IMPROVEMENT OF THE WELDING JOINTS AND COMPONENTS BY SHOT PEENING

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Abstract The commission XIII of the International Institute of Welding published in 2007 a document called “recommendations for fatigue design of welded joints and components”. It presents various processes to improve fatigue life after welding.
Shot peening is well known to improve fatigue life of metallic components, including welded joints and components, but it has never been properly qualified for the IIW recommendation.
In order to include the benefits of shot peening in this paper, Metal Improvement Company together with Cetim Senlis, started the procedure to qualify it.
The samples are longitudinal non-load-carrying fillet welds, done in DOMEX 700, a hot rolled high strength steel from SSAB Tunnplat, 8 mm thick. Twelve samples have been peened by Metal Improvement Company and three not. Then they have been fatigue tested at Cetim Senlis with 3 load levels up to 2 000 000 cycles at R = -1 and R = 0.1 in order to quantify the benefits of shot peening.
Shot peening is introducing compressive residual stress and also improving the geometry of the weld toe. It is the projection of hard shots made in steel, stainless steel, ceramic or glass of various sizes (diameters from 50 µm to 3 mm). There is also the control of the intensity and of the coverage rate (minimum 100%) of the treatment in order to get an uniform compressed layer. It can be apply manually till fully automatic controlled machines. It is used for more than 60 years to treat fatigue, fretting, pitting (contact fatigue), stress corrosion cracking, intergranular corrosion or thermal fatigue. It is applied for single as well as serial parts in all industrial fields: aerospace, automotive, energy, power generation, medical or general industry.
Fatigue test have been done with 3 loads levels up to 2 000 000 cycles at R=0.1 and R=-1 in order to quantify the effect of compressive load on the fatigue life.
The results are good. At 2.10^6 cycles, the average stress level is 126 MPa for the as-welded samples and 221 MPa for the shot peened samples. It is an improvement of 75% of the fatigue life. The residual stress level has also been measured at the surface of the part close to the welded area and gives also good results of -500 to -650 MPa.

1 INTRODUCTION

The commission XIII of the International Institute of Welding published in 2007 a document called “recommendations for fatigue design of welded joints and components”. It presents various processes to improve fatigue life after welding.
Whilst shot peening is well known to improve fatigue life of metallic components, including welded joints and components, it has never been properly qualified in the IIW recommendations [1] [2].
In order to include the benefits of shot peening in the future IIW recommendations, Metal Improvement Company together with Cetim, started a procedure to qualify it.

2 CHARACTERISTICS OF SAMPLES

The samples are longitudinal non-load-carrying fillet welds (see Figure 1), done in DOMEX 700, a hot rolled high strength steel from SSAB Tunnplat, 8 mm thick.

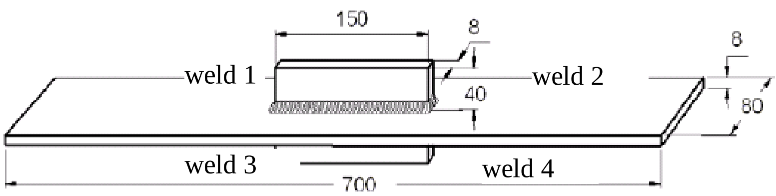

Figure 1. Sample geometry

Twelve samples have been peened by METAL IMPROVEMENT COMPANY and three not.
To characterize the weld beads, the toe radii of the welds were measured (Figure 2). The values are given on Table I (as-welded) and Table II (shot peened).

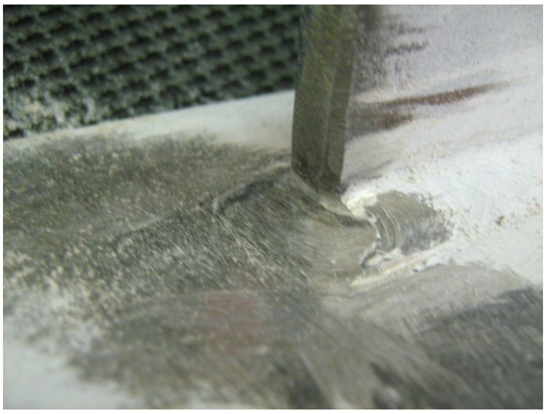

Figure 2. Weld shapes, as-welded and shot peened

Table I. As-welded joints

	radius (mm)		
	B1	B2	B3
weld 1	3.6	1.4	1.8
weld 2	6.0	5.4	4.3
weld 3	7.2	4.3	3.5
weld 4	7.9	3.2	3.4

Table II. Shot peened welded joints

	Radius (mm)									
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Weld 1	6.2	3.3	0.8	5.0	5.1	6.2	5.4	7.0	7.9	5.4
Weld 2	9.3	4.7	7.4	5.7	3.1	10.8	5.1	8.3	4.4	5.4
Weld 3	1.1	4.2	6.4	3.2	4.4	3.5	3.9	5.1	7.4	4.0
Weld 4	2.7	2.6	5.0	3.9	6.7	1.9	1.8	6.1	4.3	4.5

3 SHOT PEENING PROCESS

Shot peening is a cold working process. It introduces compressive residual stress and improves the geometry of the weld toe. It is the projection of hard rounds shots made in steel, stainless steel, ceramic or glass of various sizes (diameters from 50 µm to 3 mm). Shots can be projected by the mean of air pressure in nozzles or by a rotating turbine.

In order to get a constant and controlled process, the metallurgy of the shots, their size, their form, the Almen intensity, the coverage rate (it must be minimum 100%) and the shot angle [6] are accurately controlled and recorded to get an uniform compressive stress layer on every parts. The coverage rate is controlled by the PEENSCAN process. It is a fluorescent liquid that must be totally removed from the part after shot peening to show the 100%. It ensure that every area of a weld have been treated and are in compressive stress as it can be difficult to verify just with a magnifying glass.

This process can be manual to fully automatic controlled machines.

It is commonly used for more than 60 years to treat fatigue, fretting, pitting (contact fatigue), stress corrosion cracking, intergranular corrosion, hydrogen embrittlement or thermal fatigue on all metallic materials. It is applied for single to serial parts in all industrial fields : aerospace, automotive, energy, power generation, medical or general industry.

For this study, automatic shot peening has been performed. It is also possible to perform it with handling device as the air pressure is permanent, as with the automatic process.

Shot peening parameters :
- Shot: MI 170 H
- Almen intensity: F 35-40 A
- Controlled by PEENSCAN
- Automatic machine.

This kind of treatment is very often applied to real industrial parts and installations, in workshops or directly on site to avoid the carriage of the parts.

It has not been performed here, but better results in fatigue will be expected if the peened part is loaded to give tensile stress in the region to be peened.

4 TEST CONDITIONS

The fatigue tests were performed in tension and in tension-compression on a vibrophore with a maximum capacity of 450 kN.
The test frequency is equal to 120 Hz.
The stop criterion is the specimen failure or 5 millions of cycles.
The tests of as-welded joints and some shot peened joints were performed with a stress ration of R = 0.1 in order to compare with those of IIW "round-robin" on fatigue improvement [4] [5]. The other shot peened joints were tested at R = -1 to know the influence of a compressive load on fatigue behaviour.
The specimens were tested on two stress levels.

5 FATIGUE TEST RESULTS

The fatigue test results are given on Figure 3 with as-welded joints (AW), shot peened R = 0.1, shot peened R = -1.
The crack initiations are localised at the weld toe for as-welded joints (Figure 4) and at the weld root for shot peened joints at R = 0.1 (Figure 5).

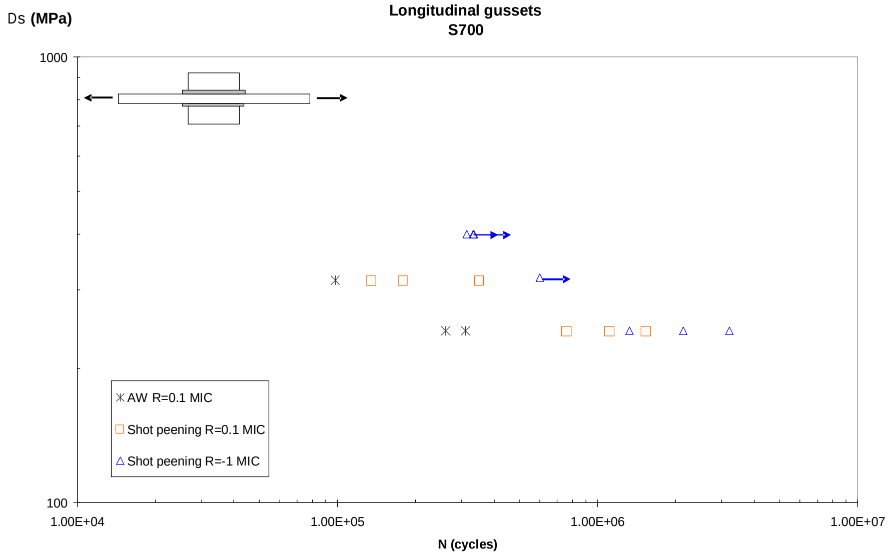

Figure 3. Fatigue test results

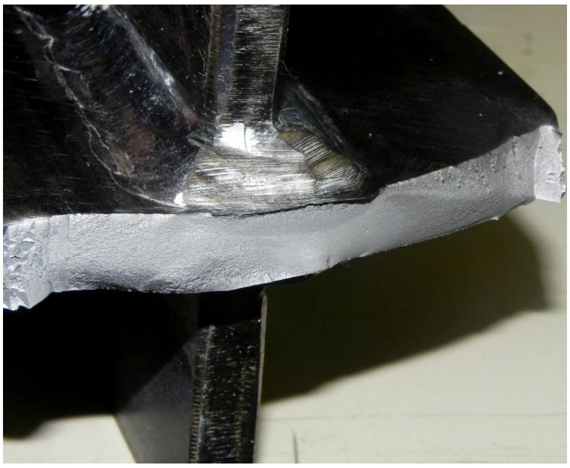

Figure 4. Crack initiation on as-welded joint (weld toe)

Figure 5. Crack initiation on shot peened joints (weld root)

6 DISCUSSION

6.1 Comparison with IIW round robin as-welded results

The test results were compared with the as-welded results of IIW "round robin" (see Figure 6 and Figure 7).
The Figure 6 shows that the as-welded joint results are better than those of IIW "round robin". It may be noted that the weld toe radii are of order of 2 mm whereas those of IIW "round robin" were of order of 0.7 mm.

Figure 7 illustrates the mean S-N curves for "round robin" as-welded joints, for as-welded joints and shot peened joints (R = 0.1) by MIC.
Comparing the results at 2.10^6 cycles, the "mean" stress range is equal :

- for round robin as-welded joints to ***82 MPa***
- for present study as-welded joints to ***126 MPa*** (gap of 50% with round robin tests),
- for shot peened joints to ***221 MPa*** (75% of improvement with regard to as-welded).

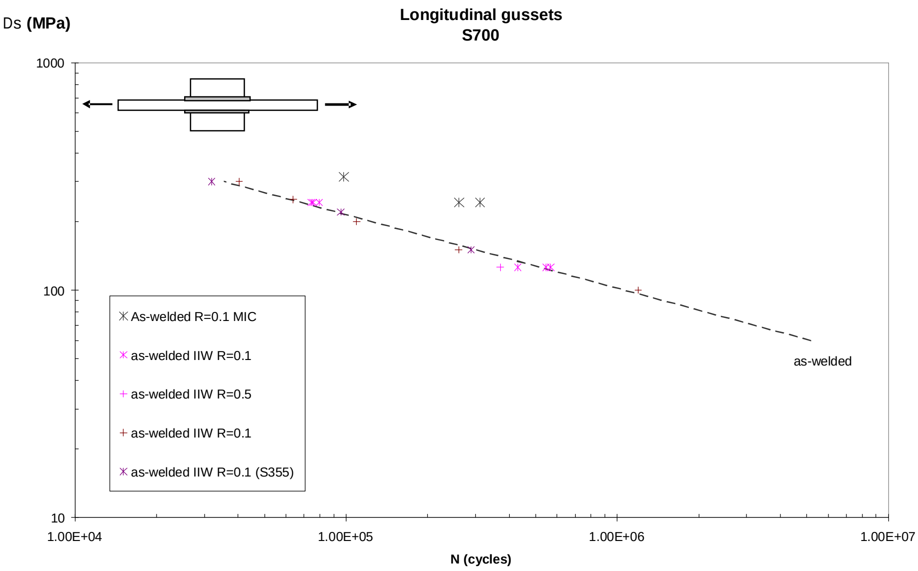

Figure 6. Comparison of tests with as-welded results of IIW round robin

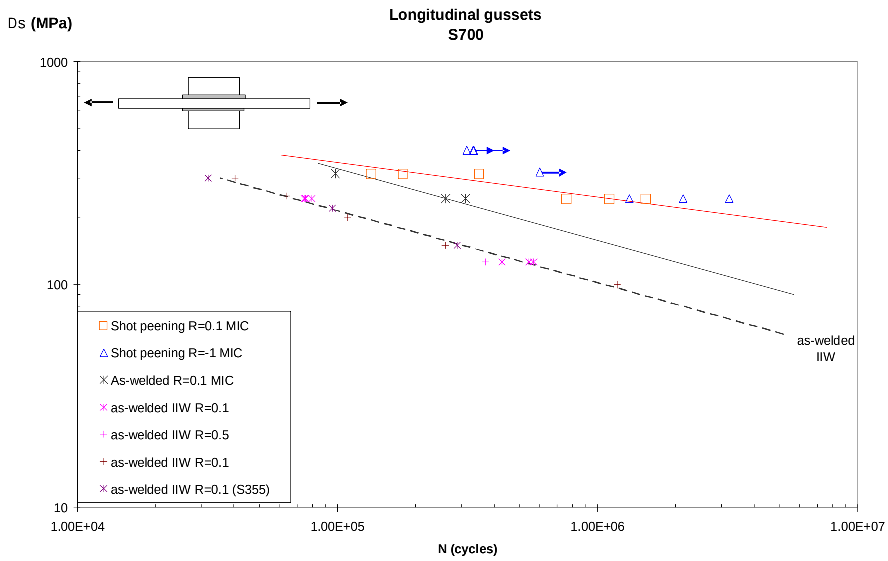

Figure 7. Mean S-N curves of tests (as-welded and shot peened R = 0.1)

6.2 Comparison with IIW round robin UIT/UP hammer peened results

The test results were compared with the UIT/UP hammer peened results of IIW "round robin" (see Figure 8). The shot peened results seem better than the UIT/UP hammer peened results [4].
It may be noted that the shot peening improves the fatigue strength of a factor of 1.75 compare to as-welded. Whilst the fatigue strength at 2.10^6 cycles observed for hammer peening is of order of 175 MPa of which is less than the shot peening improvement.

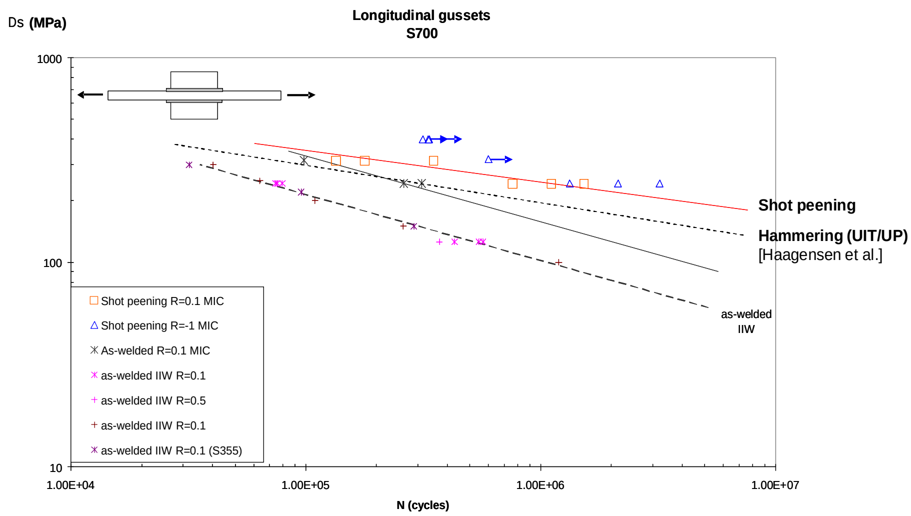

Figure 8. Comparison between shot peening and UIT/UP peening

6.3 Comparison with the IIW recommendations for improvement techniques

In the IIW recommendations for improvement techniques [1], in particular for hammer peening or needled peening, the value of the FAT (design curve) is at the maximum equal to ***112*** (see Figure 9).
The value of the FAT is :

- for shot peened joints, of ***156*** (with m = 5),
- for UIT/UP hammer peened joints [4], of ***129*** (with m = 5).

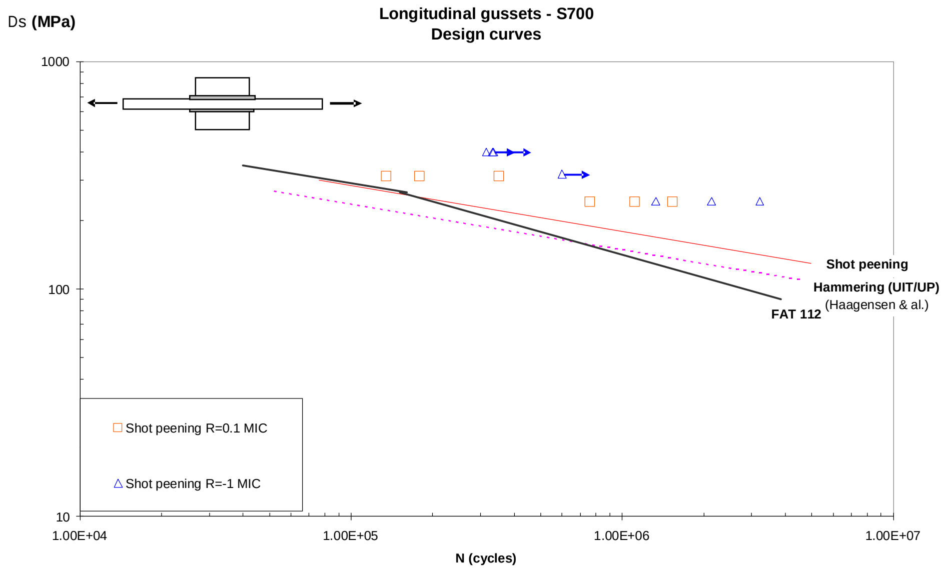

Figure 9. Comparison with IIW recommendations

6.4 Residual stress estimation

The residual stress estimation was performed near the weld toe in longitudinal direction as shown on Figure 10 by X-ray diffraction.

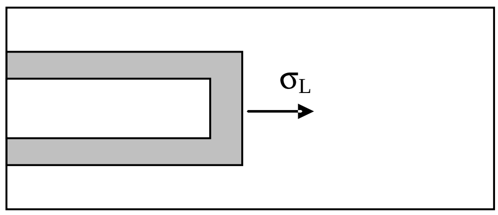

Figure 10. Residual stress measurement direction

On shot peened welded joint (G3), the results of the estimation on surface are :
- near the weld toe (weld 1) : σ_L = -507 ± 8 MPa
- near the weld toe (weld 3) : σ_L = -651 ± 10 MPa

7 CONCLUSION

The aim of this study was to characterise the fatigue behaviour of longitudinal non-load-carrying fillet welds shot peened.
Fatigue tests were performed on as-welded joints to have a reference and on shot peened joints with a stress ratio equal to R = 0.1 to compare with the results to those of IIW "round-robin" on improvement. Other shot peened specimens were tested at R = -1 to know the influence of compressive load on fatigue behaviour.

The results of as-welded joints are better than those of IIW "round robin" tests. That is the radii of the weld toe are of 2 mm about whereas those of IIW "round robin" were of 0,7 mm about.

The mean stress range at 2.10^6 cycles is equal to :
- for round robin as-welded joints : ***82 MPa***
- for as-welded joints of this study : ***126 MPa*** (gap of 50% with round robin),
- for shot peened joints : ***221 MPa*** (75% of improvement with regard to as-welded).

The design S-N curve is a ***FAT 156*** (with a slope m = 5).

The estimation of residual stresses was performed on a shot peened joint, the residual stresses on surface were in the region of -500 to -600 MPa.

8 REFERENCES

[1] P.J. Haagensen, S.J. Maddox, IIW Recommendations on Post Weld Fatigue Life Improvement of Steel and Aluminium Structures, IIW XIII-2200r7-07, Revised 06 July 2010
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[5] I. Huther, Y. Suchier, H.P. Lieurade, Fatigue behaviour of longitudinal non-load-carrying joints improved by burr grinding, TIG dressing, IIW-doc XIII-2108-06
[6] Metal Improvement Company, Applications of shot peening, 8th Edition, 2001.