INFLUENCE OF THE AGEING OF CAST STEEL SHOT ON THE FATIGUE STRENGTH OF SHOT-PEENED TA6V AND 40 NSCD 7 GRADE STEEL

Shot doesn't age

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ABSTRACT

This study presents the fatigue strength results obtained for two materials (a titanium alloy TA6V and a high strength steel 40 NSCD 7) and for shot-peened fatigue specimens. The aim of the work was to study the influence of ageing of cast steel shots during shot-peening operations.

Ageing of the shot was obtained using a shot-peening machine for increasingly long operating times. To obtain different ageing rates for the shots, the fatigue specimens were shot-peened and various tests conducted:

- study of the development of surface roughness and surface integrity
- study of the development of residual stress
- study of the development of fatigue strength
- study of the mode of fracture of the shots.

The results obtained show that ageing of the shot used (BA 300 N and BA 300 D as per French standard NF L 06-831) does not influence either the residual stress or the fatigue strength of the two materials studied, assuming that the shot-peening machine correctly eliminates any broken shots.

KEYWORDS : SHOT PEENING, SHOT, FATIGUE, STEEL, TITANIUM, ALLOY, AGEING

INTRODUCTION

BNAE's GT10 working group (Aeronautical Standardization Bureau) launched a study involving different partners: CEAT (Centre d'études aéronautiques de Toulouse), Cetim, Ensam, Messier-Bugatti, Metal Improvement Company, Snecma, Turboméca, Wheelabrator-Allevard (see table I).

The aim of the study was twofold: first, to determine the influence of internal cracking and changes in the hardness of steel shot on the quality of shot peening and second, to use the results obtained to update standard NF L 06 831 which defines the quality criteria for steel shot. To do this, the mode of damage to the shot during operation and the influence of the damage on the quality of the shot-peened parts were considered.

Within the framework of the experimental programme to be carried out, Cetim was more especially responsible for determining the fracture mechanism of the shot, checking the development of surface roughness and residual stresses on the surface of fatigue specimens, and examining the fatigue behaviour by rotative bending of the shot-peened specimens using shot aged to varying degrees.

The materials studied were titanium alloy TA6V and high strength steel 40 NS CD7 (300 M), which are used extensively in aeronautics and whose shot-peening conditions are well controlled.

The 300 M steel is highly sensitive to the notch effect and alloy TA6V is highly receptive to shot peening overlays, incrustations and angular impacts. Both should therefore be good indicators of surface defects and consequently of the quality of shot peening.

Two types of shot were used: BA 300 N, normal grade, and BA 300 D, hard grade. The steel shot was aged artificially in a turbine machine, by shot peening 300 M steel "anvils" at high intensity (F 40-45A), with the ageing time corresponding to the number of cycles.

After ageing, the broken shot was eliminated on a spiral separator.

At different stages of ageing, the shot was removed and checked: measurement of the density using a pycnometer, inspection of the granulometry as per standard NF X 11 907, examination of the appearance of the shot using a scanning electronic microscope (SEM), counting of deformed or fractured shot using an optical microscope and measurement of the hardness of uncracked shot.

SEM examinations were also carried out on rejects eliminated after ageing, in order to check the mode of fracture.

Using the shot prepared above, the materials chosen were then shot-peened in a shot-peening machine, in order to determine various characteristics i.e. measurement of the surface roughness using Snecma's 3D roughness meter, analysis of residual stress using X-ray diffraction at ENSAM in Aix-en-Provence, fatigue behaviour in repeated traction on a specimen at CEAT and fatigue behaviour in rotative bending on a specimen at CETIM.

Ageing and the mode of fracture of the shot

The shot has very different behaviour depending on the hardness.

Shot of normal hardness, BA 300 N, features high stability of its properties during use.

However, it should be noted that the SEM examinations show the beginning of damage by surface flaking after 2000 cycles (fig. 2)

On the other hand, hard shot BA 300 D becomes seriously damaged during use. More fragile, it is sensitive to cracking and fracture (fig. 3) and its hardness decreases.

Surface roughness, residual stress and fatigue

The surface roughness of shot-peened specimens is not affected by ageing of the shot, apart from a slight improvement for 600 cycle ageing (table II).

With regard to residual stress for TA6V specimens in rotative bending, the depth affected by shot peening is in the order of 160 μm, regardless of the type of shot used.

The surface compression stress increases (from - 100 to - 500 MPa) according to ageing of the shot. But this phenomenon, which does not occur with the 300 M steel, does not have any effect on the fatigue.

The development of residual stress according to ageing of the shot was also measured on 10 mm thick, 25 mm diameter pellets.

The results obtained confirm the observations made on the rotative bending specimens: ageing does not change the stresses produced to any appreciable extent (fig. 4).

With regard to the fatigue strength, shot peening does not seem to have any effect on the repeated traction specimens (fig. 5). Two explanations are possible: for TA6V, the polished specimens offer an excellent surface finish with respect to that encountered more generally on machined parts; for the 300 M steel, the fatigue cracks always begin in the carbonitrides, inclusions which may have masked the shot-peening effect.

In rotative bending, on the other hand, shot peening improves the fatigue behaviour of the two materials studied in all cases (fig. 6).

But the most important aspect is that, under the test conditions, ageing of the shot does not seem to affect the fatigue resistance of the shot-peened parts. Whatever the ageing rate, the lifetimes obtained are in the same band of dispersion as that observed for the shot-peened specimens.

More details on the all results are available in réf. 1.

As a conclusion :

The ageing of cast steel shot does not affect the fatigue strength of shot-peened high strength or titanium steel parts. Checking the unbroken cracked shot rate is therefore superfluous. However, checking the quality of the sorting and elimination of broken shot must be continued.

Necessary amendment of the standard

These results have led to the suggestion that standard NF L 06 831 should be amended by eliminating the requirement that the uncracked shot rate be checked and increasing the hardness tolerance of hard steel shot.

A hardness of 600 to 800 HV is preferable to the current requirement of 500 to 700 HV, in order to compensate for the drop in the average hardness recorded during operation.

Naturally, cracked shot still needs to be eliminated. It would therefore seem advisable to maintain periodical visual inspection of the shot in the standard, in order to check that grading is effective and that the rate of deformed or broken shot remains less than 5%.

Acknowledgements

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Fig. 1 Shot-peened specimen broken after a rotative bending test

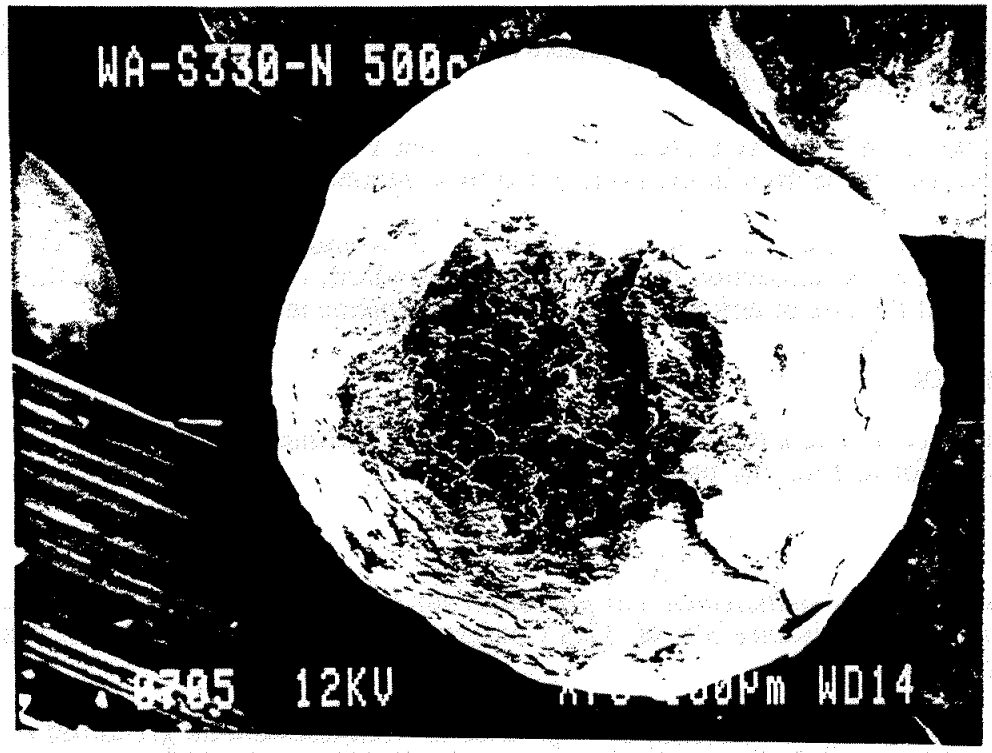

Fig. 2 BA 300 N shot after 500 ageing cycles. "Onion skin" surface flaking has begun.

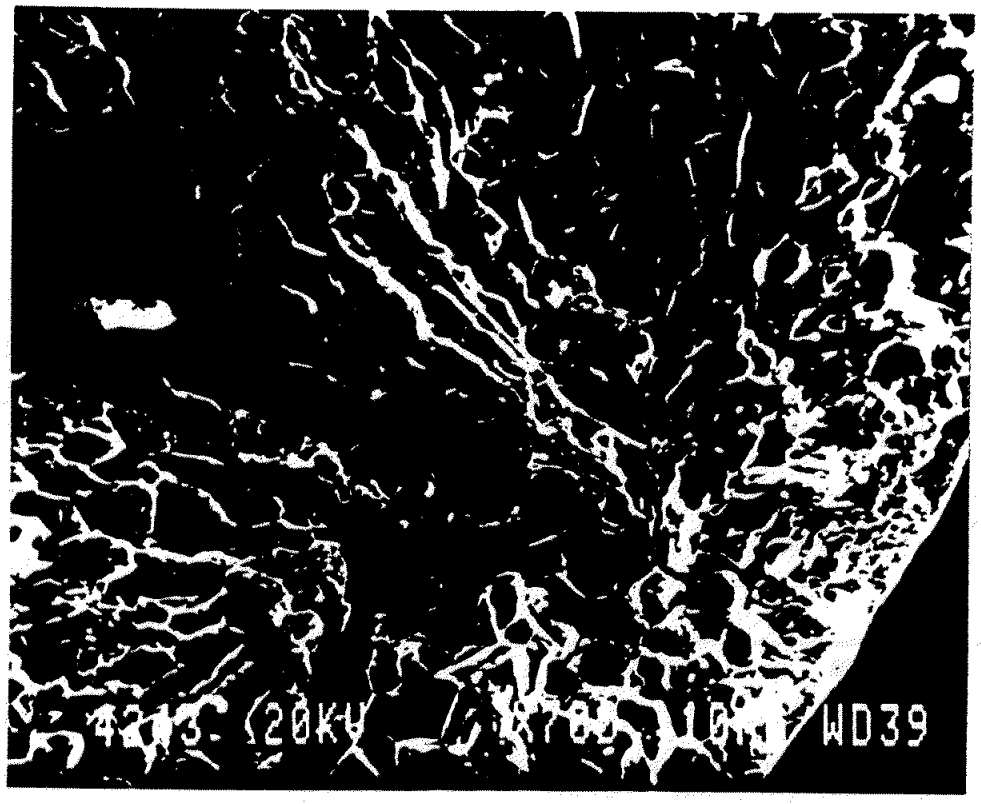

Fig. 3 BA 300 D shot broken after 1200 ageing cycles. Brittle type fracture.

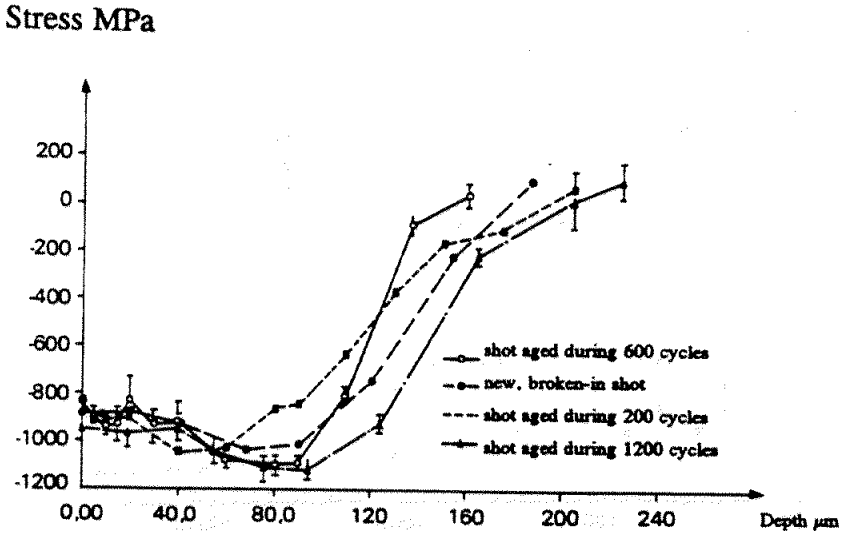

Fig. 4 Profile of residual stress on 300 M shot-peened steel (BA 300 D shot). Measurements taken using X-ray diffraction at ENSAM in Aix-en-Provence.

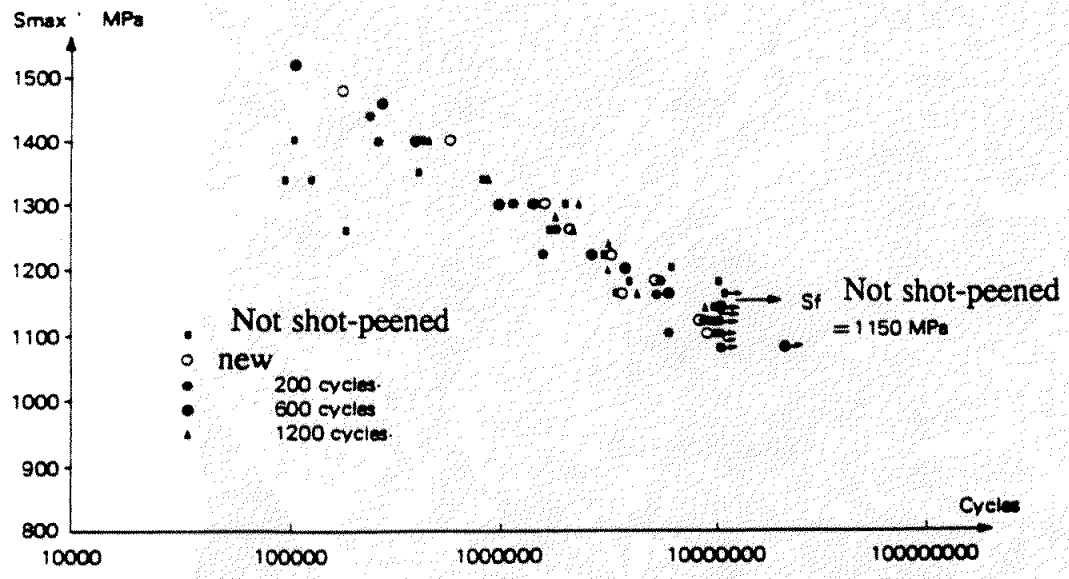

Fig. 5 Axial fatigue of 300 M shot-peened steel (BA 300 D shot). CEAT results

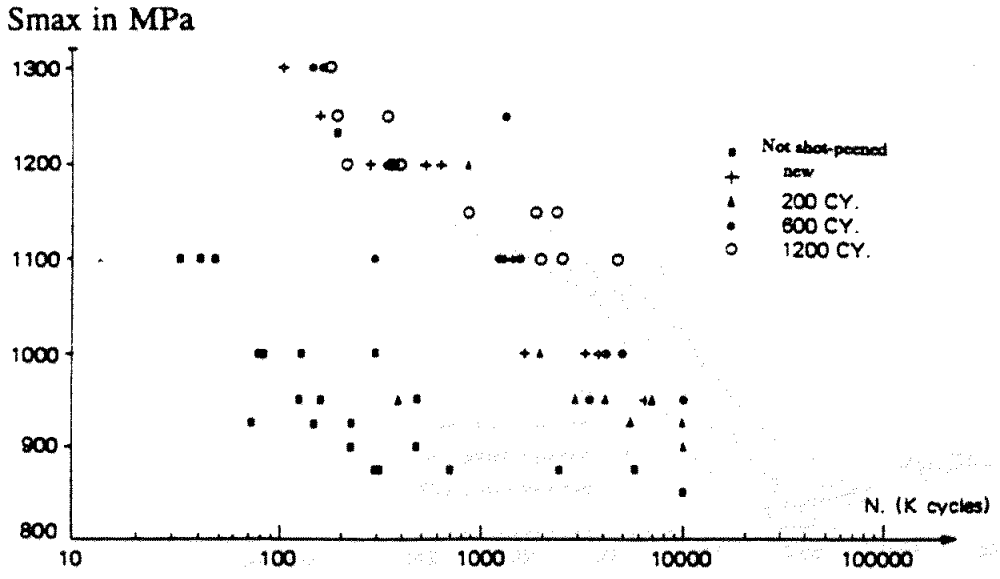

Fig. 6 Rotative bending fatigue of 300 M shot-peened steel (BA 300 D shot). Cetim results

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TABLE I

Roughness in μm	Titanium Alloy		300 M Steel	
	Ra	Rtm	Ra	Rtm
New shot	1,94	10,75	1,81	10,1
Shot after 200 cycles	1,94	10,9	1,76	10
Shot after 600 cycles	1,32	7,4	1,51	8,59
Shot after 1200 cycles	2,5	13	2	10,5

TABLE II. Development of the roughness of specimens according to ageing of the shot (BA 300 D).