Development of a testing method in high cycle fatigue on specimen with foundry skin

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Abstract This document presents a testing method developed by PSA Peugeot-Citroen in order to characterize in polycyclic fatigue some materials with effects of gradiants on the surface (skin of foundry, skin of forging mill, standard surface treatment deposit or reinforcement by shot-blasting). This method is applicable to any metallic material/ process (steel, cast iron, aluminium alloy, copper...). An example of use of this method is carried out on aluminium alloys for application HDi cylinder head. The materials and the test are described. The principal results obtained by this method and the tracks of improvement considered are also presented

1 INTRODUCTION

In automobile design, one of the first steps consists in obtaining relevant data materials to use in the structural analyses. In order to guarantee the best representativeness material/ process of a selected structure requested in polycyclic fatigue, these data must be characteristic of material in its process context. The data materials depend in particular on the microstructural state and the surface quality of the part.

In this document are presented the testing method developed by PSA Peugeot-Citroen and various applications of this method in diesel design of cylinder heads. However, the principle is applicable to any couple metallic material/ process (steel, cast iron, aluminium alloy, copper...). The interest is that this testing method makes it possible to take into account the effect of skin of foundry, the skin of forging mill, the standard surface treatment deposit or the reinforcement by shot-blasting without the measured resistance to fatigue. The technological specimen used is called " bone of dog specimen". These specimen are subjected to cyclic requests in flexion to determine the resistance to fatigue of material. These data of design are representative of the part and of its process and they allow to feed in data materials the models used for calculations of dimensioning. Thus, this testing method makes it possible to evaluate and compare the potential of several solutions materials and processes.
The operational limits of the bone of dog specimen are also approached. Lastly, various prospects for improvement of the method of characterization are in hand and are presented.

2 MATERIALS

Two aluminium alloys of foundry were characterized: Al-Si7Mg03 - T7 and alloy Al-Si7Cu05Mg03 - T7.
The chemical compositions of these two alloys are presented in the tables below:

Count I: Chemical composition of aluminium alloys tested

Alliage Al - Si7Mg0,3 T7

Fe %	Si %	Cu %	Mg %	Zn %	Mn %	Ni %	Ti %	Pb %	Sn %
0,20 maxi	6,5 7,5	0,1 maxi	0,28 0,40	0,1 maxi	0,1 maxi	0,05 maxi	0,20 maxi	0,05 maxi	0,05 maxi

Alliage Al - Si7Cu0,5Mg0,3 T7

Fe %	Si %	Cu %	Mg %	Zn %	Mn %	Ni %	Ti %	Pb %	Sn %
0,20 maxi	6,5 7,5	0,4 0,6	0,28 0,40	0,1 maxi	0,1 maxi	0,05 maxi	0,20 maxi	0,05 maxi	0,05 maxi

3 DESCRIPTION OF THE SPECIMEN

3.1 GEOMETRIE

The plan of the specimen varies according to the process of setting in. Specific tool is produced for each new process of foundry. The same tool is used then for all compositions / heat treatments / mechanical reinforcements to test with this process.
In a general way, the bone of dog specimen is a massive specimen of length of about 160 mm and thickness equal to 15 mm in the useful zone, figure 1. The heads of the specimen are machined in order to be maintained in the bits of the test facility.

a) b)

Figure 1. Bone of dog specimen a) cast lost foam b) cast gravity sand

3.2 FABRICATION OF THE SPECIMEN

The specimen described in this study were produced according to two processes: the process of gravity sand casting and the process by lost foam.

In gravity sand casting, these specimen known as "bone of dog" are cast using sand moulds made out of cold box. Regenerated sand is dependent with a resin of the type "Avécure AL301/AL602 (0,5%). The catalyst accelerating the catch is amine in gas form. The granulometry of regenerated sand is identical to that used for the manufacture of the water cores of cylinder head.

The model of the specimen resulting from technology lost foam is carried out by injection of expanded Polystyrene out of metal mould. These specimen (6) are stuck on a polystyrene descendant; the specimen as a whole constituting a bunch which will be casted after having been tight in sand.

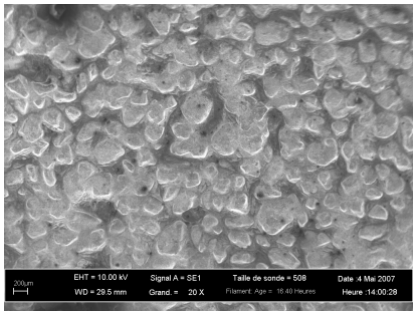
In both cases, the parameters of casting specimen are identical to those used for the casting of the cylinder heads.

3.3 REPRESENTATIVITE OF THE SPECIMEN (case of gravity casting)

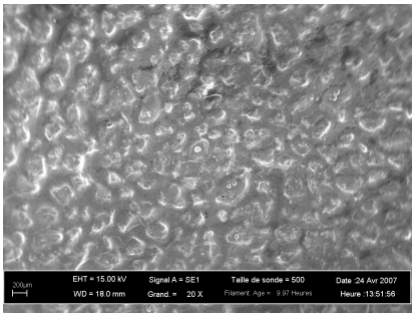
In order to validate the data obtained, the specimen must be most representative possible of the surface quality of the targeted part. In the case of the cylinder heads, the surface quality of bone of dog specimen must correspond to that critical area of the water jacket. In order to check this point, the representativeness of the specimen was analyzed from a microstructural and topographic point of view. The results of the analysis of the specimen and the cylinder head cast in gravity are presented below (figure 2). The surface quality measured and the topography of the surface observed with the MEB, are very similar for the bone of dog specimen and the water core. One can thus consider that the bone of dogspecimen is representative of the surface quality of the water chamber area.

"bone of dog" specimen

water chamber area of HDi cylinder head



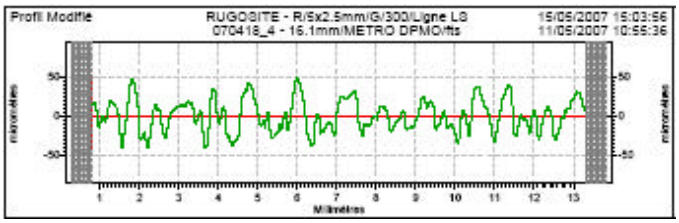
MEB of surface photographs

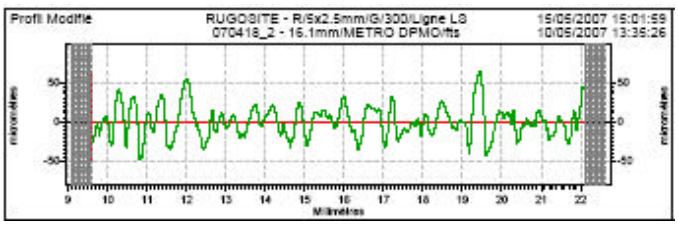


MEB of surface photographs

Microstructural cut of surface

Microstructural cut of surface





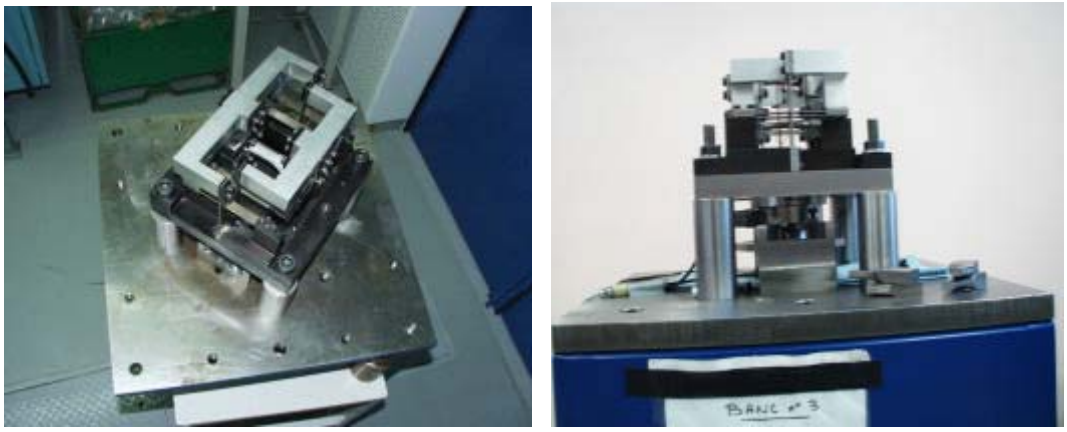
Roughness of surface

Figure 2: Comparison of surface quality of the bone of dog specimen and water chamber area of the HDi cylinder heads.

4 PRINCIPLE OF THE TEST

In the case of the cylinder heads, the bone of dog specimen must be representative of critical area of the water chamber subjected mainly to requests of polycyclic tiredness. The developed method makes it possible to evaluate the potential of solution material / process with respect to the resistance to fatigue and gives access to the associated curves of Wöhler.

In order to test the skin of the bone of dog specimen, a loading in flection is forced on this specimen. The assembly of flection test (figure 3) is provided with flexible blades authorizing a perfect rotation of the heads of the specimen. In the case of' hot tests, an enclosure includes the whole of the assembly. Before all the bench is gauged. This calibration is carried out to the instrumentation of the body of the specimen by gauges of deformation (figure 4). One thus gauges the bench of inflection for each batch tested by plotting a curve Contrainte (déformation*module of Young) according to the effort applied by the jack. The fatigue tests are made by determining the limit of endurance of material with his skin of foundry according to the traditional methodologies used in fatigue [1]: layout of a curve of Wöhler with 25 specimen; a short staircase is also integrated in the construction of this curve of Wöhler in the zone of unlimited endurance. The criterion of ruin is the rupture of the specimen. The report of load R = Fmin/ Fmax of the try can vary. Finally the assembly can adapt to carry out hot fatigue tests or corrosive ambient condition



a) b)

Figure 3: Bench of inflection allowing to carry out fatigue tests at ambient temperature and air
(a: assembly seen of top with a specimen; b: assembly seen on side)

a) **b)**

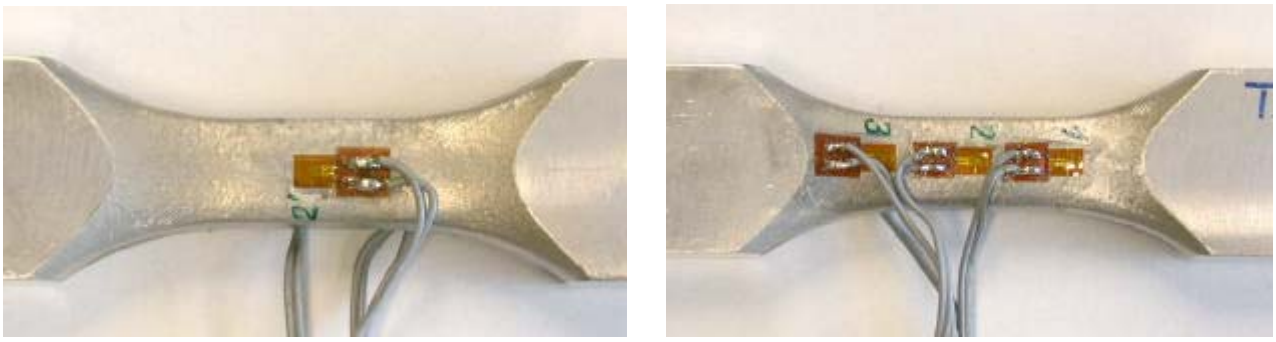


Figure 4 : "os of dog "specimen instrumented with gauges of deformation
(a: sight of lower part, b: sight of top)

5 PRINCIPAL RESULTS

The objectif of these tests is to characterize the couples material / process. For one type of alloy given, the effect of the manufactoring process can be evaluated or for a fixed process, the influence of the type of alloy can be estimated. It is noticed, figure 5, that in gravity sand casting, the resistance to fatigue with 20°C and 107 cycles of Al-Si7Mg03 - T7 is identical to that of Al-Si7Cu05Mg03 - T7. For AlSi7Mg03 - T7, the lost foam process led, at ambient temperature, a fall of 25% of the resistance to fatigue compared to gravity sand casting.

In order to validate the test results, the fracture topographies of the specimen are also analyzed after tests (figure 6).

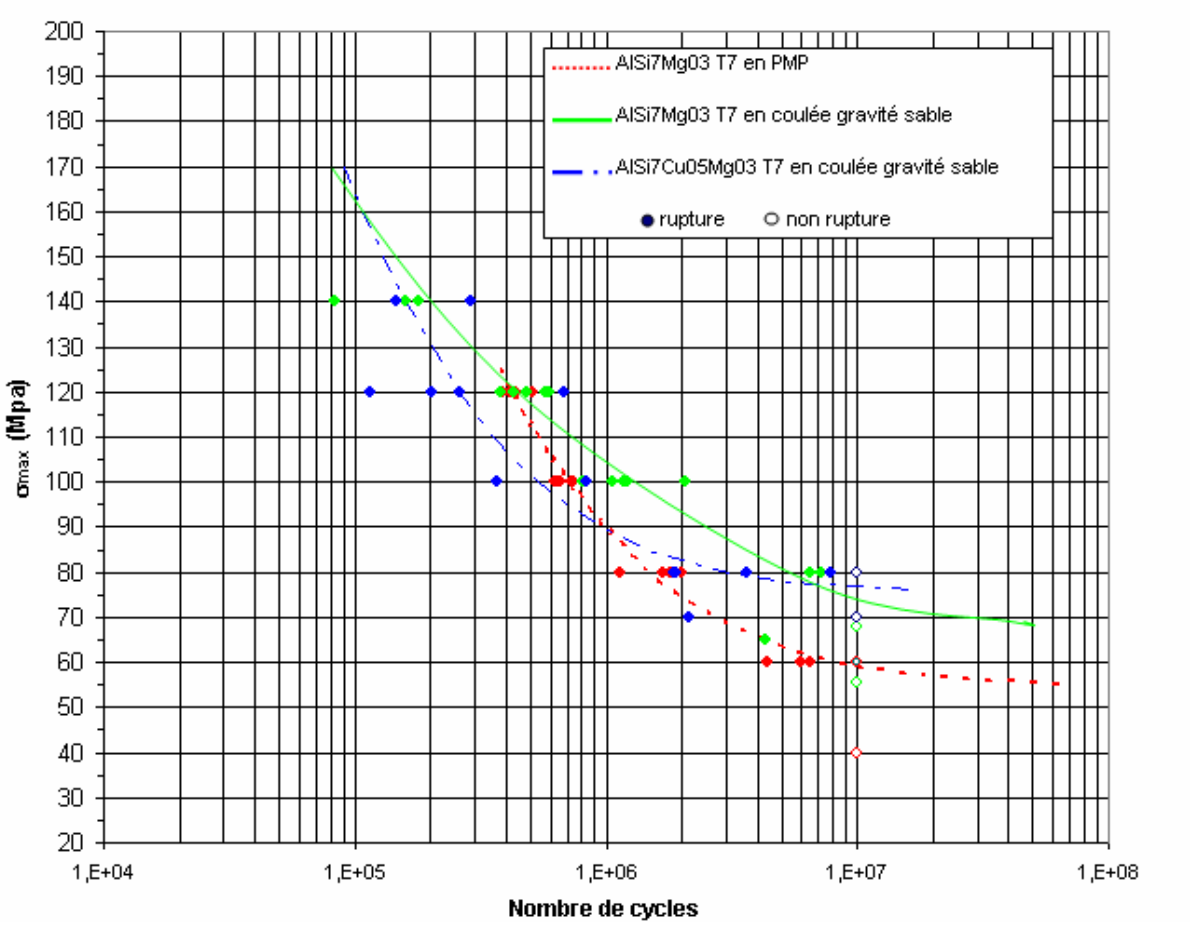


Figure 5: Curves of Wöhler - Bone of dog specimen - Alloy for cylinder head HDI - R=-1, 20°C

An evolution of the dispersion of resistance to fatigue, associated the manufactoring process, is also drawn from these tests. Even if this evolution remains semi quantitative, it proves interesting to treat on a hierarchical basis between them the manufactoring processes.

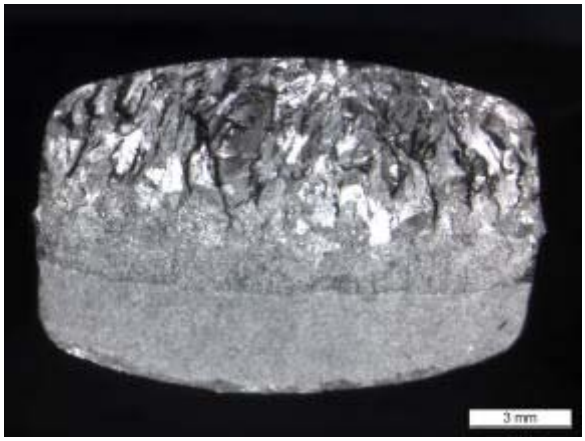


Figure 6: Photograph of the fracture topography of a "bone of dog" specimen.

6 OTHER WORK AND OUTLINES

Other works made it possible to improve the representativeness of the bone of dogspecimen for some parts on gravity die casting (parts of connection on ground in aluminiumalloy). For example, in die casting„ the roughness of the skin of part depends on the roughness of the refractory wash. In serial production, the manual final improvements of the refractory wash due to breakdowns create a local degradation of the roughness of the part. To test the influence of roughness degraded on the resistance to fatigue, we reproduce this rough refractory wash on the mould of the "bone of dog " specimen. Then we can adjust the representativeness of the specimen, for the parts of connection on the ground, and to obtain data materials for dimensioning, perfectly correlated with the behaviour on automobile parts.

7 CONCLUSIONS

This document presents a testing method developed by PSA Peugeot-Citroen in order to characterize in polycyclic fatigue some materials with effects of gradient on the surface (skin of foundry, skin of forging mill, standard surface treatment deposit or reinforcement by shot-blasting). This method is applicable to any material/process (steel, cast iron, aluminiumalloy, copper...), it gives access to data exploitable materials for calculations of dimensioning and makes it possible to evaluate the influence of a process or an alloy on the resistance to fatigue.

8 REFERENCES

[1] H.P. LIEURADE, Pratique des essais de fatigue, Commission fatigue des métaux, Broché, Paris, 1982

[2] Source PSA Peugeot-Citroën : BASMAT serveur