On the effects of Shot Peening on the fatigue strength and the residual stresses of parts made of Ti Al6 V4

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Introduction

In recent years shot peening has become an excellent procedure for forming sophisticated components in aircraft construction (1). Based on comprehensive experience, which has been acquired by changing the shape of aluminum parts and by surface hardening of titanium the additional forming of milled parts made of Ti Al6 V4 was taken up in a research programme (2)-(4). The only procedure which up to now has turned out to be acceptable for that material was the forming of titanium parts in the creep regime at 700°C. But this requires expensive equipment. Due to the high yield to ultimate strength ratio and the brittle α-phase cold forming is not accepted. As far as shot peening is concerned a research project was launched to find out whether the mechanical properties of titanium deteriote, particulary with respect to fatigue strength. Moreover, attention had to be drawn to the negative influence of residual stresses which on one hand could reduce the loading capacity of a component in operation and on the other hand favour crack initiation on the surface.

Performance of the tests

For the test programme milled plates of 3 and 6 mm thickness (fig.1) were deflected by shot peening on a Vac Jet hand peen machine with 4 mm balls and formed back by the same method to the original shape (figure 2). The peening conditions were always kept constant (steel shot diameter: 4 mm, peen pressure : 4.6 bar).

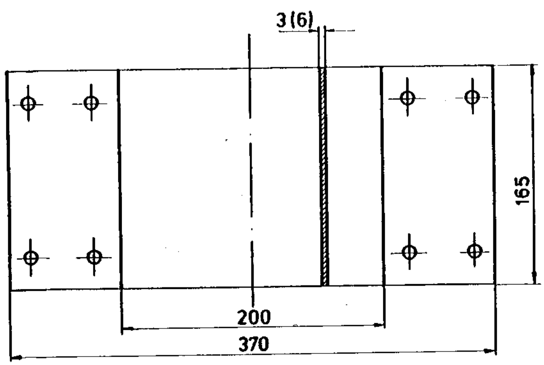

Fig.1: Plate geometry

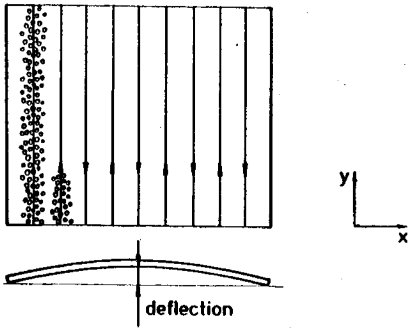

Fig. 2: Manufacture of the specimens

The comparison of the various deflections showed that the dependence on the coverage was almost linear (figure 3). The coverage is defined as the ratio of the surface area deformed by shooting balls to the whole surface area of the plate. In practice several characteristic areas were taken from each plate to determine the coverage. Additionally, one plate was exposed after shot peening by glass bead peening (TMSH) in order to harden the surface.

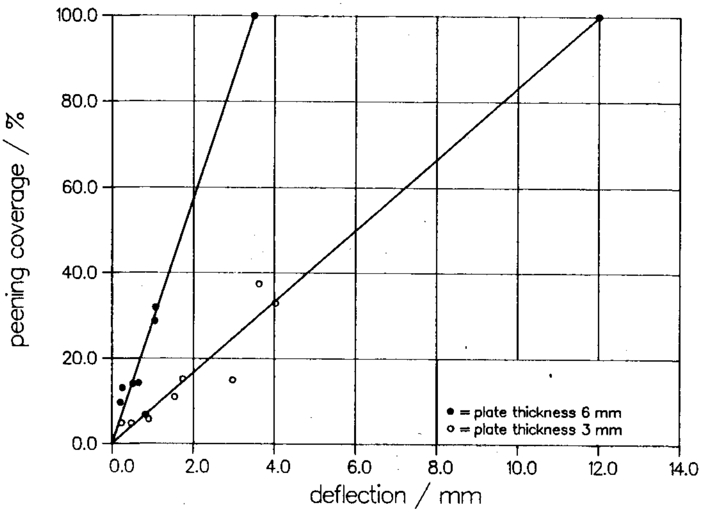

Fig. 3: Coverage in relation to the deflection

First the measurements of residual stresses were performed on all plates. Then the specimens for fatigue testing were removed from the plates.
To determine the residual stresses the bore hole drilling method was applied. This method allows the determination of stresses on the surface down to a depth of 1.6 mm (5). The stresses were examined on both sides of each plate. The fatigue testing was carried out according to HSB 64115-01 (6). The fatigue tests were performed under pulsating tensile stress by means of a resonance pulser.

Results

Residual Stresses

Figure 4 shows the interdependence of the residual stress distribution at increasing degrees of coverage. The results obtained from the shot peened plates were compared with an unpeened specimen. Maximum stress increases from -100 N/mm² to -600 N/mm². In addition to that maximum stress shifts from surface to a distance of 0.5 mm. By the secondary peening with glass beads residual stress maximum moves from 0.4 mm to 0.2 mm below the surface.

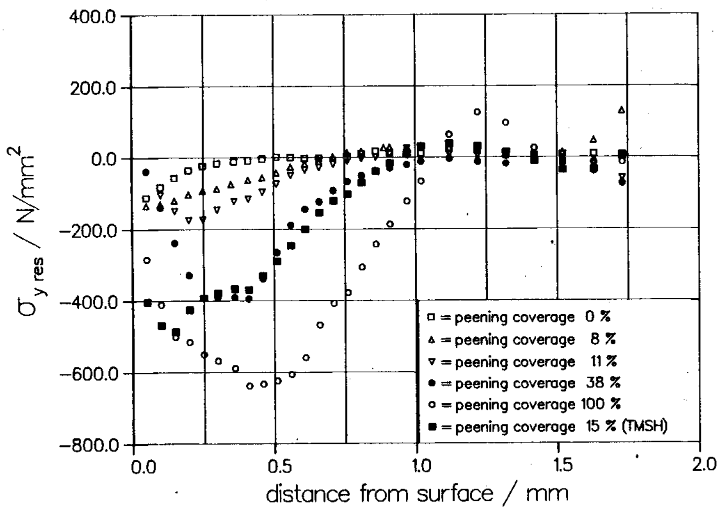

Fig. 4: Residual stress distribution for various coverage

Figure 5 shows the influence of 0% and 100% coverage on the reversely formed surface of a very irregularly peened plate (integral coverage 38%). Stress maximum decreases from -600 N/mm² to -115 N/mm² in areas with no deformation.

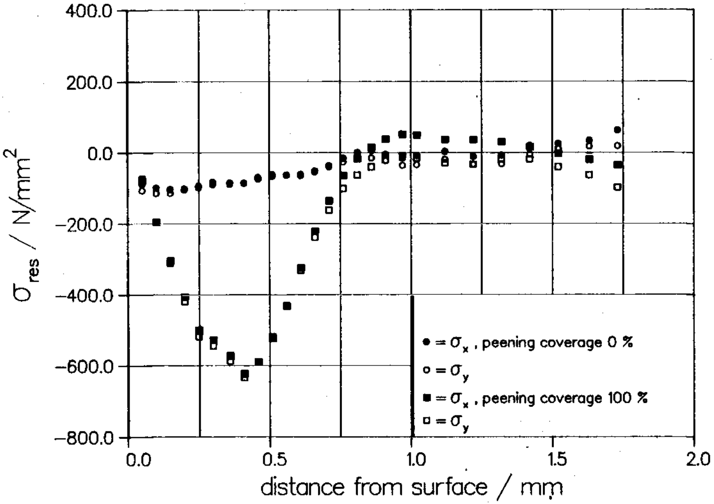

Fig. 5: Residual stress distribution of a nonuniformly peened specimen

Figure 6 contains detailed information on the stress distribution in through thickness direction of a 100% peened specimen. It is obvious that stresses in layers near both surfaces are similar.

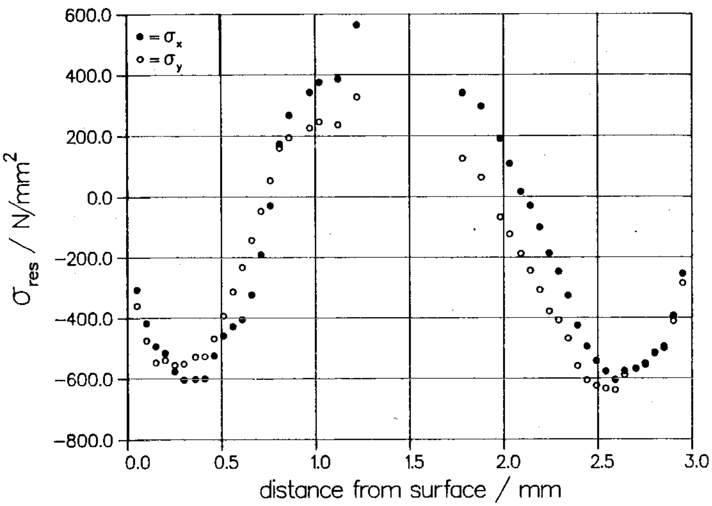

Fig. 6: Residual stress distribution of a 100% peened plate

In Figure 7 the influence of different thickness on residual stress is presented. For nearly the same coverage (approx. 38%) the results do not vary much up to a depth of 1.2 mm. Therefore it can be stated that in near surface layers the residual stresses only depend on the plastic deformation caused by shot peening conditions (2). Moreover the stresses in x- and y-direction have the same value and direction.

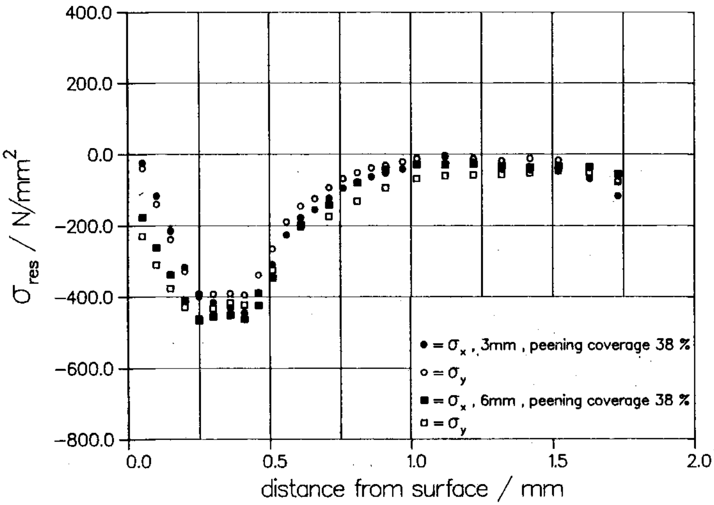

Fig. 7: Residual stress distribution in plates of various thickness

Fatigue Testing

Figure 8 shows the mean value of the number of cycles to fracture determined from fatigue testing of three specimens. The loads for the fatigue tests have been in the range of pulsating tensile stresses. Up to a coverage of 16% the fatigue strength increases noticeably. However, for those specimens peened with 38% coverage the number of cycles to fracture decrease and for a coverage of 100% the number of cycles to fracture is reduced to 50%. The same tendency revealed for a glass bead peened specimen.

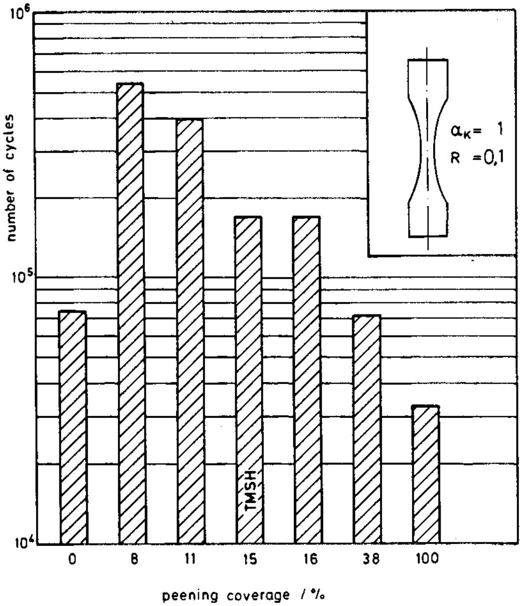

Fig. 8: Results of the fatigue tests

An evaluation of literature published in this field (3,4) gives no indication about this phenomenon. The experience is restricted to surface hardening peening with shot diameters of less than 1 mm and coverages not less than 100%.

Conclusion

On plates treated by shot peening the residual stresses have been determined by the bore hole drilling method. With increasing coverage the residual stresses rise and the stress maximum shifts deeper into the specimen interior. Areas with no coverage have also compressive stresses in near surface layers and thus do not favour crack initiation. The fatigue testing led to the result that there is an improvement of the fatigue strength up to a coverage of 16%. At a coverage of 38% a decrease of fatigue strength was found.

References

(1) : R. Kopp, K.-P. Hornauer: 1. ICSP, Paris (1981)
(2) : Al - Hassani: 1. ICSP, Paris (1981)
(3) : T. Hirsch: Dissertation Universität Karlsruhe (1981)
(4) : W. Calles: Dissertation RWTH Aachen (1986)
(5) : H. Häussler, G. König und H. Kockelmann: ICRS, Garmisch-Partenk. (1986)
(6) : Handbuch Strukturberechnung, Hrsg.:IASB Industrieausschuß Strukturberechnungsunterlagen Ausgabe E (1983)