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RESIDUAL STRESS DISTRIBUTION UNDER THE SURFACE OF A SHOOT BLASTED PUSHER AXLE COMPONENT

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1 INTRODUCTION

1.1 Residual stress

All solid products contain some residual stress. This is the same entity of the solid phase like the dimensional stability. Residual stress can be caused by plastic cold forming, heat treatment, phase transformation and every process, which result a temperature gradient in the bulk material.[1,2] Residual stress can be harmful in that case when the sign of the residual stress matches the sign of the potential strain, because in this case the residual stress is superimposed to the external load. Otherwise this is advantageous if the residual stress is opposing the unsafe load, (by the superposition principle).

Most failures of machine parts are brought about tensile stress. Therefore engineering aspires to create a compressive residual stress in the dangerous cross section, usually being the surface layer. Compressive residual stress near the surface significantly improves the fatigue properties. This is the most important reason which made the designed compressive residual stress widely spread and used.

1.2 Inducing compressive residual stress

There are several methods used in the industry to induce direct compressive residual stress in the surface region of the machine parts to increase the fatigue resistance [3]. Methods which produce residual stress on the surface are called surface-compressing methods, such as shot peening, burnishing, rolling and laser shock peening. The distribution of the residual stress induced by these methods depend on many parameters. One of the most important of them is the type of the material. To obtain residual stress in the surface of an alloy with low strength is more difficult. In this case the maximum available induced residual compressive stress is smaller (its absolute value). Moreover, this stress relaxes more easily during the application [4].

Using different surface compression technologies the distributions of the compressive stress under the treated surface can be widely modified with the parameters of the technologies. For example the velocity, the size, the hardness of the balls used for shot peening, or the applied force, or tool geometry during burnishing [5,6].

1.3 Measurement of compressive residual stress

Different procedures were developed to measure the residual stress such as the Almen test, hole drilling, ultrasonic or magnetic methods, Raman spectroscopy or Barkhausen noise methods [7]. Unfortunately, only a few of them give a sufficient deviation and reproducibility while giving qualitative and quantitative results. The Almen strip has been used for more than 60 years in the industrial

quality control but quantitative results can be obtained only by the diffraction methods. Disadvantages of the X-ray diffraction methods include the limited sample size and the long measuring time. It is probably the reason that only limited examples can be found about the measurement of the residual stress by X-ray diffraction in the industry (large number of samples and short cycle length). [9]

1.4 Theoretical setup of X-Ray diffraction

Lattice spacing in crystalline materials can be determined by X-ray diffraction analysis. The fundamental equation of X-ray diffraction analysis is Bragg's law, which describes the interrelation between the interplanar distance d , the incident angle θ (angle between the incident beam and the diffracting lattice plane), the wave length λ of the X-ray used and the order number n of the diffraction.

$$n\lambda = 2d\sin\theta \quad (1)$$

If stress is present, this interplanar distance becomes larger (tensile stress) or smaller (compressive stress). Assuming linear elastic distortions, the related normal stresses can be calculated [8].

$$\sigma = \frac{d_\psi - d_0}{d_0} * \frac{E}{(1 + \nu)\sin^2 \psi} \quad (2)$$

Where d_0 and d_ψ are the interplanar distances of unstrained and the strained material (in the tilted position defined by the angle ψ) respectively. E (elastic modulus) and ν (Poisson number) are the elastic parameters of the material.

2. EXPERIMENTAL

2.1 Material

The shoot blasted samples of pusher axle component were made of quenchable 30MnB5 alloy according to the EN 10083-3 standard and subsequent shot peening was performed with the same peening parameters. The initial state of the samples were different (before shoot blasting), listed below:

Raba 1: hardened (840°C, coolant 10% polymer), tempered (510°C), the surface decarbonized layer was removed by chemical etching,

Raba 2 three times hardened (see above), tempered -this causes a wide decarbonized surface layer,

Raba 3 ordinary hardened (see above), tempered.

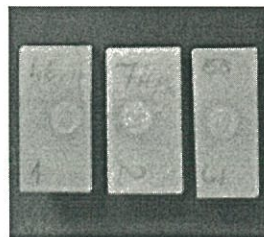


Fig. 1, The investigated samples

2.2 Measurements

The residual stress distribution measurements were carried out with a Bruker D8 Advance X-ray diffractometer equipped with Eulerian cradle and MonoCap primary beam optic. Co K α radiation was used to measure the stress values at the surface layers of the samples. The Eulerian cradle provides the necessary movements (tilting) of the sample holder, while the MonoCap is suitable for the selective area measurements. The diffractometer fulfils the qualification and verification requirements of the European standards (ASTM E915-96, CEN/TC 138.[10])

The residual stress data were calculated from the θ shift of the reflection of {211} miller indexed plane series using Diffra^{plus} Stress (Stress and Edstress) software package. The 2Θ scan interval was 97,5°-102° with $\Delta 2\Theta=0,05^\circ$ steps and collecting time of 20 sec. The Bragg position was measured at the $\psi = 0^\circ; 10^\circ; 20^\circ; 30^\circ; 40^\circ$ tilting positions. To improve the accuracy of the background subtraction, smoothing, K α 2 correction, absorption correction, Lorentz and polarisation corrections were performed

2.3 Electrolytical etching

Nowadays some industrial participants treated the residual stress state of a product as a compliance criterion just like hardness or tensile strength. It can be required from the suppliers to guarantee the given rate of residual stress under the surface at a certain depth in their products.

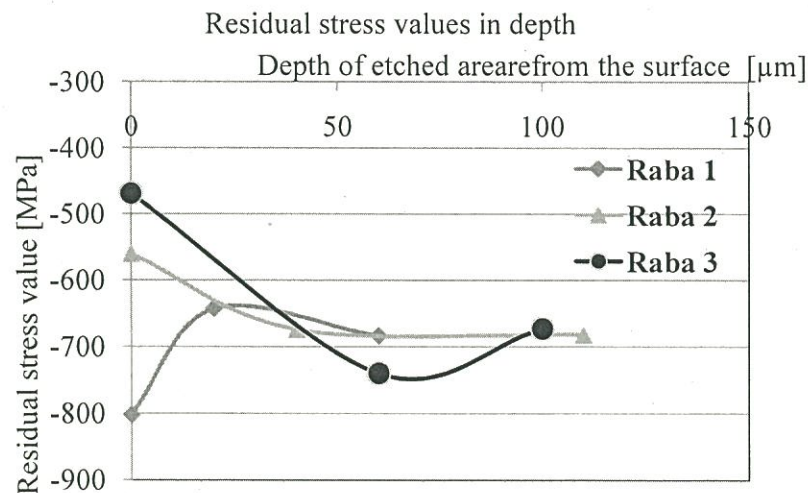


Fig. 2 Residual stress values in depth

For this reason the identification of the residual stress dispersion under the surface of the samples was attempted. During my work it was necessary to remove the surface layer from the target area. A Struers LectroPol-5 type microprocessor controlled electrolyte polishing and etching apparatus was used for this purpose. The surface layers were removed from a 0,5 cm² round (Fig. 1), in multi steps and the residual stress was measured in each depth. The electrolytic deposition was

carried out meanwhile the samples were anod connected and the voltage was 60 V, for 60 second while the average amperage was 2.5 A. The parameters of the electrolytic deposition were permanent during the whole investigation.

The depth of the etched surfaces were scanned with a laser odometer.

3. RESULTS

The results were represented in a depth-stress graph (Fig. 2). It is convinced that clear relationship exists between the heat treated state of the work piece and the residual stress holding ability. It was also observed that the heat treated state influences the flow of the electrolytic depositions. The decarbonized samples (**Raba 2, Raba 3**) hold smaller compressive residual stress, but around 50 μm depth the residual stress values meet and stick together.

4. SUMMARY

The repeated or corrective heat treatment impact the successfully of a subsequent process.

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