield of this research is the numerical determination of the quasi-static material properties of the single ply.

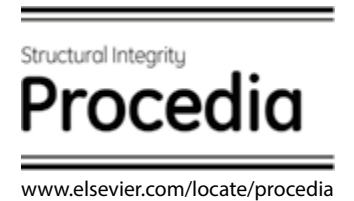
In this context, a Representative Volume Element (RVE) module was developed in Abaqus. The RVE system with periodic boundary conditions computes the homogenized effective material properties from the heterogeneous material components of fiber and matrix. A comparison with experimentally determined material properties shows that a symmetrically hexagonal fiber matrix structure represents the material properties of the single ply only to a limited extent. The results in the fiber direction are sufficient, whereas the results transverse to the fiber direction require improvement. Thus, the fiber distribution and the geometric shape of the fibers which have a decisive influence on the material properties must be considered. To generate random fiber distribution, the Random Microstructure Generator by Merlo and the Random Distribution Generator by Ge, Wang Sun and Liu were integrated into the RVE module. In addition, extensions were developed that can accommodate elliptical fiber geometry as well as fiber undulations. Finally, a comparison is made between differently generated fiber distributions and their influence on the quasi-static stiffness values.



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FATIGUE DESIGN 2021

FD21-88

Stress-related structural durability engineering of mounting parts subjected to inertia forces with multi-axial dynamic excitations

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BMW AG, Munich, Germany

For various vehicle functions components are used and must be integrated into vehicles. During inertia force excitation, the mounted parts impose stress on their brackets and their supporting structures. With the continued vehicle electrification, such mounted parts are increasingly connected to structures which are not only excited by accelerations caused by road surfaces, but also by high amplitude and frequency oscillations, e.g. oscillation of power trains. With knowledge of maneuvers relevant for structural durability, load data collectives for the design of mounted parts can be derived which comprise of both road and power plant excitations. Utilizing dynamic FEM simulations, this load data collective is used for designing brackets and the supporting vehicle structure for mounted parts with regard to structural durability. This is usually conducted at an early stage of the design process to prevent late and therefore expensive design changes. Using a compact test set-up comprising of pre-series test parts, a final system test is carried out to verify the integration of the mounted parts with regard to structural durability. The results of testing are used to issue a recommendation to release to the construction department.



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FATIGUE DESIGN 2021

FD21-90

Ply scale modelling of the fatigue behaviour of a glass fibre / acrylic matrix composite material covering the service temperature range of wind turbine blades

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¹I2M, Université de Bordeaux, Bordeaux, France. ²I2M, Arts et Métiers, Bordeaux, France. ³TENSYL, Perigny, France

Wind energy industry mostly uses thermoset-matrix composites to manufacture its components. Thus, to reduce the environmental footprint, new polymer matrices have been developed in recent years to replace commonly used thermoset resins, including acrylic thermoplastic matrices. These have better recycling and repair opportunities; a good fatigue and impact strengths and they are lighter. They also reduce manufacturing costs since their polymerisation is performed at room temperature, resulting in a better production rate.

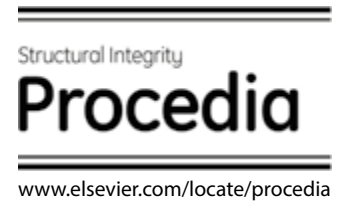
In this study, a model formulated at the ply scale was considered to describe the mechanical behaviour of this acrylic-thermoplastic-matrix and glass-fibre-reinforced laminated composite under monotonic tensile and fatigue loadings within a temperature range of -20°C to +60°C. The model parameters are first identified mostly at room temperature in order to validate the use of this damage model. The study showed that the temperature dependency of the composite transverse and off-axis mechanical behaviour could be done in a simple way, by only considering the temperature dependency of the matrix initial elastic properties (i.e. fibre initial elastic properties and parameters of damage and hardening evolutions laws are kept constants). This is a relevant result for the industrial field, for a better design of composites structures such as wind turbine blades, with a limited set of experimental data. This finding is all the more useful when dealing with such an innovative composite material.



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FATIGUE DESIGN 2021

FD21-104

Fatigue strength of adhesively bonded tube-tube specimens under multiaxial loading with constant and variable amplitudes

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Adhesive bonding is commonly used in the manufacturing of vehicle bodies. A bond-line has the advantage that the joined flanges are stressed homogenously compared to a standard spot-welded design. In addition, bond line provide a higher stiffness and better damping behavior.

There exists still quite some uncertainty in the assessment left that is countered by an over-dimensioning of the bond due to a lack of reliable approaches to assess the fatigue strength of such joints. This is especially true for the case of more complex loading conditions as variable amplitude loading and multi-axial loading. For example, the experimentally determined actual damage sum in literature shows a high scatter and is according to Miner well below the theoretical value of one.

In order to identify the fatigue strength behavior under constant and variable, multiaxial loading, fatigue tests on adhesively bonded tube-tube joints with a thickness of the bonding of 0.3 mm have been performed under load control. The results of the fatigue tests are shown. The endurable damage sums according to a damage accumulation by Miner are evaluated and compared to data from literature. In addition, existing approaches to assess the influence of multiaxial loading are applied. The resulting numerically determined fatigue strength is compared to the test data and the results are discussed.

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2D Detector

NEW
2020

Industry 4.0 compliant equipment

Collaborative Robot

Flexible arm for easy positioning

Transport

Heavy duty tripod for easy installation in lab or on site

Safety

Laser scanner full-safety system around the equipment



X-Ray Tube

Air-cooled X-ray tube
Easily exchangeable by the user

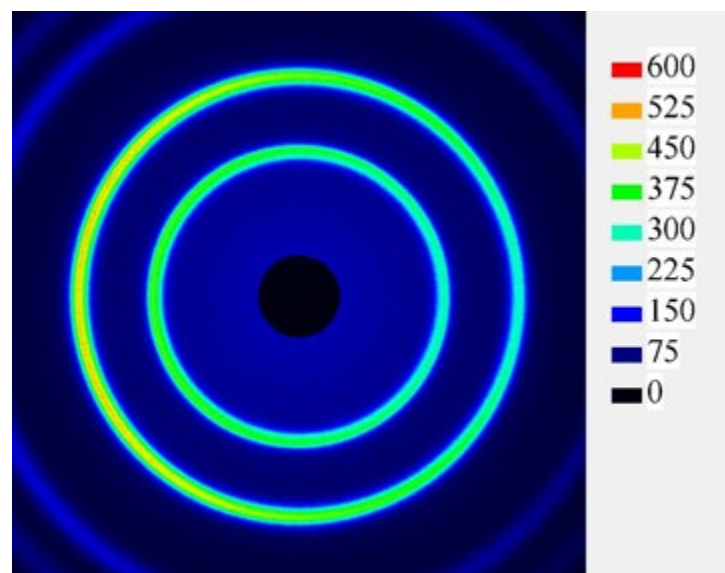
2D Detector

Silicon 2D detector
permitting to acquire entire diffraction rings

Positioning

Patent laser triangulation system for sample positioning

Software



- ✓ Multiple exposure technic to avoid significant systematic errors existing in the classical cosine α method
- ✓ Complete stress tensor components evaluated in less than 1 minute
- ✓ Robust error bars evaluation according to the Guide of Uncertainties in Measurements (GUM)
- ✓ The diffraction rings can be described by more than 300 polar diffraction diagram cuts
- ✓ Each diffraction pattern is fully fitted through a non-linear best fit method that permits to account for overlapping peaks

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S05

Contact fatigue, fretting and vibration

Chairmen:

Y. chen & L. Amar



FATIGUE DESIGN 2021

FD21-37

**Effects of inappropriate sampling on counting algorithms
in vibration fatigue**

Arvid Trapp, Quirin Hösch, Peter Wolfsteiner

Munich University of Applied Sciences, Munich, Germany

Carrying out a fatigue strength assessment for variable amplitude loading generally consists of deriving classified load spectra from local stress states in order to compare them with structural strength parameters (e.g. stress-life-/Wöhler-curves). Commonly, stress states are available as time-discrete series derived from measurements or numerical simulations (e.g. finite-element method, multi-body systems). Processing them requires counting algorithms to identify damaging cycles which are collectively represented as a load spectrum. Among the counting algorithms, rainflow-counting is certainly the most popular. However, the processing of sampled stress states bears pitfalls that can have considerable effects on structural lifetime predictions which is investigated in this contribution.

The assessment of rapidly varying stress states, e.g. due to vibration or shocks, places certain requirements on the sampling, which have not been sufficiently specified yet. Since counting algorithms count peak-to-peak stresses, these peaks must be sufficiently resolved by the sampling. Insufficient sampling results in lower stress amplitudes (peak is in between samples) and lower cycle counts (turning points in between samples).

Techniques known as signal reconstruction allow to fully recover insufficient sampling provided that the Nyquist-Shannon sampling theorem is upheld. The aim of this contribution is to investigate and to quantify the effects of insufficient sampling on predicted fatigue damage. We give a short review of signal reconstruction and compare the available methods for random vibration fatigue. The main contribution is to provide a semi-analytical approach to relate the frequency decomposition of stress states to the expected error in a fatigue assessment of random vibration loading.

Fretting cracking behaviour of an Al/SiC composite: influence of the anisotropy of the reinforcing particles orientation

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The aim of this study was directed towards understanding the effect that a reinforcement-banded microstructure would have on the fretting cracking behavior of an Al-SiC metal matrix composite. After having characterized this behavior by testing diverse sampling angles in plain fretting, Zcracks finite elements simulations have been performed in order to estimate the value of the stress intensity factor range threshold in the long crack domain for each tested angle θ .

Keywords: Fretting, Metal matrix composite, Microstructure, Zcracks simulation

1. Introduction

Metal matrix composites (MMC) have been widely used in the aerospace industry. Adding SiC particles to an aluminium matrix improves its mechanical characteristics while keeping its weight low enough to compete with conventional aluminium and titanium alloys [1]. This study focuses firstly on the influence of the microstructure on the fretting cracking behaviour of an MMC produced by a powder metallurgy route, whose reinforcing particles exhibit an orientation anisotropy. The effect of the angle between the fretting loading direction and the particles preferential orientation was analysed. A reverse identification of the stress intensity factor range threshold (ΔK_{th}) for each angle has been carried out using finite elements - Zcracks simulations.

2. Methods

Al/SiC samples were extracted from a T4 sheet with a variety of angles θ ranging from 0° to 90° (Fig 1.a). They were submitted to plain fretting loadings in sphere-on-flat configuration and in partial slip condition, leading to the nucleation of cracks (Fig 1.b). The number of cycles was chosen to guarantee a crack arrest condition.

The extension of fretting cracks was measured by SEM cross-section observations. Image analysis techniques such as ellipse fitting and Voronoi diagrams were used to characterize the spatial distribution and direction of the banding of reinforcing particles with respect to the direction of the normal of the fretted surface. The angle measured between those two directions was subsequently linked to the relative resistance to fretting cracking of the composite.

The results of those fretting tests were then simulated by finite elements modelling. The observed fretting crack geometry was meshed and inserted into a sane mesh (Fig 1.c). The Zcracks software allowed us to compute ΔK_{eff} at the tip of the crack using the stress fields obtained by the finite element calculations.

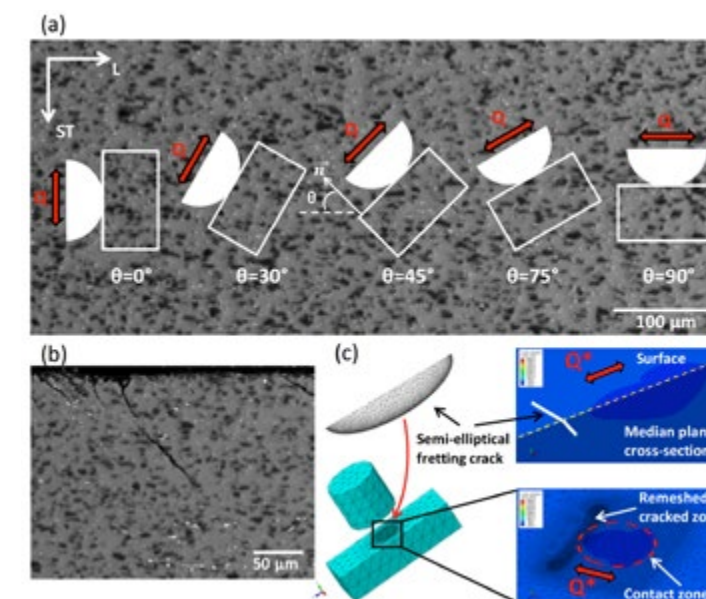


Figure 1:

a) sample extraction for the fretting tests.

b) cross-section SEM image of a fretting crack.

c) schematic view of the Zcracks method.

3. Discussion

Fretting crack length measurements for all the tested angles showed that the crack length decreases with θ until $\theta=45^\circ$, then reaches a plateau. This indicates that cracks growing along the banding direction can propagate significantly farther. In addition, Zcracks simulations allowed to obtain a crack length b_0 at the short / long crack transition. Subsequent Zcracks calculations performed in the short and long crack regimes were used to extract an intrinsic ΔK_{th} value as a function of θ .

4. References

[1] T. . Clyne and P. . Withers, An introduction to metal matrix composites. Cambridge university press, 1993.

Multi-scale modelling and testing of overhead conductors under vibrating loadings

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³Centre des Matériaux, Mines PARISTECH, Evry, France. ⁴Rte, Paris La Défense, France

Overhead conductors used for long range electrical transport endure aeolian vibrations, tensile loads and clamping efforts that induce fretting-fatigue damage between contacting strands in the clamping assembly. The aim of this research is to predict the fretting-fatigue life of conductors subjected to vibrations through a multi-scale modelling of the conductor-clamp assembly. Two models have been developed. A global model is used to assess the fretting loading conditions as well as the fatigue stress for every strand. Then, a second model simulating a single contact between two aluminium strands predicts the associated lifetime using multiaxial fatigue criteria. To support this numerical strategy, experimental tests were also conducted at two distinct scales. On the one hand, single contact tests were carried out to calibrate the local modelling method, thanks to an adapted test bench using two hydraulic actuators. On the other hand, full portions of overhead conductor assemblies have been tested in a dedicated facility to acquire data on the behavior of conductors under vibrating loadings. These tests gave additional insights about the damaging processes involved and experimental endurances, which could be compared with the results of the modelling approach.

Keywords (from 3 to 5 max): fretting-fatigue, Finite Element Modeling, overhead conductors, aluminium

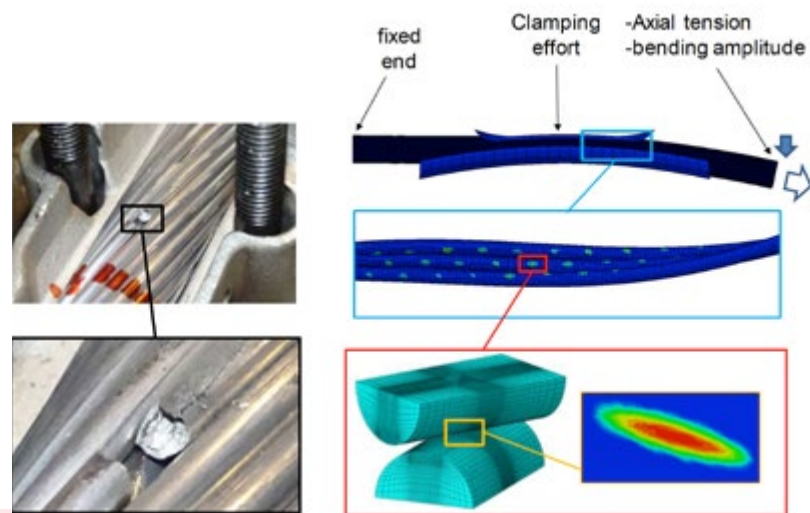


Figure 1

(a): view of the outer layer of an overhead conductor after testing;

(b): overview of the numerical strategy developed to predict the fretting-fatigue endurance of a conductor.

Wear resistance under fretting conditions, an alternative to hard chrome plating by using thermal spraying

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KEYWORDS: Fretting; fretting wear; friction tests, thermal spray coatings; replacement of hexavalent chromium.

Electrolytic hard chromium coatings are widely used for their good tribological performances. Confronted to more restrictive safety and environmental requirements, manufacturers need to find alternative solutions to the use of hard chrome plating. Therefore, a contribution in this field is proposed by comparing the fretting wear performances of hard chromium with interesting candidates such as thermal spraying coatings.

In addition, fretting is a common wear mechanism of mechanical components characterized by motion with a low amplitude. It can result in cable breaks, actuator blockages, bearing destruction (false Brinelling effect) and splined shaft loosings and electrical contact faults ... For parts subject to cyclic stresses, fretting favors crack initiation by fatigue (fretting fatigue). We observe the generation of fine particles often oxidized (fretting corrosion) around the contact zone.

Fretting wear is strongly influenced not only by the amplitude, frequency and trajectory of the movement, pressure and contact geometry, but also by different parameters such as the material, the roughness and the surrounding environment (grease, humidity). Therefore, for all conditions, it is difficult to evaluate the effectiveness of each solution likely to have a risk of fretting.

Moreover, according to a statistic study carried out by the CETIM on 560 cases of wear damage, 29% of mechanical component damage is caused by fretting, just behind galling (35%). This high percentage is mainly due to the lack of knowledge about the fretting wear mechanisms and the lack of reliable data for design offices and maintenance services.

To reduce fretting industrial failure cases and to propose a representative friction test for various mechanical applications, CETIM has previously worked on the realization of fretting tests according to ASTM G-204. This test was performed by using a ball-on-plate configuration and frequency and amplitude domains representative of the mechanical applications. Thus, after having generate fretting wear tracks on coated plates by performing

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this previous fretting test method (ASTM G204), the present work aims to obtain a better understanding of the fretting wear mechanisms by carrying out a multi-scale and multi-technique approach. This latter approach is partly based on the realization of measurements of friction coefficient, volume wear of the 100Cr6 ball and the coated plate and analyses of the worn surfaces by using roughness measurements and scanning electronic microscopic (SEM) observations coupled to energy-dispersive X-ray spectroscopy analysis (EDS). For this purpose, the fretting wear behavior of various material couples composed by a 100Cr6 ball and a plate with different coatings is studied. More precisely, these coatings are composed by an electrolytic hard chromium coating and thermal spraying coatings, such as Cr2O3, T800, WC-10Co-4Cr, Cr3C2/25(Ni-20Cr), generated by three suppliers.

These tests have shown that the six different material couples exhibit low wear and very similar friction coefficients. In addition, it is underlined a higher average total wear volume of the couple 100Cr6 / hard chromium coating than for the other five material couples (as shown the figure 1). Indeed, compared to the couple 100Cr6 / hard chromium coating, there is a reduction of the average total wear volume from approximately 27% to 72% for the other material couples. Therefore, this study shows that thermal spraying coatings represent a good alternative to hard chromium coatings to enhance the wear resistance.

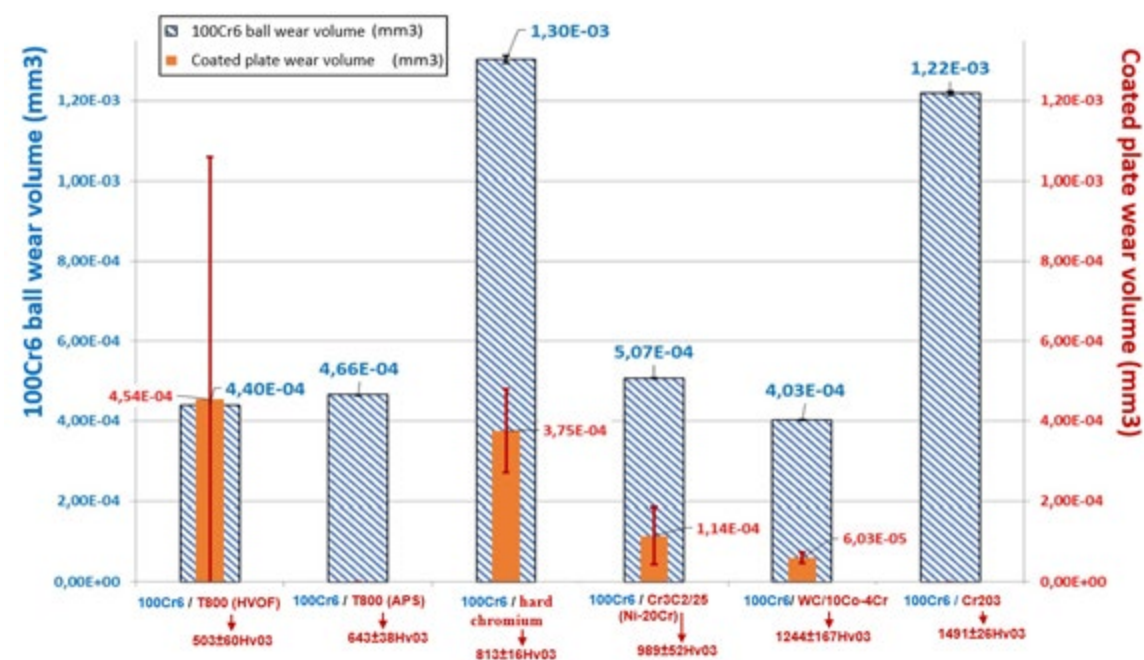


Figure 1: Evolution of the wear volume of the 100Cr6 ball and the various coated plates under fretting wear conditions according to the ASTM G-204 standard.

S06

Damage tolerance and fatigue life

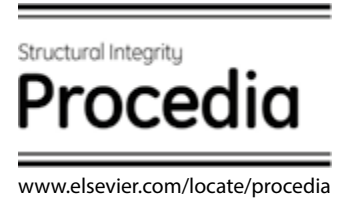
Chairmen:
T. Palin-Luc & B. Bholah
R. Schrank & M. Marzin
JF. Flavenot & A. Govaere



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FD21-13

3D FEA based surrogate modeling in fatigue crack growth life assessment

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Runtime efficient models designed for damage tolerant life assessment are desired in Structural Health Management and Digital Twin development. While 3D FEA is commonly used in the industry to assess health of a nominal structure design in service, in probabilistic assessments, reduced order models are preferred due to lower runtime compared to the deterministic models at the cost of solution accuracy.

It is commonly believed that remeshing process is man-power intensive and generating fine mesh around the crack front is computationally expensive. Consequently, any mesh convergence study or uncertainty quantification assessment becomes a burden for the engineer in charge of a structural integrity assignment. Under the assumption that a quick runtime model is needed, closed-form solutions for simple crack representations (i.e. elliptical corner crack at a hole under uniform loading) are still developed and used even though they often provide a relatively lower accuracy solution compared to a 3D finite element structural analysis due to the assumptions made in the modeling process.

Instead of developing a generic model specific to a location susceptible for cracking or already containing a crack, the 3D FEA representation of the structure can be utilized to accurately compute crack driving forces and therefore take into account nominal geometry and the stress gradient that controls crack advancement.

Fatigue crack growth experimental data is used for validation purposes and for laying out details of the modeling procedure. Solution accuracy and runtime of the 3D FEA based surrogate models are assessed to demonstrate the efficiency of the method.



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FD21-20

Experimental study of a CoCrMo alloy treated by SMAT under rotating bending fatigue

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Gwénaëlle Proust³, Delphine Retraint¹**

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To strengthen materials and therefore improve the mechanical properties of parts, some of the most widely used techniques are the mechanical surface treatments. Among them, Surface mechanical attrition treatment (SMAT) exhibits great potential in strengthening mechanical components that undergo cyclic stresses. SMAT is based on multidirectional impacts of materials with flying shot boosted by an ultrasonic generator. It is able to generate a superficial hardened nanostructured layer along with a transition region beneath the treated surface. In addition, high compressive residual stresses can be generated especially in the near-surface region where the plastic deformation is highly activated. Studies show that SMAT is able to significantly improve the properties of various materials, such as their fatigue resistance.

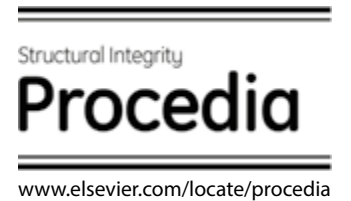
The main objective of this study is to understand the fundamental damage mechanisms of a CoCrMo alloy under rotating bending high cycle fatigue. For this purpose, bending loadings are imposed on cylindrical specimens in the untreated and SMATed states. The results of the fatigue tests are presented in the form of S-N curves according to the JSME S 002 method. A broad materials characterization is done before and after the fatigue tests, in order to evidence what features play an important role in fatigue life. Such characterization englobes the use of: Scanning Electron Microscopy (SEM), Electron Backscatter Diffraction (EBSD), Surface Roughness Profilometer, X-Ray Diffraction Analysis (XRD), Micro and Nano hardness tests, etc. Particular attention will be paid to the effects of residual stresses and work hardening on the fatigue properties of the CoCrMo alloy.



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FD21-21

The effect of the environmental conditions on the threshold against fatigue crack propagation

Larissa Duarte, Mauro Madia, Uwe Zerbst

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The threshold against fatigue crack propagation (together with the near-threshold regime of the da/dN-DK curve) is a parameter that is of paramount importance for damage-tolerant component design. Although its determination has long been specified through widely used testing guidelines, problems have been revealed in recent times which call for a rethink of the whole concept. In this context, environmental variables, such as air humidity and temperature, play an important role. Load frequency can be regarded as an indirect influence parameter. These all influence corrosion, which, in principle, can be detrimental or beneficial for fatigue crack growth. The negative effect is caused by anodic metal dissolution or hydrogen embrittlement (lower threshold), the positive one is a consequence of the oxide-induced crack closure effect (higher threshold).

The work focuses on the latter. It shows up that the environmental conditions have a significant effect on the da/dN-DK curve at low cyclic crack driving forces or crack propagation rates, especially for low stress ratios. The test frequency, which has an influence on the test duration and thus on the time-dependent processes such as the transport of the medium to the crack tip, influences significantly the development of oxide-induced crack closure and the resulting threshold values. The effects, their potential causes and their consequences in the determination of the residual lifetime of components are examined.



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FATIGUE DESIGN 2021

FD21-22

Determination of fatigue crack propagation thresholds using small-scale specimens

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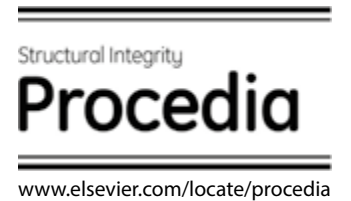
The damage tolerance approach is widely used in the design and estimation of inspection intervals of safety-relevant metallic components subject to fatigue loading. The approach relies on the knowledge of the fatigue crack propagation characteristics, wherein a relevant role is played by the fatigue crack propagation threshold. Nevertheless, the use of material data determined by testing on conventional specimens is not straightforward in case of thin-walled components such as turbine-blades or additively manufactured parts, in which the local variation of material properties in highly stressed regions must be considered. In these cases, the possibility of investigating the fatigue crack propagation properties on a limited portion of material is crucial. For this purpose, a new test methodology has been developed for small-scale specimens which allows the determination of the intrinsic fatigue crack propagation threshold and the near-threshold regime. The use of small-scale specimens poses a challenge to the applicability of the method to metallic materials, especially regarding the limitations on material strength and requirements for the application of the linear elastic fracture mechanics concepts. These aspects are discussed in this work. Furthermore, the application on the high strength steel S960QL and on an additively manufactured 316L is presented, along with a comparison with data determined by conventional testing.



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FD21-25

Estimation of the Kitagawa-Takahashi diagram by cyclic R-curve analysis

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The Kitagawa-Takahashi (KT) diagram is a proven concept for describing the fatigue limit in presence of a defect or crack. It can be determined empirically with great experimental effort. It can also be estimated by means of the El Haddad relationship if the endurance limit and the long fatigue crack propagation threshold are available in reasonable accuracy. A third option is the determination by a cyclic R-curve analysis. The cyclic R-curve describes the dependency of the fatigue crack propagation threshold on the crack growth at the short crack propagation stage. This can be experimentally determined using a closure-free initial pre-crack. It can then be applied to the determination of crack arrest for a given applied load and a given defect or crack size.

Compared to the other two methods mentioned above, this option has considerable advantages: It can be applied to any component and any stress ratio. It allows the treatment of multiple cracks and provides the fatigue life in the upper part of an S-N curve as well as the endurance limit. Compared to the empirical determination of the KT diagram, the experimental effort is significantly lower and compared to the El Haddad approach it avoids problems such as the use of non-conservative fatigue long crack propagation thresholds (when the conventional load reduction method is applied to materials prone to corrosion) and the mathematical predetermination of the curve shape. The work introduces the method and provides a critical discussion as well as quantitative comparison between the different methods.



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FD21-34

Fatigue strength of autofrettaged component-like specimens made of ultra high strength steel

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The elevation of injection pressures in Diesel engines to reduce pollutant exhausts is a necessary consequence of environmental policy. For this purpose, the usage of ultra high-strength steels for pressure bearing components is investigated. Focus of the investigation is put on the intersection of two bore holes, which typically occur in Diesel common rail systems. The pre-treatment process of Autofrettage is also considered. The Autofrettage process induces compressive residual stresses into highly-stressed areas of the components and is the decisive factor for the fatigue lifetime assessment. In order to describe the residual stresses, stress-strain data from fatigue testing of the hot work tool steel W360 was approximated with the Chaboche material model and finite-element analysis was performed. For the analysis, the material behavior was set to follow the experimentally assessed initial stress-strain curves for loading and unloading. As results from preliminary works have shown, that crack arrest has to be taken into account when calculating fatigue lives of autofrettaged specimens as the endurance limit is otherwise underestimated. Therefore, the subsequent fatigue life calculations are separated into the description of crack initiation and crack arrest, the latter described with the strip yield model. The calculated results are then compared to experimentally assessed results from pulsating fatigue testing of component-like specimens at different Autofrettage pressures.

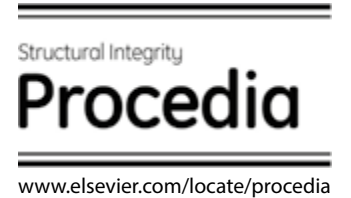
This work is part of an AiF/iGF project under the funding code 19790 N and is supported by the Federal Ministry for Economic Affairs and Energy on the basis of a decision by the German Bundestag.



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FD21-53

Assessment of fatigue crack growth based on 3D finite element modeling approach

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Fatigue crack growth assessment of structural components enables manufacturers to quantify damage tolerance capability of high-risk components. In the crack propagation simulation process since reduced order models are commonly employed, crack front shapes are generally approximated as being elliptical and categorized as internal, corner or surface type depending on their location. A more comprehensive simulation process should consider the component level geometry, loading conditions and eliminate assumptions related to crack front shape or planarity of the crack path. This study seeks to evaluate crack growth behavior of panel like structures with different 3D crack geometries and multiple cracks under cyclic loadings. For verification purposes, an analytical solution-based model has been developed and implemented in Matlab to predict crack growth life and crack front evolution for three different crack types: semi-elliptical, corner quarter-elliptical, and internal elliptical cracks in plates. The analytical model results are compared to 3D finite element (FE) based predictions using a commercial software package, SimModeler Crack. The 3D FE modeling approach has been further tested and validated with experimental data of AI 2024-T3 specimens with multiple site cracks. Crack growth simulation results obtained from 3D FE models in comparison to analytical models and experimental results show that the FE-based modeling approach provides an effective modeling tool for crack growth analysis and damage assessment of structural components considering different initial crack geometries and multiple site cracks.



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FD21-54

The REX-model: a phenomenological approach for crack growth evolution description under fatigue loading

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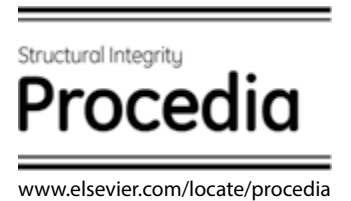
Modelling crack extension under cyclic loading is crucial in terms of prevention and maintenance operations in a multitude of applications when the damage-tolerance design is applied and prediction of the remaining service life of components susceptible of fatigue damage is ineludible. The evolution of the a-N curves follows a characteristic law that can be adequately identified as cumulative distribution functions (cdfs) of the generalized extreme value family by using a novel phenomenological proposal, denoted REX-model. In this work, the suitability and usefulness of the REX-model are confirmed when applied to three different experimental campaigns. The presented methodology allows the transition between the traditionally referred to as short- and long-crack regimes to be analytically described and, additionally, its conversion to fatigue crack growth rate (FCGR) curves to be achieved. Some further benefits are also discussed, as the estimation of the corresponding threshold for the long-cracks regime (ΔK_{th}) by applying retrospective evaluation. In this way, the new a-N model provides the basis for reliable statistical analysis. The statistical distribution of the fatigue lifetime can be assessed as the response of the material during the damage process from a specific defect «control» size.



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FD21-65

Crack propagation analysis using XFEM and following evaluation of deck repair projects at rib-to-deck welding for steel orthotropic bridge decks

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Orthotropic Steel Deck (OSD) systems have become a fundamental element in many modern large bridge structures. OSDs generally consist of a flat and thin steel plate strengthened by a series of longitudinal stiffeners called ribs that are supported by orthogonal transverse beams.

The root of a fillet weld in a rib-to-deck welding connection is a critical location of observed fatigue initiations for bridges with OSDs, in particular with a lack of penetration exceeding one millimetre, to reach even three millimetres. It was alleged that the intensity of the transversal tension within the deck plate near the weld could compel the cracks initiated at the root to propagate either horizontally towards the weld or more vertically towards the deck plate.

Vertical cracks can go through the deck plate without being detected and put the structure in a crucial condition, especially for bridges with large cantilevered balconies.

Crack initiation analysis representing the real loading conditions was used to verify the initiation location at the root. Then the XFEM method implemented in Code_Aster was used to verify the influence of the transverse tension on propagation: with a tension higher than 220 MPa, cracks move vertically.

Repairing actions without precaution can induce such residual stresses in the very restrained OSDs. It will be discussed about the opportunity of using Tungsten-Inert-Gas (TIG) dressing and High-frequency impact treatment (HFMI) to reduce the residual stresses. However a fully bolted solution will be also presented to avoid any residual stress. It is specially adapted to treat isolated cracks.



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FD21-87

Residual Life Assessment (RLA) of structures and equipment

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Cetim, Senlis, France

This paper deals with the problem of evaluating residual life of structures and equipment often in service for years and that may have reached or exceeded the end of their design life. In spite that the problem is encountered in many industrial sectors and represents a major concern, references available for dealing with it are often limited.

Selected European and ISO references potentially suitable for this purpose for steel structures and cranes are presented and discussed in this paper together with some of the practical problems faced by the engineers responsible for evaluating the residual life of equipment and structures.

A general methodology is presented for the assessment and management of residual life of existing equipment and structures that has been developed by CETIM (Technical Institute for Mechanical Industry), with an example of its application to loading bridges of Calais harbour.

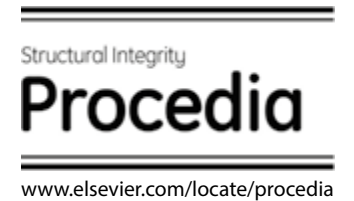
The paper also deals with the potential links with the EN 45550 series of standards dedicated to the assessment of energy-related products concerning their durability and ability to be repaired and reused.



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Structural Integrity Procedia 00 (2021) 000-000



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FD21-100

Instrumented fatigue tests on 316L and TA6V samples produced by wire arc additive manufacturing

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The wire arc additive manufacturing process (WAAM), is a derivative technology from arc welding, allowing the production of large metallic parts, within reduced durations. In the scope of studying the material produced with this process, samples have been produced via a 6-axes robot equipped of an arc welding torch, allowing the deposit of material layers, in a reproducible manner according defined trajectories. The arc technology chosen is the gas-metal-arc-welding process, in its commercial CMT variant, usually used for this application.

In order to obtain different microstructures and residual stresses states, various sets of welding parameters and post-welding heat treatments are implemented. Possible defects such as porosities can also be present inside material.

Instrumented fatigue tests are performed on samples extracted from WAAM material. A CCD camera is used to implement the digital image correlation technique. This allows the in-situ study of the evolution of the strain fields, with observation of the material heterogeneities induced by this particular process. In addition, an infrared camera is implemented in order to observe the thermal effects linked to the dissipative mechanisms. By combination of datas from both cameras, energy balances are established, in order to estimate the part of deformation energy involved in damage and the stored part.

Finally, microscopically observations are realised on cracked fatigue samples, in order to try to correlate initiation and growth with microstructural features.

S07

Experimental and numerical design and validation methods

Chairmen:

S. Fouvry & O. Bardou

M. Facchinetti & G. Servanton

K. Barthoux & M. Manchid



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FATIGUE DESIGN 2021

FD21-6

Structural integrity proof of automotive safety parts

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Mechanical design of automotive components such as chassis system parts still deserves and captivates technical and scientific attention.

On one hand, the load spectrum coming from customer use is widespread and spans from very high cycle fatigue at low amplitude to single events up to possible definitive failure.

On the other hand, it is matter of high grade safety components, whose reliability has to be proved to fulfil basic and strong requirements.

But, contrary to many other industrial domains, no international standard is published as a general rule to demonstrate the required structural integrity.

Thus, each carmaker is expected to self-certificate its vehicles, through numerical simulations and experimental tests, calling for its own proven-by-use experience.

This paper aims at describing the basic principles applied at PSA Groupe, notably for passenger cars.

They come from several decades of successful field practice and may be considered as a relevant state-of-the-art.



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FD21-30

Identification method of vehicle loads using a multi body vehicle model, real sensors and an extended Kalman filter

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¹PSA Groupe, Vélizy, France. ²Supméca, Quartz Lab, Saint-Ouen, France

The mechanical components of a vehicle must be optimally designed, limiting the oversizing, both in terms of their reliability and of their cost. The component sizing approach is generally fed by instrumented vehicle running on a track comprising various «obstacles» which are the expression of a chosen level of severity. Moreover reliable knowledge of forces defining the design of components requires knowledge of the loads on driven customers vehicles . These loadings depend on customer behavior and the road profiles on which the vehicle is traveling. Today the signal reconstruction method is obtained by a linear transfer function approximation method of neural network between different sensors. This method is not robust for the tails of designing efforts distribution, that is to say during heavy loads for example.

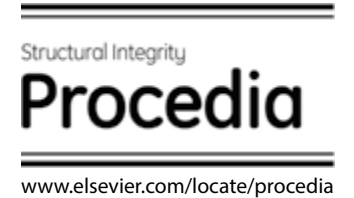
The objective of the work presented here is an approach aimed at reconstructing probability densities of the wheel center forces by using a physical vehicle model and real sensors measurements. The physical multibody vehicle model is described as accurately as possible and a number of sensors and their position are identified to reconstruct the three dimensions forces and the wheel base excitations. Then the model is reduced as much as possible by considering the uncertainties of the model, the measurements, the precision objectives of the quantities of interest and the frequency bands studied. Finally, we implement a nonlinear identification approach of the Kalman filter type aiming to identify the dynamic behavior of the vehicle and the efforts with a real time target.



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FD21-32

Optimized vehicle durability testing by means of an intelligent test driver guidance system

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Vehicle manufacturers use special test courses which must be endured damage-free by the vehicle prototype until a compulsory mileage is reached. The driving instructions of this endurance road test cannot always be implemented in a reproducible manner, for example due to the influence of driver, weather conditions or route closures. Furthermore, a test course based on many years of experience can only be slowly adapted to new trends in customer usage behavior.

This article presents a new type of driver guidance system which, depending on the loads already endured, indicates the test driver the optimal route to reach a customer-oriented load target. The route calculation is dynamically adapted according to the actually generated and measured loads. For this purpose, the system accesses the relevant in-vehicle sensor data and combines it with road segments of a digital map. In this way, a database of the loads which were achieved on each road segment depending on the driver and the weather, is filled. This information is used as input of a heuristic algorithm which determines the best combination of road segments ahead for reaching the load target. As the load database is updated with every road segment driven on during the test, a learning process takes place that continuously adapts the route determination to driving style and changed road conditions. Thus, by monitoring the measured loads and by using the artificial intelligence of the driver guidance system, the customer-oriented load target of the durability road test is optimally achieved resulting in a high testing quality.



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FATIGUE DESIGN 2021

FD21-36

Towards a better understanding of mechanical stress applied by passenger vehicle customers with optimized instrumentation and relevant data post-processing methodologies

Denis Chojnacki

PSA GROUPE, Sochaux, France

The various mechanical parts of a vehicle must be designed to ensure a target level of reliability compatible with safety objectives while limiting oversizing.

This requires automobile manufacturers to implement the relevant methodological tools adapted to the component failure mechanisms.

Several improvements have been made over the past 10 years on this topic, in particular with tools taking into account the local properties of materials and thus delivering local stresses and damage at any point of each part.

These procedures require track measurements or virtual road load data representing the image that each manufacturer chooses to have of a given customer severity level.

This arbitrary level of severity then makes it possible to express a target performance threshold of the component to guarantee objective reliability.

The difficulty in these methods is to be able to capture the severity levels of customers all over the world, which is by definition very variable because depending on several inputs like the road geography and quality, the customer behaviour and style.

The objective of this paper is to share the state-of-the-art methodologies implemented by PSA to capture this information with the best efficiency and also to reduce its cost through a Big Data approach.

Three main themes will be addressed:

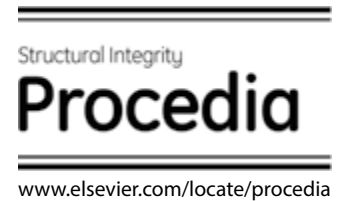
- Instrumentation strategy
- Sampling methodology to catch the reality of the customer's field
- Objectification and classification of customer life situations



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FATIGUE DESIGN 2021

FD21-49

Phase-field model, fatigue, residual stresses, local strain approach, Paris law

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and Markus Kästner^{1,4}**

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An alternative to classical fracture mechanical approaches for fatigue life estimation, the phase-field approach for modelling crack initiation and growth has gained enormous popularity within the last decade due to its unified and strong mathematical and theoretical background and efficient computational flexibility. In the field of fatigue fracture, different approaches have been pursued [1-4], gradually reducing the fracture toughness of the material or increasing the crack driving force in order to incorporate fatigue effects into the phase-field model. However, a numerical study based on a direct simulation of the loading history becomes unfeasible when dealing with high cyclic fatigue with cycles to failure larger than 10⁴, including inelastic material models. Therefore, time-efficient simulation methods are required. This presentation explores some recent research results of the phase-field model for fatigue fracture [5].

The first part of the talk focuses on combining the phase-field method for brittle fracture [6] with the local strain approach (LSA) [7]. In this way, we avoid the explicit simulation of the load cycles by executing a local cyclic damage calculation, obtaining accumulated fatigue damage, which is used to degrade the critical fracture energy locally in order to describe dissipation. Computation time is significantly reduced compared to an elastic-plastic analysis because the LSA provides a plastic revaluation of elastic stresses and strains. This allows for purely elastic finite element simulations. During a revaluation, plasticity as the reason for fatigue crack initiation and propagation in metals is considered in terms of cyclic stress-strain curves. The cyclic degradation of the material is characterised by standard strain-controlled Wöhler fatigue tests. Furthermore, a critical plane concept is adopted to deal with multi-axial loads. We show that the developed method is able to simulate fatigue crack initiation as well as propagation and can reproduce Paris behaviour. The model is parametrised using CT tests [8].



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Structural Integrity Procedia 00 (2021) 000-000



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The second part of the presentation deals with the incorporation of residual stresses into the model. To this end, residual stresses are introduced into the specimen with the help of laser shock peening [9]. Within the LSA, the residual stresses are treated as mean stress, whereas a simple and efficient strategy to superpose residual stresses and stresses and strains from cyclic loading in the phase-field fatigue model is presented. The simulations are able to capture the crack inhibiting and accelerating effect of compressive and tensile residual stresses, which are compared to the experiments [8].

References

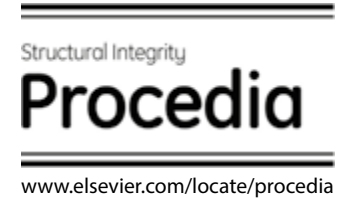
- [1] P. Carrara et al., CMAME, 361: 112731 (2019). DOI 10.1016/j.cma.2019.112731.
- [2] A. Mesgarnejad et al., Theor. Appl. Fract. Mech, 103: (2019). DOI 10.1016/j.tafmec.2019.102282.
- [3] J. Ulloa et al., CMAME, 373: 113473 (2019). DOI 10.1016/j.cma.2020.113473.
- [4] Y. Lo et al., J Mech Phys Solids, 132: 103684 (2019). DOI 10.1016/j.jmps.2019.103684.
- [5] M. Seiler et al., Eng. Frac. Mech. 224 (2020), DOI 10.1016/j.engfracmech.2019.106807.
- [6] C. Miehe et al., CMAME 80: 1273–1311 (2010). DOI 10.1002/nme.2861.
- [7] D. Radaj and M. Vormwald, Ermüdungsfestigkeit für Ingenieure (2007), ISBN 978-3-540-71458-3.
- [8] M. Seiler et al., Arch. Appl. Mech. (2021), DOI 10.1007/s00419-021-01897-2.
- [9] S. Keller et al., Int. J. Fat. 124 (2019), DOI 10.1016/j.ijfatigue.2018.12.014.



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FD21-59

Advanced fatigue assessment - The future of wind turbine towers

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One of the sustainable development goals of the Green Deal established by the European Union is the demand of affordable and clean energy. Among the renewable energies, the wind energy is already indispensable to reach the ambitious goals and will become even more important in future. Since economic aspects will gain more importance, an efficient use of the materials and resources is essential, especially in the field of fatigue design of wind turbine towers made of steel.

This paper presents an advanced fatigue assessment method, using the strain life approach and the crack propagation method, named Two Stage Model. This model combines the two phenomenological aspects of crack initiation life and crack propagation life for a more reliable fatigue service life prognosis compared to commonly applied methods. By applying the Two Stage Model various input parameters can be explicitly considered that allow a more in-depth analysis and more precise results of the fatigue resistance.

The paper gives, firstly, a brief overview of fatigue assessment methods for wind turbine towers. Then, the Two Stage Model and the relevant input parameters are presented with the focus of their effect on the service life of wind turbines. The paper continues by presenting a probabilistic prognosis analysis considering realistic uncertainty distributions for selected parameters, e.g. material, geometry, weld parameters. Probabilistic density functions are assigned to the scattering model parameters for a reliable fatigue design to ensure a better prognosis safety. This advanced fatigue assessment facilitates an economically efficient design of wind turbine towers.



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FATIGUE DESIGN 2021

FD21-62

Digital twin for fatigue analysis

Amaury Chabod

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As part of fatigue from finite elements (FE) analysis inputs (geometry, material, and loading), stress level in component is a key input for representativity of simulation. Indeed, due to power law between stress and life, a small variation in stress input is propagated to a large variation of output simulated life.

To reduce these epistemic uncertainties, correlation with strain gages is a fundamental added value to numerical FE model, to validate mesh convergence, model, stiffness, and boundary conditions. Construction of a robust digital twin uses this important step for further usage and to improve predictability.

This presentation will show how to extract insights from strain gages measurements:

- Virtual strain gage analysis for better test/CAE correlation
- Strain gage position and orientation optimization for better representativity of independent load cases
- Load reconstruction to get load histories from strain gage measurements and independent unitary FE load cases
- Extrapolate stress level and life results from discrete points (strain gages) to full component with previous load results, accessing life results in hot spots with large stress concentration

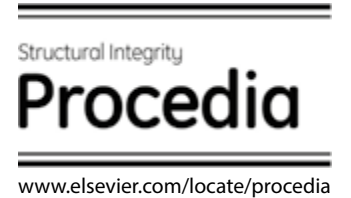
Theoretical background will be described, as methodology on an application.



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FD21-75

Fatigue strength of laser-dressed non-load-carrying fillet weld joints made of ultra-high-strength steel

Tuomas Skriko, Antti Ahola, Ilkka Poutiainen, Timo Björk

Lappeenranta-Lahti University of Technology LUT, Lappeenranta, Finland

Laser dressing or remelting is one of the post-weld treatment methods that is based on the modification of the local weld toe geometry, and generally, it is similar to TIG or plasma dressing. However, the laser dressing is not covered by common fatigue design guidelines and recommendations of welded structures at the moment. In this research, the effect of laser dressing on the fatigue performance of non-load-carrying fillet-welded cruciform joints made of direct quenched S960 grade steel was studied by means of experimental fatigue testing and geometry and residual stress measurements together with finite element analyses and different statistical calculation processes, such as nominal, structural and effective notch stress methods. In addition, the 4R method was also employed and its applicability for fatigue assessment of laser-dressed weld joints in question was investigated. The experimental results showed the enhancement of the fatigue strength for laser-dressed fillet weld joints compared to as-welded condition and the recommended FAT class for similar TIG dressing case was exceeded. However, the fatigue strength improvement of laser dressing was less compared to the corresponding TIG-dressed joints when applied stress ratio was low. In proportion, the disparity between the improvement effect of laser and TIG dressing methods was reduced with higher applied stress ratio. This can be explained by different residual stress state in the critical weld toe treatment area of laser- and TIG-dressed joints that can be taken into account when using the 4R fatigue assessment method.



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FATIGUE DESIGN 2021

FD21-93

On the evaluation of overload effects on the fatigue performance of engineering materials

Kimiya Hemmesi¹, Franz Ellmer², Majid Farajian³, Michael Luke¹

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In the present work experimental and numerical methods are used to analyse the influence of overloads on the fatigue behaviour of the quenched and tempered steel 42CrMoS4 and the wrought aluminium alloy EN AW-6082 T6. The main objective is to quantitatively incorporate the influence of overloads into the fatigue damage evaluation. Blocks of five overloads at two different overload levels were applied prior to constant amplitude fatigue tests at a stress ratio of $R = -1$. The overload levels were 75% of the static strength, calculated according to the FKM guideline. Digital Image Correlation technique is used during the course of overloading for a 3D measurement of local notch deformation. In addition, the x-ray diffraction technique is employed to measure the overload-induced residual stresses in the notch. Experimental results give evidence that depending on the material and the overload level, the fatigue limit is either decreased, increased or only insignificantly affected. To explain this behaviour residual stresses and their evolution under fatigue loading as well as the hardening behaviour of the material under overloading are analysed. The 3D FE method is used in conjunction with the experiments to calculate the local stress-strain field at the notch under different load and overload cycles. Finally, in conjunction with selected fatigue parameters the obtained stress-strain fields are applied to the damage calculations to quantify the effects of overloads in terms of magnitude and number of cycles on the fatigue behaviour.

S08

Fatigue of assemblies (mechanical, welded, adhesive-bonding, multimaterials,...)

Chairmen:

HP. Lieurade & I. Huther

M. Braun & I. Huther

A. Bignonnet & M. Bennebach

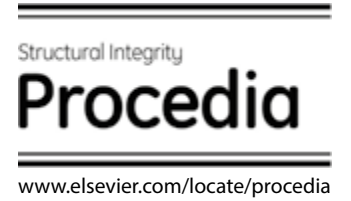
M. Leitner & B. Depale



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FATIGUE DESIGN 2021

FD21-2

Life-cycle energy analysis of a high strength steel heavy vehicle component subjected to fatigue loading

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KTH Royal Institute of Technology, Stockholm, Sweden

This study focuses on comparing the life-cycle energy required for Conventional Steel and HYBRIT (Hydrogen Breakthrough Ironmaking Technology) Steel. The application chosen for this comparison was a bogie beam of Volvo's articulated hauler A30. HYBRIT is new generation of a fossil-free steel technology developed by SSAB (Swedish Steel Company) which aims to replace coal with hydrogen during steel production to reduce CO₂ emissions. The different phases analyzed were; material extraction, steel production, component manufacturing, use and end of life phases. Where the use phase is predominantly fatigue loading. It is concluded that HYBRIT Steel consumed 8-10% less energy than Conventional Steel. For applications with less dominant use phases, the percentage of energy saved by HYBRIT Steel would be even larger.



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FATIGUE DESIGN 2021

FD21-3

Fatigue and ultimate strength assessment of post weld treatedstrenx 1100 plus butt welds

Tobias Jonsson¹, Torbjörn Narström², Zuheir Barsoum¹

¹KTH Royal Institute of Technology, Stockholm, Sweden. ²SSAB AB, Oxelösund, Sweden

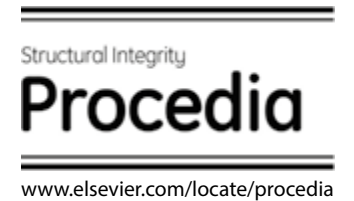
The demand of stronger and lighter structures is rapidly growing. Today's applications vary over a large range of industries where the requirements are different for different products which requires application driven research of the 3rd generation Advance High-Strength Steels (AHSS). These are high-strength steels that are tailor-made to get desired mechanical properties. One AHSS manufactured by SSAB is their Strenx® 1100Plus steel that is specially designed to get excellent welding properties. In the current study the fatigue life improvement was investigated when using post weld treatments, TIG dressing and HFMI (High Frequency Mechanical Impact), for butt welded joints in Strenx® 1100Plus. Fatigue testing and assessment was carried out, using nominal stress and effective notch stress approaches, and the results were compared with fatigue strength recommendations for similar joints and steel grades given by the International institute of Welding (IIW). It is concluded that one additional FAT class increase could be observed in comparison to what is recommended by IIW for both types of post weld treatment methods.



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FATIGUE DESIGN 2021

FD21-14

The peak stress method applied to fatigue lifetime estimation of welded steel joints under variable amplitude multiaxial local stresses

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Fatigue actions of most engineering welded structures involves variable amplitude (VA) loadings cycles. According to the idea that fatigue damage increases with applied cycles in a cumulative manner, the fatigue design of welded joints in such structures is based on the use of fatigue strength criterion for constant amplitude (CA) loading in conjunction with a cumulative damage rule. In the present work, the Peak Stress Method (PSM), has been reformulated to estimate the lifetime of welded joints subjected to VA loadings. The PSM is an engineering finite element (FE)-oriented technique to rapidly estimate the notch stress intensity factors (NSIFs) [1] at the weld toe or at the weld root, which are modelled as sharp V-notches with a null tip radius. The fatigue strength under CA loading is then evaluated by combining the simplicity and rapidity of the PSM in evaluating the NSIFs with a robust and validated fatigue strength criterion such as the one based on the averaged Strain Energy Density (SED), which can be written as a function of the relevant NSIFs. To preserve the simplicity of the method, its extension to VA loading conditions has been achieved by assuming the Miner's Linear Damage Rule (LDR) as cumulative damage rule.

The proposed method has been validated against new experimental results generated by testing cruciform non-load-carrying (nlc) fillet-welded attachments having different inclinations made of structural steel. Thanks to this joint geometry, either uniaxial or multiaxial local stresses under variable amplitude loading could be investigated by applying an axial load.



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FATIGUE DESIGN 2021

FD21-17

Fatigue assessment of welded joints including the effect of residual stresses

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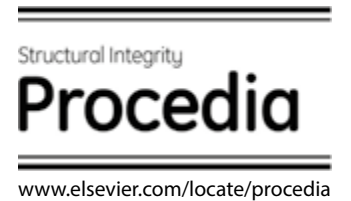
Residual stresses are an inseparable consequence of the most common manufacturing processes, resulting in high magnitude and not easily predictable stress field inside the material. Fatigue design codes usually account residual stresses through highly conservative assumptions, resulting in poorly optimized designs or unexpected failures. Innovative residual stresses calculation techniques and the increased motivation towards an optimized use of materials allow for a more accurate fatigue assessment of welded joints. This work investigates the influence of residual stresses in the fatigue assessment of a pipe-to-plate welded joint made of S355JR structural steel. Firstly, an uncoupled thermal-structural finite element simulation was performed to evaluate the overall residual stress field inside the specimen due to the welding process. Secondly, the aforementioned residual stresses were embedded, as the initial condition, within numerical models intended for fatigue damage factors calculation.



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FATIGUE DESIGN 2021

FD21-64

Fatigue evaluation of beam cope holes in the web coinciding with thickness transition in the flange (study commissioned by ASF-Vinci and French Road Directorate)

Jacques Berthelémy

Cerema, Marne la Vallée, France

Under a large amount of heavy traffic, the fatigue damage of steel bridges is prone to occur, leading to serious disasters. The choice of the right economic features for the details is important. The cope hole feature is economic and allows an easy control of the butt weld of the flange. For this reason, it is still used in many countries for the welded joints on site.

In France a web cope hole concomitant with a thickness transition in the flange was experimentally used in the '70s and after that not recommended. However, the lack of specific rules in the present Eurocodes has induced many designers to think wrongly after 1987 that it was acceptable again.

The fatigue strength category of 71 MPa is only adapted when no thickness transition is present and it only considers the hot spot in the flange caused by the longitudinal stress.

Therefore, this paper proposes additional stress concentration factors to evaluate the effect of the thickness transition regarding the stress along the cut as well as the longitudinal stress in the flange. The principal aim is to evaluate, and if needed assess and repair motorway bridges already in service.

The flange-web weld is also a weak point which is studied specifically because of the various geometric cases that can occur. For new projects a butt-welded flange-web liaison is recommended. However existing bridges often present a fillet weld all around the bottom corner of the cope hole that may need to be cut and rewelded.



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FATIGUE DESIGN 2021

FD21-67

Overview on the fatigue strength of single-sided transverse and longitudinal fillet weld joints

Antti Ahola¹, Tuomas Skriko², Timo Björk¹

¹Laboratory of Steel Structures, LUT University, Lappeenranta, Finland. ²Laboratory of Welding Technology, LUT University, Lappeenranta, Finland

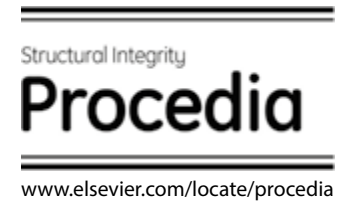
In the present study, the fatigue performance of single-sided fillet welds is evaluated. Both longitudinal load-carrying joints, for instance existing in beam structures and welded hollow sections, and transverse joints are considered in this work. Experimental data of such joints made of mild and ultra-high-strength steel (UHSS) is extracted from existing studies to evaluate the fatigue strength properties. A general rule is that a higher static strength does not contribute to achieving higher fatigue strength in welded components. The main characteristics affecting fatigue strength properties of these joints are discussed. Furthermore, the paper evaluates the fatigue strength of single-sided fillet weld joints in comparison with the joints with double-sided welds and addresses potential for improving fatigue performance applying geometrical modification in groove shapes and welding preparation. The experimental results indicate that in the transverse welds, an increase in material's yield strength shows a slight decrease in fatigue strength compared to mild steels, while in the longitudinal load-carrying seams, in the case of continuous weld root geometry, high fatigue strength can be achieved. The double-sided welds provide one FAT class higher fatigue strength for transverse non-load-carrying joints, obtained in terms of mean fatigue strengths. In addition, in transverse joint configurations, intermediate welding was found to have no detrimental effect on the fatigue performance compared to the joints with continuous welds. In longitudinal load-carrying joints, double-sided welds do not provide any additional benefit unless full penetration and, thus, continuous longitudinal weld root shape is achieved with such weld preparation.



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FATIGUE DESIGN 2021

FD21-69

Influence of overload on fatigue behaviour of longitudinal non-load-carrying welded joints

Isabel Huther¹, Fabien Lefebvre¹, Benaouda Abdellaoui¹, Vincent Leray²

¹Cetim, Senlis, France. ²Nov BLM, Nantes, France

Techniques of controlled overload (like initial overload or proof load) are often used to verify the structural integrity of the mechanical systems. For example, the cranes are subjected to proof load before start-up, the turbomachinery to over-speed and pressure vessels to internal over-pressure. These initial overload techniques are often imposed by Standards like ASTM or DNV which defines overload conditions to apply based on professional knowledge. However, no technical justifications, nor beneficial (or negative) effects are usually given on in-service behaviour.

The aim of this study is to evaluate the effect of one overload on the fatigue behaviour for various levels of plastic strains on welded specimens in S355 steel grade. The hypothesis made is that the initial overload will introduce compressive residual stresses at the weld toe, the area where the fatigue crack initiates and propagates. These stresses would normally have a beneficial effect on fatigue strength as after hammer-peening.

Fatigue tests were performed in tension ($R = 0.1$) on longitudinal stiffener welded specimens without overload to establish the reference and specimens after one overload for three levels (corresponding to a local stress near the weld toe equal to yield stress (YS), $1.25 \cdot YS$ and $1.56 \cdot YS$). The fatigue results show an increase of the fatigue strength, after one overload, if the local stress near the weld toe is over than YS. Greater the overload is, better the fatigue strength is. The residual stress analysis shows a significant relaxation of these stresses after the overload, that explains the performance in fatigue.



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FATIGUE DESIGN 2021

FD21-78

Influence of out-of-plane deformation on fatigue strength of web gusset welded joints

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¹*Kansai University, Osaka, Japan.*

²*Hanshin Expressway Management and Applied System Engineering, Osaka, Japan*

In Japan, infrastructures including numerous highway and railway bridges, were constructed during the rapid economic growth era from 1960's to 1970's. Those structures are warned to be aged and may deteriorate in the near future. Since in Japan fatigue designs had not been applied to highway bridges until 2002, there is high possibility that lots of fatigue crackings will occur in the future. Therefore, it is important to grasp the fatigue behavior in order to estimate time and location of fatigue crackings in such existing highway bridges.

In the previous study, the fatigue behavior of fatigue weak points were investigated through fatigue tests using the one side gusset specimen which had been used in an urban expressway for more than 40 years before removed in 2005. As a result, it was confirmed that the fatigue strength of this type of the as-welded web gusset joint satisfies JRA Fatigue Category D which is one-rank higher than that of the toe ground web gusset joint satisfies JRA Fatigue Category E. It was considered the effect of the out of plane deformation on one side gusset.

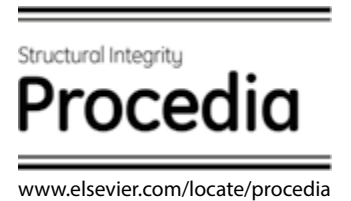
In this study, effects of out-of-plane deformations on fatigue strengths of web gussets welded joint were investigated through fatigue tests of specimens with gussets on both sides or one side. As a result, it was confirmed that the out of plane deformation has an effect on the fatigue strength of the web gusset welded joint.



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FATIGUE DESIGN 2021

FD21-81

Investigation of fatigue performance for structural steels and their weldments in VHCF domain

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¹*University of Strathclyde, Glasgow, United Kingdom.* ²*Weir Minerals, Johannesburg, South Africa*

There is very limited data on VHCF for structural steels and their weldments for >10⁷ cycles. Unalloyed low-carbon steels (BS EN 10025) are dominant structural materials for products made for minerals and mining applications. The main purpose of this research is a comparison of fatigue performance between current material (steel S355JR) and the candidate material (steel S275JR) in both parent and welded conditions. Steel components and their weldments are expected to work for several years at normal frequencies (16-20 Hz) of loading with low stress amplitude. The work focuses on ultrasonic fatigue testing of S275 and S355 steel grades in both as-manufactured and welded conditions. The idea is to compare the fatigue strength of welds in the gigacycle domain and pick a better performing grade. The expectation is that S275 weldments may perform better, because the residual stress is limited by a lower yield stress. Moreover, this grade has higher ductility making it less prone to accumulation of microcracks in fusion zone. In order to reach the conclusions, the values of the obtained experimentally fatigue limits are going to be compared. A significant challenge is the interpretation and utilisation of the obtained ultrasonic data and as there is significant frequency sensitivity. Since the ultrasonic fatigue data is intended to be applied to the fatigue assessments of the equipment operating at normal frequency, the effect of frequency sensitivity needs to be investigated and quantified. Data at normal frequency would be required in order to adapt «ultrasonic» fatigue limit to normal frequency.



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FATIGUE DESIGN 2021

FD21-83

Parametric calculations of service fatigue life of welded t-joints

Miloslav Kepka, Miloslav Kepka Jr.

University of West Bohemia, Pilsen, Czech Republic

When developing a new machine, the prescribed fatigue criteria must be fulfilled in important structural nodes. These structural nodes are often weldments. S-N curves of welded details are prescribed by standards or they are determined by statistical evaluation of results of laboratory fatigue tests.

Dynamical loading of machines are mostly random processes. To predict fatigue life, these processes must be converted into stress spectra. Then fatigue life calculations can be performed or amplitudes of harmonic cycling with equivalent fatigue damage can be determined.

The stress-time processes can be calculated or measured by strain-gauge technics. It is not always easy to calculate the time courses of service stresses well. And the measurement can be realized when the prototype is ready.

In the case of some structures, such as railway bogies, there are regulations according to which the design load/stress spectra can be derived. In most cases it is necessary to estimate the design spectra.

Based on this knowledge, it is possible to perform parametric calculations of fatigue life and look for the most suitable design solutions, or for the required service life to derive the maximum permissible stress amplitudes of the assessed structural nodes.

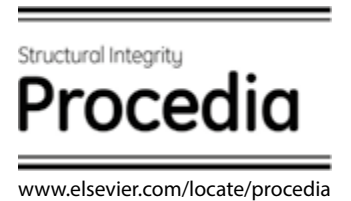
The paper describes parametric fatigue life calculations of a simple welded node occurring in agricultural machines. S-N curves were determined experimentally for various materials and welding parameters and design stress spectra were estimated. It was possible to approximately quantify the differences in the fatigue life of individual variants of welded joints and recommend the best solution.



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FATIGUE DESIGN 2021

FD21-89

Fatigue design of mild and high-strength steel cruciform joints in as-welded and HFMI-treated condition by nominal and effective notch stress approach

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Graz University of Technology, Institute of Structural Durability and Railway Technology, Graz, Austria

According to the Recommendations for Fatigue Design of Welded Joints and Components by the International Institute of Welding (IIW), the fatigue strength of welded steel joints is in general independent of the base material strength. Post-treatment methods, such as the High Frequency Mechanical Impact (HFMI) treatment, can significantly increase the fatigue performance of welded joints especially in case of high-strength steel applications, which is already considered within the IIW Recommendations for the HFMI Treatment.

This paper firstly investigates the effect of the base material strength on the fatigue resistance of welded and HFMI-treated steel joints. Therefore, mild steel S355 and high-strength steel S700 cruciform joints are cyclically tested in both conditions and the statistically evaluated S/N-curves are compared.

Secondly, the test results are assessed by the fatigue design curves of the corresponding structural detail within the IIW-recommendations using the nominal stress concept. Moreover, the applicability of the procedure applying the effective notch approach is analyzed. In order to numerically evaluate the effective notch stress, the geometry of the cruciform joint is modelled according to the given guidelines within the recommendations applying a reference radius of 1 mm at the weld toe for both conditions. On the basis of the numerically computed effective notch stress, a local fatigue design is performed for all test series.

Finally, conclusions on the impact of the base material strength as well as the applicability of the nominal and effective notch approach for cruciform steel joints in as-welded and HFMI-treated conditions are given.



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FATIGUE DESIGN 2021

FD21-101

Fatigue testing and analysis of aluminum welds in highway bridge decks

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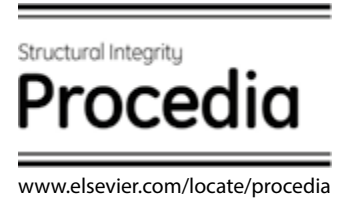
Welded joints are vital in the fabrication of extruded aluminum vehicular bridge decks. These joints are susceptible to fatigue and tend to initiate cracks under variable cyclic vehicular loads, which could cause a brittle fracture of the structure. A relatively new welding technology known as friction stir welding (FSW) has been found to be most suitable for aluminum alloys and used extensively in aerospace and automotive applications due to enhanced weld quality and improved mechanical strength. However, its application in bridge construction is very limited due to the absence of relevant design codes, standards, and specifications, especially concerning its fatigue performance under vehicular traffic. This paper investigates the fatigue behaviour of butt-lap friction stir welded joints used in extruded aluminum bridge decks. 3-point bending fatigue tests were conducted on large-scale specimens extracted from real FSW extrusions. Results show that specimens failed in the upper flange butt-lap joints. Fatigue cracks initiated from the hook feature – a preexisting welding defect- to the weld surface under fatigue loading. Then, the structural stress approach was used to correlate the experimental fatigue data obtained in this study with data from literature and existing master S-N curves documented in welding standards.



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FATIGUE DESIGN 2021

FD21-111

A stochastic modeling of fatigue behavior on welding joints in automotive structures

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A. Patigniez³, S. Bouyaux³**

¹*Sorbonne Universités, Université de Technologie de Compiègne, Laboratoire Roberval FRE UTC-CNRS 2012.*

²*Sorbonne Universités, Université de Technologie de Compiègne, Laboratoire LMAC EA2222.*

³*Renault, Le Mans, France*

The fatigue is an important failure reason for mechanical structures, such as automotive structures. The welded joints are always the critical locations due to the stress concentration, and their performances are quite different from one to another because of the randomness of welding process. The validation of a fatigue design for industries is realized by means of experimental structural test and numerical simulation. The fatigue behavior of welding joints is required when perform the finite element simulation, that could be described by probabilistic S-N curve. However, such a probabilistic model obtained from standard homogeneous specimen tests is not representative for welded joints. Thus, our study proposes an identification strategy of probabilistic S-N curve based on data collected from real mechanical tests on automotive structures. The strategy is composed by an inverse approach based on the minimization of an objective function.

The framework of our study is as follows:

- The experimental fatigue life data for every welded joint of a given structure is interval censored because of the non-real time inspections.
- The S-N curve is described by a stochastic model with probabilistic parameters. It is assumed that the deterministic numerical model is reliable, and the S-N curve performs the effect of all the uncertainty sources.
- The identification methodology of probabilistic S-N curve by minimizing the distance between the computation results and the experimental fatigue life which is represented by objective functions.

The method was firstly applied on synthetic data and application on the real experimental data is ongoing.

S09

Reliability-based approaches and probabilistic methods

Chairmen:

F. Kihm / X. Hermite



FATIGUE DESIGN 2021

FD21-33

Fatigue characterization of car loading histories using equivalent load approaches

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The complexity of service loads on automotive structures lies both in the variability of car uses and in their multidimensionality. At Groupe PSA, we use a statistical approach based on Stress-Strength Interference (SSI) to assess the reliability of our cars relatively to fatigue damage [Bignonnet 98]. Industrial constraints limit the scope of relevant measurable and distributable variables, the duration of measuring campaigns and thus the amount of data.

Historically, we use an equivalent load theory to make the best of our available data, as shown in [Thomas 98], and formalized in [Raoult 2020]. One of the advantages of equivalent load approaches is to simplify the specification of test loads for validation of requirements on a new project's reliability. The form of such test loads varies from simple sinus loads (as in Wöhler curves), theoretical Gaussian loading spectra (as in Gassner curves) to realistic loads derived from ad-hoc measurements (so-called standardized load–time histories [SLH]) [Berger 2002]. However, only the simple ones are today integrated in a full SSI approach.

In this paper, we propose several solutions to characterize the fatigue induced by multidimensional service loading histories on uncertain car structures, by relating them to realistic reference loads (as in SLH methods) using equivalent load approaches. This allows specifying reproducible loads that are representative of service conditions and at the same time quantifying client severities for further use in reliable design.



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FATIGUE DESIGN 2021

FD21-55

A methodology for the probabilistic analysis of fatigue cumulative damage cases

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¹Spanish Royal Academy of Engineering, Madrid, Spain. ²Bundesanstalt für Materialforschung und –prüfung (BAM), Berlin, Germany. ³University of Oviedo, Gijón, Spain. ⁴University of Oviedo, Gijón, Spain

The experimental test results from fatigue-related phenomena can be classified as sample data, i.e. independent random results, and stochastic sample functions, i.e. process realizations, respectively.

In the first case, the sample data represent the lifetimes necessary to reach a certain terminal state, such as those in the S-N field, and their assessment pursues to determine the lifetime distribution of such a final state. In the second case, the process realizations are determined as the register of a quasi-continuous succession of physical states, such as those in the crack growth process, which is assumed to represent the cumulative damage evolution along the specimen lifetime and their assessment intends an analytical truthfully description of such sample functions.

According to the above, the probabilistic assessment for both approaches with descriptive and predictive purposes requires two different methodologies of analysis, which are presented in this work. The use of Bayesian techniques allows both approaches to be unified in a simple procedure providing the multivariate distribution of all the parameters intervening into the fatigue damage model or, alternatively, univariate distributions related to single parameters according to the interest of the analysis.

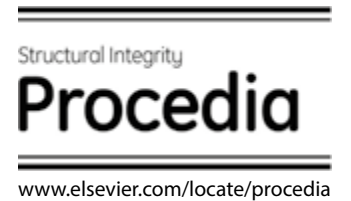
The methodology is illustrated by applying the procedure to the case of crack growth data of an external experimental campaign.



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FATIGUE DESIGN 2021

FD21-70

A new generic method to analyze fatigue results

Robin Hauteville, Xavier Hermite

Cetim, Senlis, France

Fatigue is subject to variability and therefore a defined number of experiments is needed to characterize the fatigue behaviour properties as efficiently as possible. These mechanical properties are critical because induce more than 80% of the in-service failure. Fatigue behaviour must then be strongly considered in the design and manufacturing processes of mechanical equipment.

Wöhler curves, also called SN curves, are commonly used to estimate the lifetime of mechanical component subjected to fatigue under different stress levels. The characterization of this fatigue behaviour model needs mathematical analysis of fatigue experiments results performed on standardized samples or on specific parts or equipment.

Depending on the mathematical model used to characterize the fatigue behaviour of the studied system (Inverse Power or Basquin Law, Stromeier Model, Bastenaire Model, Weibull Model, etc.), the evaluation of the parameters is more or less complex, and usually performed through the well known least square regression method associated to mathematical consideration for the more complex expressions (typically the asymptotic models) and for the consideration of censored data.

CETIM proposes a generic method to deal with the model expressions and the censored (or not) data and creates its own software algorithm to analyse fatigue experiments results. This method is a combination of the least square regression method, the probabilistic regression known as the maximum likelihood estimates, and a numerical iterative process such as Newton – Raphson or Generalized Reduced Gradient to estimate model parameters, fatigue strength standard deviation, and correction factor KC used to estimate the design curves associated to a probability of failure, a confidence level, and a sample size. This tool is validated through a series of experiments and compared to the results of existing and usually used software.



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FATIGUE DESIGN 2021

FD21-97

Scatter and size effect in high cycle fatigue strength due to the effects of porosity in cast aluminum-silicon alloys: Probabilistic modelling

**Driss El Khoukhi^{1,2}, Franck Morel¹, Nicolas Saintier³, Daniel Bellett¹,
Pierre Osmond², Viet-Duc Le¹**

¹Arts et Métiers Institute of technology, Angers, France. ²PSA group, Carrières-sous-Poissy, France. ³Arts et Métiers Institute of technology, Bordeaux, France

In this paper, a probabilistic model based on the Monte-Carlo approach is applied to predict the fatigue behavior of cast aluminum alloys. The objective of the proposed approach is to investigate the effect of porosity (i.e. the defect size distribution and spatial density) on the fatigue strength and its associated scatter. The proposed model is applied to two cast aluminum alloys with very different defect characteristics. The results for these two alloys confirm that the model can be used to predict the average fatigue strength with a relative error of less than 5%. It also accurately reproduces the experimentally observed trends concerning the scatter in fatigue strength. The scatter is underestimated but is of the same order of magnitude as the experimental values. It is believed that this is because the proposed model considers that the porosity is the only source of scatter. It is demonstrated that the model is well adapted for the prediction of the volume or scale effect in fatigue. The model can also be used to estimate the Representative Volume Element in Fatigue for cast aluminum alloys.

S10

Taking into account manufacturing process in fatigue analysis (effect of microstructure, welding, residual stresses,...)

Chairmen:

M. Risbet & H. Rognon

L. Remy & M. Chollet



FATIGUE DESIGN 2021

FD21-24

**Design of microstructural gradient for fatigue properties
of pearlitic steels**

Lais Avila de Oliveira Silva¹, Christophe Mesplont², Jérémie Bouquerel¹, Jean-Bernard Vogt¹

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The use of pearlitic steels wires on structural applications such as bridge cables and steel ropes require an especial attention to the fatigue resistance, since these components undergo cyclic loadings and, therefore, fatigue represents the main cause of failure. Although pearlite may appear as a “classical” dual phased material, many factors induced by thermomechanical treatments can change its cyclic response. The interlamellar spacing is one of the features that can modify cyclic accommodation and behaviour of short cracks. Since the latter tend to initiate at the surface, the idea to promote a fatigue resistant-layer of perlite at the external surface becomes attractive.

In this work, an attempt to produce a gradient of microstructure from the surface to the core in an eutectoid pearlitic steel is considered. It can be obtained by an accurate control of the temperature gradient in order to provide different phase transformations at different temperatures and depths. Specimens of 6 mm in diameter were treated in a dilatometer in an innovative way that allows having a strict production control of both the monolithic and the graded samples. The fatigue resistance is evaluated by low cycle fatigue tests at room temperature under control of total strain, ranging between 0.6% to 1.2%. The microstructure gradient effects are presented by the cyclic accommodation as well as the fatigue resistance, with attention on the mechanisms of crack initiation and propagation. These tests will guide the feature of the gradient production and the definition of its ideal morphology and thickness.



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FATIGUE DESIGN 2021

FD21-35

Estimation of fatigue life for clinched joints with the local strain approach

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Widely used in automotive and aerospace industry, clinched joints are subject to failure due to neck fracture and disjoining if exposed to high static loads. For cyclic loading cases, the formation of eyebrow cracks can be observed. The main objective of ongoing research is the application of the Local Strain Approach to clinched joints joining extruded aluminium wrought alloy sheets, thus being able to predict crack initiation location and fatigue life.

Complex geometrical features of a clinched joint and lacking of nondestructive methods to track local stresses and strains require a combined approach utilizing numerical and experimental techniques. Material characterisation for an aluminum wrought alloy EN AW 6060 T66 is accomplished by common uniaxial tension tests to determine flow curves and cyclic properties by strain controlled constant amplitude tests, respectively.

Commercial finite element software LS-Dyna® is used to perform the process simulation in 2D, followed by mapping to 3D with constant amplitude loading to investigate local stresses and strains within the contact region. The Local Strain Approach with damage parameter PSWT [1] is applied to estimate the fatigue lives of the clinched joint variants. Fatigue life estimations obtained from simulation results are compared to those from experiments.

The results obtained so far indicate that the Local Strain Approach is suitable for fatigue life estimations of complex structural components such as a clinched joint.

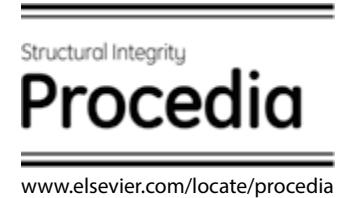
[1] Smith, K.N., Topper, T., Watson, P.: A stress-strain function for the fatigue of metals. Journal of Materials, 1970



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FD21-41

A comparative study on fatigue performance of various additive manufactured titanium alloys

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Titanium alloys have been used extensively in aerospace and medical applications due to their exceptional strength to weight ratio, biocompatibility, and corrosion resistance. While these alloys are known to be difficult to machine, they are typically weldable. Therefore, various titanium-based alloys have been recently considered for production via additive manufacturing technology. Additively manufactured titanium alloys are used to produce a wide range of high-performance components in marine, automotive, defense, and aerospace industries which are often under cyclic or periodic loading. While the most used titanium alloy (i.e. Ti-6Al-4V) has been extensively characterized, there is a gap in the literature with regards to the fatigue performance of many other titanium alloys considered for additive manufacturing. This study aims at assessing the microstructural, mechanical, and fatigue performance of several additively manufactured titanium-based alloys and comparing the results with the ones for the well-studied Ti-6Al-4V. An EOS M290 laser beam powder bed fusion (LB-PBF) additive manufacturing machine is used to fabricate specimens from various titanium alloys for this study. Specimens are characterized and compared side by side for their porosity, microstructure, tensile, and fatigue behavior.



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FD21-56

Fatigue software smart use to calculate by FEA a complete map of the damage due to a duty cycle, regarding thermo-mechanical fatigue failure modeApplication to a truck cylinder head lifetime assessment

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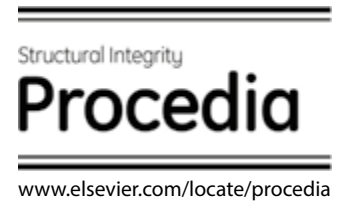
Physical tests considering real customer usages for truck engine components durability validation, are very expensive and time consuming. Using a calculation method enabling to determine cumulative damage due to a specific duty cycle, seems then a priority, especially for thermo-mechanical fatigue failure mode. However, most of these complex engine components have several brittle areas, and the current calculation methods allow only to analyze one or few critical areas. Moreover, they do not consider the complete behavior of the component in the analysis, which can influence the results on these specific areas. With the smart use of fatigue software tools, it is then now possible to calculate by FEA the complete damage field, all over the part, regarding thermo-mechanical fatigue failure mode. In this paper, one industrial example is detailed, to show the effectiveness of the methodology: a damage analysis of a truck cast iron cylinder head.



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FD21-82

Effect of machining, heat and surface treatment process on gear fatigue performance (bending and pitting)

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In agricultural transmissions, gears are the most common components used to transmit power. The gear meshing induces a complex multiaxial load on the gear tooth, those loads generates bending stresses on the gear root fillets and contact stresses on the active flank. The tooth breakage coming from bending fatigue and gear pitting after contact fatigue are some of the identified failures on agricultural tractors transmissions, the mechanisms leading to those failures are the object of this project. Mechanical strength of gears, regarding bending & contact fatigue performances, depends among other parameters, on material, heat treatment and machining processes. Surface treatments can also be applied on gears to enhance the bending performances. Each process produces different results in terms of mechanical, geometrical and metallurgical characteristics. This study will mainly be focused on the residual stresses, roughness, internal oxidation and retained austenite produced by each process to investigate its influence on the gear bending fatigue and contact fatigue.

Moreover, the microstructure of the surface layer needs to be investigated in detail to understand the mechanism leading to the increase or decrease of the performances (bending & contact) on the gear.

For the bending fatigue endurance tests, a pulsator machine was used. These test data are analysed using the ISO 6336-2019 standard to go from the force to the stress at the tooth root. The results make it possible to establish the SN curve and the endurance limit to compare the different material, heat treatment and machining process.

For the contact fatigue performances, the same configurations were tested on a back-to-back test rig. The results are analysed and compared to the Life Factor ZNT curves (no pitting permissible and limited pitting permitted) given in the ISO 6336-2-2019 Method B standard.

During the study, a POC was carried out on the application of the self-heating method on the tooth base. The purpose is to allow the rapid estimation of the fatigue limit in bending tooth root. The study was done in two phases, first on specimens notched then full gear.

The paper will present a comparison between different machining, surface and heat treatment process regarding the gear bending fatigue & contact fatigue performance. The aim of the study is to identify the interaction of the fabrication process and their effects into the treated layer on gears.



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FD21-103

High cycle fatigue behaviour of high-pressure die-cast aluminium alloy AlSi9Cu3: Role of defects and loading conditions

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Aluminium alloys have good weight-to-strength ratios, which make them good candidates for the ecological transition in the automotive industry. An interesting manufacturing process for these alloys is the high-pressure die-casting (HPDC) which combines high production rates and the possibility of producing thin parts with complex geometries. However, this process results in the creation of many microstructural defects. It is well known that defects determine the fatigue response depending on their size, position, shape, nature and other features.

This study aims to investigate the High Cycle Fatigue behaviour of a HPDC AlSi9Cu3 alloy used in the automotive industry. A thorough characterization of the defect population is carried out by X-ray tomography. It is shown that the distribution of porosity is highly inhomogeneous with a higher density in the middle of the specimens.

Fatigue tests have been performed under tensile and bending loading conditions on samples of different thickness. The main observations are i) a change in the as-cast samples thickness does not significantly affect the fatigue behaviour when tested in bending ii) Changing the loading condition from bending to tension-compression shifts the crack initiation location from surface defects to intern porosity iii) Machining the samples (i.e. removing the as-cast surface) leads to crack initiation from near-surface porosity in bending.

This investigation is the first stage towards the development of an original numerical probabilistic approach using various characteristics of the defect population to assess the fatigue strength.

Keywords

High Cycle Fatigue, High Pressure Die Casting, aluminium alloy, porosity, stress gradient, X-ray tomography

Poster session



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FATIGUE DESIGN 2021

FD21-2

Life-cycle energy analysis of a high strength steel heavy vehicle component subjected to fatigue loading

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This study focuses on comparing the life-cycle energy required for Conventional Steel and HYBRIT (Hydrogen Breakthrough Ironmaking Technology) Steel. The application chosen for this comparison was a bogie beam of Volvo's articulated hauler A30. HYBRIT is new generation of a fossil-free steel technology developed by SSAB (Swedish Steel Company) which aims to replace coal with hydrogen during steel production to reduce CO₂ emissions. The different phases analyzed were; material extraction, steel production, component manufacturing, use and end of life phases. Where the use phase is predominantly fatigue loading. It is concluded that HYBRIT Steel consumed 8-10% less energy than Conventional Steel. For applications with less dominant use phases, the percentage of energy saved by HYBRIT Steel would be even larger.



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FATIGUE DESIGN 2021

FD21-12

The cyclic strain evolution and the fatigue prediction in non-proportional multiaxial loadings of NiTi SMAs

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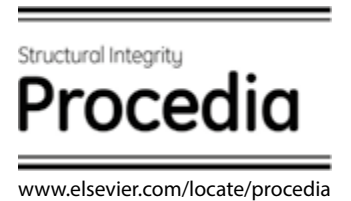
NiTi shape memory alloy is a kind of smart materials which present unique properties of super-elasticity, shape memory and excellent biocompatibility. The applications of such alloys are generally the connectors and fasteners, vibration dampers, and endovascular stents, etc.. These components are inevitably endure complex cyclic loadings during the using process, leading to the multiaxial cyclic deformation and fatigue failure are key issues that need to be investigated. In this paper, the evolutions of the peak/valley strains in non-proportional multiaxial fatigue loadings of NiTi SMAs are considered, and the fatigue failure mechanism is investigated. The results show that the martensite transformation and martensite re-orientation process greatly influence the transformation ratchetting and fatigue life of NiTi SMAs, and a life-prediction model that considers these deformation mechanisms particular for NiTi SMAs is also proposed to give reasonable predictions.



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FATIGUE DESIGN 2021

FD21-23

Comparison of the fatigue behavior of wrought and additively manufactured AISI 316L

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Additive manufacturing (AM) is becoming increasingly important in engineering applications due to the possibility of producing components with a high geometrical complexity allowing for optimized forms with respect to the in-service functionality. A good example is given by valves and pressure vessels in the chemical industry, which typically have complex geometries and must withstand cyclic pressure loading during their operational lifetime, besides having good resistance against chemical aggression at various temperatures. Despite the promising potential, AM components are still far from being applied in safety-relevant components mainly due to a lack of understanding of the feedstock-process-properties-performance relationship. This work aims at providing a full characterization of the fatigue behavior of the additively manufactured AISI 316L austenitic stainless steel and a direct comparison with the fatigue performance of the wrought steel. To this purpose, a set of specimens has been produced by laser powder bed fusion (L-PBF) and subsequently heat treated at 900°C for 1 hour for complete stress relief, whereas a second set of specimens has been machined out of hot-rolled plates. Low cycle fatigue (LCF) and high cycle fatigue (HCF) tests have been conducted for characterizing the fatigue behavior. In addition, fatigue propagation tests have been carried out to investigate the short-crack behavior and the interaction of a growing crack with the microstructure.



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FD21-26

Investigation of residual stresses and microstructure effects on the fatigue behavior of a L-PBF AlSi10Mg alloy

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Al-Si alloys produced by Laser Powder Bed Fusion (L-PBF) allow the manufacture of complex-shaped components that find use in aerospace, automotive, biomedical applications.

Due to the high cooling rates occurring during the building process, L-PBF AlSi10Mg alloys exhibit an ultra-fine silicon network that leads to superior quasi-static mechanical properties in the as-built condition, when compared to conventionally casted material. In contrast, high thermal gradients induce undesirable residual stress (RS) that, if uncontrolled, could lead to part distortion and unpredicted failures. In order to relax detrimental RS and to increase the ductility, post-processing heat treatments are generally performed. Apart from RS relaxation, heat treatment above 260°C initiates the breaking down of the silicon network into spheroidized particles.

The objective of this contribution is to investigate the evolution of the microstructure and RS under different heat treatment conditions. To this purpose, various heat treatments are performed in a range of temperatures between 265°C and 295°C, for durations ranging between 15 minutes and 2 hours. The microstructure modifications are analyzed by scanning electron microscopy (SEM) and the RS state is evaluated by means of energy-dispersive X-ray diffraction.

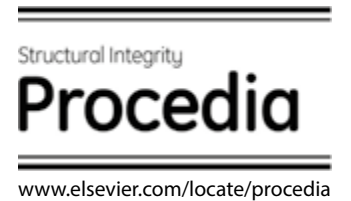
The optimized temperature and duration for the stress relief heat treatment is defined in view of Low Cycle Fatigue (LCF), High Cycle Fatigue (HCF) and crack propagation tests.



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FD21-35

Estimation of fatigue life for clinched joints with the local strain approach

Boris Spak¹, Markus Kästner², Melanie Fiedler¹

¹Structural Durability Group, TU Dresden, Dresden, Germany. ²Chair of Computational and Experimental Solid Mechanics, TU Dresden, Dresden, Germany

Widely used in automotive and aerospace industry, clinched joints are subject to failure due to neck fracture and disjoining if exposed to high static loads. For cyclic loading cases, the formation of eyebrow cracks can be observed. The main objective of ongoing research is the application of the Local Strain Approach to clinched joints joining extruded aluminium wrought alloy sheets, thus being able to predict crack initiation location and fatigue life.

Complex geometrical features of a clinched joint and lacking of nondestructive methods to track local stresses and strains require a combined approach utilizing numerical and experimental techniques. Material characterisation for an aluminum wrought alloy EN AW 6060 T66 is accomplished by common uniaxial tension tests to determine flow curves and cyclic properties by strain controlled constant amplitude tests, respectively.

Commercial finite element software LS-Dyna® is used to perform the process simulation in 2D, followed by mapping to 3D with constant amplitude loading to investigate local stresses and strains within the contact region. The Local Strain Approach with damage parameter PSWT [1] is applied to estimate the fatigue lives of the clinched joint variants. Fatigue life estimations obtained from simulation results are compared to those from experiments.

The results obtained so far indicate that the Local Strain Approach is suitable for fatigue life estimations of complex structural components such as a clinched joint.

[1] Smith, K.N., Topper, T., Watson, P.: A stress-strain function for the fatigue of metals. Journal of Materials, 1970



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FD21-51

High temperature tensile and fatigue behaviors of additively manufactured IN625 and IN718

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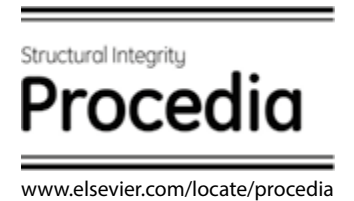
Recent advancement and research efforts in additive manufacturing (AM) have made it a promising technology to fabricate nickel-based superalloy parts in near net shapes. IN625 and IN718 are the commonly used superalloys in high-temperature applications in the aerospace and energy sectors. However, the fatigue performance of the additively manufactured (AMed) components often depends on the defects like porosity, micro-cracks, and lack of fusions, etc. In addition, the presence of columnar grains and residual stresses also affects their fatigue performance. In this study, IN625 and IN718 specimens were fabricated via AM followed by stress-relief and standard heat treatments. Both alloys exhibited similar defect characteristics and grain morphologies. High-temperature tensile and fatigue properties of both IN625 and IN718 were measured and then compared with the wrought data available in the literature. The AMed alloys specimens showed tensile strengths similar to their wrought counterparts. The tensile and fatigue strengths of both alloys decreased with increasing testing temperatures. AMed IN718 always showed higher tensile and fatigue performance compared to the AMed IN625. The fractographic analysis identified that the presence of defects, precipitation behavior, and phase transformation controlled the high temperature tensile and fatigue performance of the IN625 and IN718.



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FATIGUE DESIGN 2021

FD21-57

Planning and assessment of dental implant fatigue tests using a specific software program

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The high commercial competition among the dental implant companies promotes technical design and material advances in the new offered products implying higher performance and guarantee of reliable lifetime prediction. In particular, mechanical incidences, as premature fatigue failures, often related to implant and prosthesis design, has to be avoided, ensuring their expected lifetime and mechanical function. The mentioned advances must be supported by experimental fatigue tests. Those related to mechanical fatigue failure are costly due to the long duration and the high number of tests involved in order to ensure the required reliability. With this aim, the use of the free software ProFatigue, based on a well-known probabilistic fatigue model is proposed. This free-use program represents a reduction of the test number required to reach a prefixed reliability level of the lifetime prediction when compared with the statistical methodology proposed in the current ISO14801. In this way, a suitable test strategy is established allowing the confidence of the lifetime prediction of the tested implants to be enhanced and the testing costs to be reduced.



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FATIGUE DESIGN 2021

FD21-60

Fatigue assesment of the wind induced vibrations of a cableat St Nazaire cable stayed bridge

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Fatigue cracks led to a replacement alike to the initial in 2000 of cable stay H32, then no solution was found fulfilling every strengthening requirements. However, wires ruptures occured again in 2017 due to cable flexion at the point where the cable comes ot of the adjustable threaded cylindrical socket.

The identification of the most appropriate solution to preserve the structural integrity of the H32 cable is performed using the Cerema's PCP software. The three-dimensional model uses beam elements, considering the catenary effect and the cable bending inertia. Aim is to assess the effects of high frequency vibrations induced by vortex shedding or turbulent wind on the global behavior of the cable.

Modal properties of the cable are evaluated: eigenfrequencies, mode shapes, modal masses and damping.

The dynamic analyses show that wind loads which frequency range from 10 Hz to 30 Hz induce the maximal stresses at cable ends. In order to reduce these bending stresses, the use of Stockbridge dampers is investigated to increase the damping in the frequency range of the excitation.

The design parameters of a Stockbridge damper implemented on the cable, geometry, mass and stiffness distributions, are derived from a simplified model. In addition, numerical simulations with a more detailed finite element model carried out with EdF's Code_Aster software were carried out to get more precisely the relevant resonant frequencies of the damper.

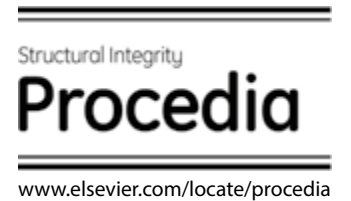
Additional protection device is studied to optionally complete the control system and avoid cable flexion near the socket at the cable ends.



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FATIGUE DESIGN 2021

FD21-71

Fretting fatigue of shrink fitted assembly under rotating bending loading: A numerical and experimental study to compare Crossland fatigue stress analysis and Ruiz contact stress approach

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In this study, rotating bending tests are performed and simulated with 3D Finite Element Analysis (FEA). Two different well known approaches (Crossland fatigue stress analysis and Ruiz contact stress approach) have been compared, showing inaccurate results on term of damage localization and prediction of life span on the tested conditions. The combination of these criteria with non-local methods, consolidated with a parametric study (numerical and experimental) on both interference size and outer sleeve geometry, showed improved results.

Keywords (from 3 to 5 max): fretting-fatigue, shrink-fitted assemblies, rotating bending

1. Introduction

Shrink-fitted assemblies are commonly used in industrial applications to join sleeves and shafts or axles, where they are submitted to a complex multiaxial loading including bending, compression and torsion. In this configuration of large conform contact, fretting fatigue damage between the two parts may occur and lead to cracking. The aim of this research is to determine the best method among Crossland fatigue stress analysis and Ruiz contact stress approach to predict such damage through the influence of the interference size and the sleeve edges filet geometry conducting both experiments on samples and a 3D FEA.

2. Methods

Considering the complexity of the typical industrial case conditions, a simplified loading case is being investigated on a steel shaft and a shrink-fitted bronze sleeve, displaying three different outer sleeve geometries.

2.1 Experiments

Rotating bending tests are conducted on a dedicated bench to assess the type of damage along with the lifespan of the shaft specimen. Experiments are carried out until partial failure, characterized by a stiffness drop during the test. The specimen is then studied using interference profilometry, Energy Dispersive X-ray spectroscopy (EDX) and fractography techniques.

2.2 Simulation and post-processing

Tests are modelled using a full scale 3D FEA. Both fitting and bending are taken into account, as well as friction at the interface, granting access to contact data including slip and surface shear. Both Crossland [1] (extensively applied criterion for multiaxial fatigue damage analysis) and surface stress Ruiz approach [2] (dedicated for tribological damage analysis) are investigated.

These two approaches are first calibrated using a restricted number of rotating bending tests. Then they are compared to another set of loading conditions to evaluate their capacity to predict the fretting fatigue damages.

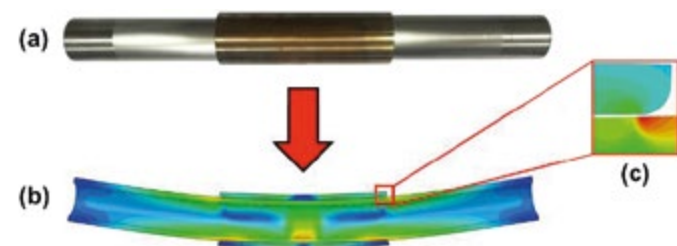


Figure 1:

- a) rotational bending sample;
- b) deformed shape of the sample and Von Mises equivalent stress distribution;
- c) detail of the sleeve edge with its fillet.

3. Results and Discussion

The two criteria fail to predict the crack nucleation locations. In addition, the Crossland analysis, which consists in comparing an equivalent fatigue stress versus the alternated shear fatigue limit, tends to underestimate the cracking risk. For this reason, non-local methods [3] (critical volume and length) are applied to better predict nucleation, showing improved results.

A parametric study is eventually conducted using modified numerical models and new tests, addressing the interference size and the geometry of the sleeve edges filets effects.

This study constitutes a first step towards a quantitative and reliable design method for shrink-fitted assemblies under highly multiaxial loadings.

4. References

- [1] B. Crossland. Effect of large hydrostatic pressures on the torsional fatigue strength of an alloy steel. In Proceeding of the International Conference on Fatigue of Metals, Institution of Mechanical engineers, London, 1956, pp. 138–149.
- [2] K. Anandavel, R.V. Prakash. Extension of Ruiz Criterion for Evaluation of 3-D Fretting Fatigue Damage Parameter, Procedia Engineering 55 (2013), pp. 655-660.
- [3] S. Fouvry, H. Gallien, B. Berthel. From uni- to multi-axial fretting-fatigue crack prediction: development of a stress-gradient-dependent critical distance approach International Journal of Fatigue 62 (2014), pp. 194–209.

FD21-76

Fretting fatigue of lug-bush connection members with interference fit: Comparison between a multiaxial fatigue stress analysis and “tribological” Ruiz surface stress approach

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Failures of several industrial pieces have been reported to be due to fretting-fatigue at the interference fit joints. For fretting fatigue contacts in partial slip, the classical methods of prediction of fatigue crack initiation have been successfully applied to non-conformal contacts. For conformal contacts, the contact surface is much more important and the level of stress lower than for non-conformal contacts. We wonder in this case whether the crack initiation is strongly affected by the tribological phenomena occurring at the contact zone (adhesive points, particles) or whether only the stress singularity induced by the sliding front is the main driving force of crack initiation. The crack initiation of lug-bush connections with 3 different shrink fit levels subjected to high cycle tensile fatigue loading is investigated. The predictions given by the classical multiaxial fatigue criteria (Crossland, SWT) and tribological criteria (Ruiz) are compared with the results of experiments.



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Proposal and verification of countermeasure against fatigue cracking from welded joints between trough ribs and cross ribs in orthotropic steel decks

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¹Kansai University, Suita, Japan. ²The Japan Civil engineering Consultants Association, Osaka, Japan.

³Japan Bridge Association, Osaka, Japan. ⁴Ministry of Land, Infrastructure, Transport and Tourism Kinki Regional Development Bureau, Osaka, Japan

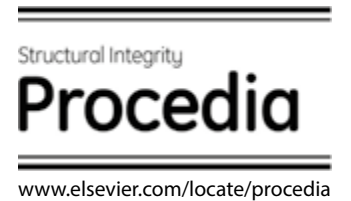
Orthotropic steel decks have advantage in regard to lightness of dead load and shortness of construction period. While fatigue durability of orthotropic steel decks is low. The effective countermeasure against fatigue cracking at welded joints between a deck plate and trough ribs have been already proposed. In this study, countermeasures against fatigue cracking at welded joints between trough ribs and cross ribs in existing bridges and new bridges were proposed and verified by conducting the fatigue test using a full-scale specimen. Principal results obtained through this study are as follows. (1) In the existing structure, angle steel attachments retrofitted at the undersurface of a trough rib and a cross rib using TRS were verified that enough effects of the preventive countermeasure and the post countermeasure against fatigue cracking at welded joints around slots in cross ribs by conducting the fatigue test. However, it didn't have no effects against fatigue cracks initiated at the weld root jointed between a deck plate and trough ribs and propagated to a deck plate. (2) In the proposed structure for new bridges, no fatigue cracks weren't detected at connections between trough ribs and cross ribs, and joints between a deck plate and trough ribs.



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FATIGUE DESIGN 2021

FD21-82

Effect of machining, heat and surface treatment process on gear fatigue performance (bending and pitting)

Victorien Gautheron¹, Simon Jolivet¹, Hind Orkhis², Marion Risbet³, Julie Marteau³, Fabien Lefebvre¹, Hervé Rognon¹

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In agricultural transmissions, gears are the most common components used to transmit power. The gear meshing induces a complex multiaxial load on the gear tooth, those loads generates bending stresses on the gear root fillets and contact stresses on the active flank. The tooth breakage coming from bending fatigue and gear pitting after contact fatigue are some of the identified failures on agricultural tractors transmissions, the mechanisms leading to those failures are the object of this project. Mechanical strength of gears, regarding bending & contact fatigue performances, depends among other parameters, on material, heat treatment and machining processes. Surface treatments can also be applied on gears to enhance the bending performances. Each process produces different results in terms of mechanical, geometrical and metallurgical characteristics. This study will mainly be focused on the residual stresses, roughness, internal oxidation and retained austenite produced by each process to investigate its influence on the gear bending fatigue and contact fatigue.

Moreover, the microstructure of the surface layer needs to be investigated in detail to understand the mechanism leading to the increase or decrease of the performances (bending & contact) on the gear.

For the bending fatigue endurance tests, a pulsator machine was used. These test data are analysed using the ISO 6336-2019 standard to go from the force to the stress at the tooth root. The results make it possible to establish the SN curve and the endurance limit to compare the different material, heat treatment and machining process.

For the contact fatigue performances, the same configurations were tested on a back-to-back test rig. The results are analysed and compared to the Life Factor ZNT curves (no pitting permissible and limited pitting permitted) given in the ISO 6336-2-2019 Method B standard.

During the study, a POC was carried out on the application of the self-heating method on the tooth base. The purpose is to allow the rapid estimation of the fatigue limit in bending tooth root. The study was done in two phases, first on specimens notched then full gear.

The paper will present a comparison between different machining, surface and heat treatment process regarding the gear bending fatigue & contact fatigue performance. The aim of the study is to identify the interaction of the fabrication process and their effects into the treated layer on gears.



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FATIGUE DESIGN 2021

FD21-84

Fatigue life of welded junction by electron beam in Ti-6Al-4V

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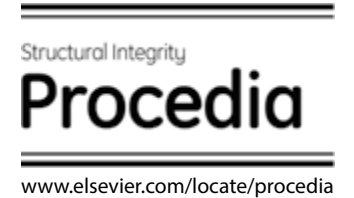
The objective is to study the high cycle fatigue behaviour of electron beam welded Titanium alloys. Several plates have been welded to find the optimum process condition. Fatigue tests are conducted under four point bending as well as tension loading. As residual stresses is an important issue, the width of the sample varies from 12 to 60 mm. All test are analysed through fractography analysis to understand the weakest point of the junction. Finite Element simulations are conducted in order to understand the evolution of local stresses, including the effect of residual stresses.



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FATIGUE DESIGN 2021

FD21-85

Interaction hydrogen/microstructure of a nickel base superalloy: Impact on low-cycle fatigue behavior and fatigue crack initiation

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Hydrogen, the most abundant element on earth, is inevitably present in the gaseous state at the material/environment interface or generated by physical-chemical reactions. Moreover, hydrogen is the only element liable, even at room temperature, to penetrate and diffuse in metallic materials.

This work is part of a global study, which aims at understanding the impact of hydrogen on several metallurgical and physical parameters due to the hydrogen absorption. It tackles specifically the potential reduction of the mechanical properties of a nickel superalloy and assess the risks in order to determine the intrinsic parameters to damage induced by hydrogen embrittlement.

To improve the life of the materials, it is hence necessary to study the consequences of the interactions between hydrogen and the different elements of the microstructure, on the process of localization of the deformation, the initiation and the propagation of the damage under cyclic loading.

For this, low cycle fatigue, charge-discharge and multi-relaxation tests are carried out with and without hydrogen cathodic polarization on a nickel based superalloy having two different microstructures (in terms of the sizes of hardening precipitates). These tests allow evaluating and comparing the components of work hardening (back stress and effective stresses) to show the impact of hydrogen on the damage initiation. In addition the potential for acoustic emission monitoring of these tests is being studied, in order to determine whether this technique is relevant for capturing the movement of dislocations in the presence of hydrogen, and to determine signals representative of work hardening regimes.



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FATIGUE DESIGN 2021

FD21-92

Designing very high-cycle fatigue specimens of additively manufactured Ti-6Al-4V with different porosities and microstructures

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High cycle fatigue properties of material obtained with additive manufacturing (AM) processes such as LPBF (Laser Powder Bed Fusion) remain misunderstood. These properties are complex due to the porous and anisotropic properties of AM parts. Moreover, a high number of process parameters can influence the obtained fatigue behavior. In this context, a rapid determination of the high and very high cycle fatigue properties is necessary in order to optimize process parameters with regard to fatigue response. This work aims to compare two accelerated fatigue determination methods: ultrasonic fatigue testing and fatigue limit evaluation through lock-in thermography. Ultrasonic fatigue testing achieve frequency up to 20 kHz through resonating test pieces. In the second method, the threshold stress between two self-heating regimes is determined and used as an assessment of the fatigue limit.

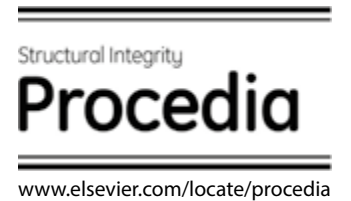
Ti-6Al-4V alloy produced with LPBF is used in this comparison. In order to evaluate the performance of these rapid determination methods for AM parts, test pieces with different porosity rates and microstructures are used. Before fatigue testing, the processing and post-processing parameters leading to different porosity rates and microstructure are determined. Then, staircase campaigns at 107 cycles using ultrasonic testing and lock-in thermography evaluations are performed.



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FATIGUE DESIGN 2021

FD21-96

Scatter and size effect in high cycle fatigue of cast aluminum-silicon alloys: A comprehensive experimental investigation

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Cast Al-Si alloys have been widely used in automotive applications with regard to their low density and excellent thermal conductivity. Many components made of these alloys are subjected to cyclic loads which can lead to fatigue failure. Furthermore, for these materials the well know size effect in fatigue, whereby the fatigue strength is reduced when the size is increased, can be significant and need to be properly evaluated. This paper analyses the role of casting defects on the fatigue strength's size effect sensitivity and scatter.

A uniaxial fatigue testing campaign ($R=0.1$) has been conducted using two cast aluminium alloys, fabricated by different casting processes (gravity die casting and lost foam casting), associated with the T7 heat treatment, and with different degrees of porosity. The fatigue response of different specimens (smooth and notched) with different stressed volumes has been investigated. The first part of this article is dedicated to the experimental characterization of the size effect in both alloys via the concept of the Highly Stressed Volume. The second part investigates the effect of the Highly Stressed Volume on the critical defect size via Kitagawa-Takahashi diagrams.

The results show that the magnitude of the size effect and the experimental scatter are strongly linked to the characteristics of the defect population present in the alloy.

FD21-120

Methodology for evaluating the probability of failure of a mechanical component in multiaxial fatigue

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STATE OF THE ART

The fatigue phenomenon is one of the main causes that leads to the rupture of a mechanical component as the result of random or cyclic loads. Regarding industrial components, it is quite common for the state of stress under loading to be multiaxial. In order to estimate a fatigue lifetime, it is therefore necessary to implement a multiaxial fatigue post-processing. Multiaxial fatigue criteria are criteria distinguish the safe domain and the failure domain (blue curve on Figure 1) for a given number of crack initiation cycles.

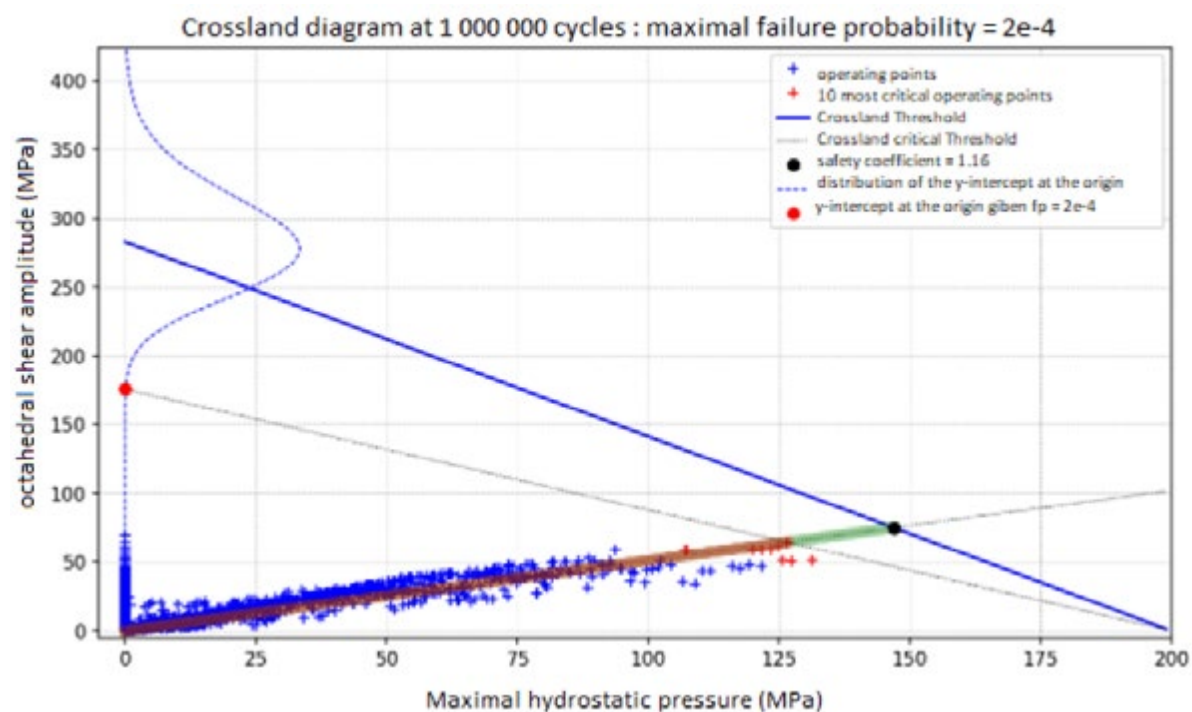


Fig 1 : Operating points and Crossland diagram

NEW APPROACH

Most of the time, a safety coefficient in relation to this boundary is evaluated. The lifetime is therefore evaluated for a fixed probability of failure. Yet, there are several sources of variability that may modify the position of the operating points, but also the position of the threshold associated with the multiaxial fatigue criterion considered:

- Variability of the loading
- Variability of the material characteristics
- Variability intrinsic to the fatigue phenomenon, represented by a dispersion on the S-N curve.

To evaluate the probability of failure, the distribution of the y-intercept at the origin of the threshold is first evaluated by propagation of uncertainties. Then, we evaluate for the most critical operating point (associated with the threshold having the highest y-intercept) the associated probability in this distribution (red y-intercept on the graph). Finally, in order to capitalize on the reliability of this post-processing and to make it easy to use, a graphic interface has been developed.

ADDED VALUE FOR DIMENSIONING IN AN INDUSTRIAL CONTEXT

The safety coefficient usually used with multiaxial fatigue criteria does not allow to precisely quantify the margin. The evaluation of the probability of failure allows to optimize the sizing for a reliability objective, and thus to ensure the durability of the product while minimizing the material costs and the environmental impact.

References:

- Technique de l'ingénieur, M4170 V1, Essais de fatigue, Partie I
- Robert, IFMA, Dimensionnement en fatigue des pièces mécaniques et des structures métalliques, Fatigue sous chargement d'amplitude variable, Fatigue multiaxiale.
- B. Weber, Fatigue multiaxiale des structures industrielles sous chargement quelconque, 1999
- Mines Douai, Critère de fatigue multiaxiale: critère de Crossland/ critère de Dang Van.
- N. Nadjitonon, Contribution à la modélisation de l'endommagement par fatigue, 2010
- K. Dang Van, B. Griveau and O. Message. On a new multiaxial fatigue limit criterion: theory and application, Proc. of the 2nd International Conference on Biaxial and Multiaxial Fatigue, Sheffield, England, 479-496, 1989.
- Paulin-Luc, Introduction au dimensionnement en fatigue des structures sous chargements complexes, Institut de Mécanique et d'Ingénierie, UMR CNRS 5295 Arts et Métiers ParisTech, campus de Bordeaux

References

Authors	Abstract number	Authors	Abstract number	Authors	Abstract number	Authors	Abstract number
Abbad El Andaloussi Hamza	79	Berg Lars	19	Brot Grégoire	92	Dallago Michele	29
Abdellaoui Benaouda	69, 73	Berthel Bruno	45	Brugger Charles	94, 98	Defaisse Clément	76
Ahmadivala Morteza	65	Berthelley Jacques	60, 63, 64, 65	Brunnhofen Peter	89	Delattre Benoit	33
Ahmed Nabeel	51	Bertini Leonardo	17	Buffière Jean-Yves	68	Denis Chojnacki	30
Ahola Antti	67, 75	Berton Edouard	60	Buzzi Christian	89	Depale Bruno	87
Aldén Rickard	4, 74	Bertrand Wattrisse	100	Cailletaud Georges	72	Dieu Benjamin	71
Alexandre Debarbouillé	30	Besa Beatrice	14	Calloch Sylvain	46	Dinis Miguel	44
Álvarez-Arenal, Ángel	57	Bianne Guillaume	63	Campagnolo Alberto	14	Doudard Cédric	46
Amargier Rémi	84	Bilger Felix	88	Camus Etienne	66	Duarte Larissa	21
Ambati Marreddy	49, 50	Billardon René	105	Caous Damien	90	Dupuy Corinne	92
Amuzuga Philippe	66, 73	Bissing Hendrik	59	Castillo Enrique	54, 55	Dusautoir Théo	45
Annan Charles-Darwin	101	Björk Timo	67, 75	Castro-Moreno Antonio	98	Duval Romain	91
Arash Soltani-Tehrani Arash	41	Blanc Sandy	105	Causse Guillaume	120	Ehlers Sören	9
Avila De Oliveira Silva Lais	24	Blasón Sergio	22, 54, 55, 57	Chabod Amaury	62	El Khoukhi Driss	96, 97
Baeßler Matthias	106	Bodlet Natan	84	Chieragatti Rémy	20	Eliasson Sara	19
Balmon Jean	68	Bois Christophe	90	Chiocca Andrea	17	Ellmer Franz	93
Baroux Emilien	33	Boissin Eileen	90	Chojnacki Denis	36	Erbe Alexander	47
Barsoum Zuheir	19, 2, 3, 4, 74	Bonato Marco	61	Christophe Hacquard	100	Fabien Soulié	100
Baumgartner Jörg	104	Bonnand Vincent	92	Chéreau Sébastien	88	Facchinetti Matteo	6
Beier Heinz Thomas	34	Bonneric Matthieu	98	Comlekci Tugrul	81	Facchinetti Matteo Luca	46
Bellec Enora	46	Bouquerel Jérémie	24	Conrad Fabian	47	Farajian Majid	93
Bellett Daniel	96, 97	Brasileiro Lucas	20	Constantinescu Andrei	33	Favergeon Jérôme	85
Bellett Daniel	103, 105	Braun Moritz	9	Coudray Olivier	44	Favier Véronique	92
Benedetti Matteo	22, 29	Bridier Florent	71	Coulangeon Marc	72	Feaugas Xavier	85
Bennebach Mohamed	87	Bristiel Philippe	44	Cronnier Matthieu	95	Feraille Julien	68
Benz Christopher	18	Brocard Jerome	72	Cugniere Arnaud	7	Fernández-Canteli Alfonso	54, 55, 57

References

Authors	Abstract number	Authors	Abstract number	Authors	Abstract number	Authors	Abstract number
Fiedler Melanie	35, 58	Hantschke Peter	48	Juin Alexian	73	Le Viet-Duc	96, 97
Fink Richard	18	Hauteville Robin	70, 73	Kalin Boris	15	Lefebvre Fabien	66, 92, 95
Fontanari Vigilio	29	Hecht Matthias	104	Kamilia Barthoux	56	Lefebvre Fabien	69, 82
Fouvry Siegfried	45, 68, 71, 72, 76	Hedegård Joakim	4, 74	Kavvadias Dimitrios	43	Leitner Martin	89
Franck Renaud	30	Heindel Leonhard	48	Kellner Leon	9	Leray Vincent	69
Frendo Francesco	17	Hemmesi Kimiya	93	Kempf Andreas	31	Loghin Adrian	13, 53
Frédéric Deschaux-Beaume	100	Hermite Xavier	70, 95	Kepka Jr. Miloslav	83	Luke Michael	93
Fällgren Carl	34	Hervé Nicolas	76	Kepka Miloslav	83	Lusuardi Danilo	29
García-García Ismael	57	Hilgenberg Kai	31	Keribin Christine	44	Mabru Catherine	20
García-González Marta	57	Hor Anis	102	Kihm Frédéric	61	Madia Mauro	21,22,23,25,26,31
Ghiaasiaan Seyed	51, 52	Hubert Blondet	56	Killmann Martin	10	Maitay Frédéric	80
Giannakis Efstratios	43	Huther Isabel	69	Knobloch Markus	59	Malard Benoit	102
Gorash Yevgen	81	Häusler Stephan	18	Koch Ilja	50	Manai Asma	63
Gornet Laurent	80	Hénaff Gilbert	85	Konishi Hideyuki	77	Marckmann Gilles	80
Grober Florian	32	Höhbusch Jochen	86	Kontermann Christian	47	Marteau Julie	82
Grosjean Christophe	66	Hösch Quirin	37	Koutiri Imade	92	Matzen Paul	45
Guda Maik	50	Ilie Paul	53	Kraemer Karl Michael	47	Meck Klaus-Dieter	45
Guillemot Nicolas	68	Ince Ayhan	11, 53	Kraft Jan	42	Mellé David	105
Guldner Jean Charles	80	Ismonov Shakhrukh	13	Kruse Julius	22, 31	Meneghetti Giovanni	14, 28
Gupta Alok	8	Ivannikov Alexander	15	Kästner Markus	35, 48, 49, 50	Merklein Marion	10
Haensel Henning	86	Jablonski Frank	27	Kühne Robert	50	Mesplont Christophe	24
Hafid Fikri	72	Janßen Andreas	32	Küçükay Ferit	32	Miu Tudor	61
Haghshenas Meysam	40, 41	Jean-Luc Dion	30	Lamela-Rey María Jesús	57	Monin Martine	105
Hagnell Karlsson Mathilda	2	Jean-Michel Muracciole	100	Landron Thomas	103	Morel Franck	96, 97
Hajializadeh Farshid	11	Jolivet Simon	82	Le Falher Mélody	76	Morel Franck	103, 105
Hammersberg Peter	4, 74	Jonsson Tobias	3	Le Viet Duc	103	Mouton Luc	79

References

Authors	Abstract number	Authors	Abstract number	Authors	Abstract number	Authors	Abstract number
Moyne Sylvain	46	Quentin Pierre	60	Santus Ciro	29	Teranishi Taiga	78
Muhammad Muztahid	52	Radi Achraf	85	Savaidis Georgios	43	Thiele Marc	106
Munch Thomas	66	Radlof Wiebke	16	Schmidt Franziska	63	Tranchand Benoît	98
Muniz-Calvente Miguel	55	Ranc Nicolas	92	Schmiedt-Kalenborn Anke	15	Trapp Arvid	37
Ménard Christian	71	Raoult Ida	33	Scholten Jan	86	Trimech Mahmoud	101
Mösenbacher Andreas	7	Rauch Marion	59	Schrank Ronald	99	Tusch Olaf	7
Nadot Yves	84	Raßloff Alexander	50	Schulz Paul	50	Uematsu Yoshihiko	5
Narström Torbjörn	3	Retraint Delphine	20	Seiler Martha	49	Vecchiato Luca	14
Oechsner Matthias	47	Rieger Martin	89	Serrano-Munoz Itziar	26	Villechaise Pat	68
Omori Koichi	77	Rigon Daniele	28	Shaha Sugrib	51	Vogt, Jean-Bernard	24
Orkhis Hind	82	Risbet Marion	82	Shamsaei Nima	40, 41, 51, 52	Vormwald, Michael	34, 42, 58
Osmond Pierre	96, 97	Risbet Marion	85	Shao Shuai	40, 41, 51, 52	Wahl, Jean-Christophe	90
Osmond Pierre	103	Robard Pierre	80	Shetye Nitish	2	Walbridge, Scott	101
Otto Johannes L.	15	Rodríguez Cristina	54	Shiraishi Yuichi	77	Walther, Frank	15
Oudriss Abdelali	85	Rognon Hervé	82	Siegert Dominique	60	Wennhage, Per	19, 2
Palin-Luc Thierry	90	Roirand Hugo	102	Skriko Tuomas	67, 75	Werner, Tiago	22, 23, 25
Pamphile Patrick	33, 44	Roveda Ilaria	26	Soltani-Tehrani Arash	40	Wolfsteiner, Peter	37
Paturaud Josselin	68	Rozycki Patrick	80	Song Di	12	Yalamas, Thierry	120
Penyaz Milena	15	Said Julien	68, 72	Spak Boris	35	Yang, Christine	72
Pertoll Tobias	89	Saintier Nicolas	94	Spanke Sebastian	86	Yasin, Mohammad Salman	40
Pessard Etienne	105	Saintier Nicolas	96, 97	Styger Gary	81	Yu, Chao	12
Pirotais Marie	94	Saintier Nicolas	10	Sun Zhidan	20	Zeißig, Michaela	27
Poetter Kurt	88	Sakamoto Chihiro	77	T. Zeuner André	50	Zerbst, Uwe	21, 23, 25
Poudel Arun	51	Sakano Masahiro	77, 78	Takada Yoshihiko	78	Zimmermann, Martina	50
Poutiainen Ilkka	75	Salman Yasin Mohammad	41	Takahashi Yuki	78	Zoran, Dimitrijevic	30
Proust Gwénaëlle	20	Sander Manuela	16, 18	Tehrani Arash	52		

Notes

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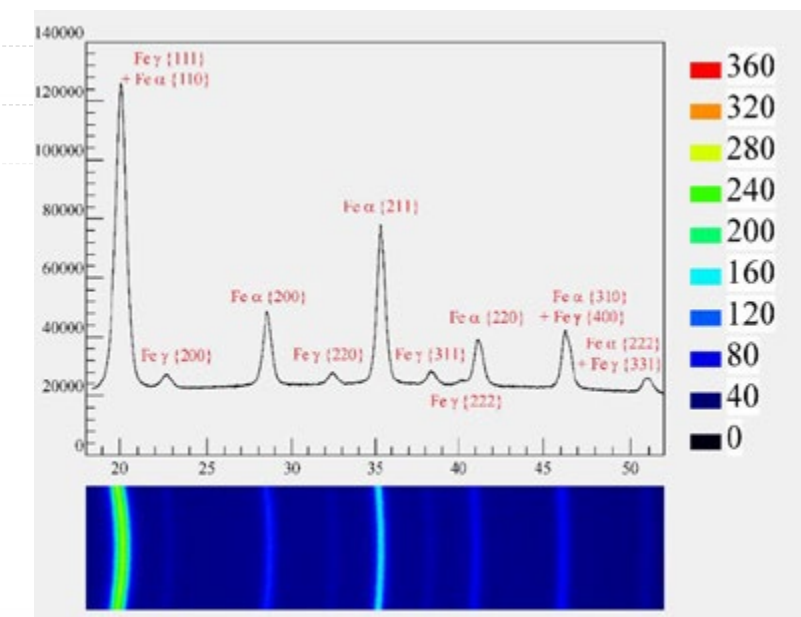
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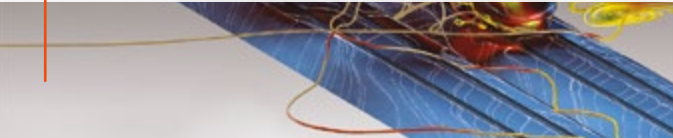
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