THE ORIGIN AND THE INFLUENCE OF THE RESIDUAL STRESSES THE MECHANICAL PROPERTIES OF THE MATERIALS

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INTRODUCTION

Many defects of the resistant structure of the machine's parts during working, as well as when is stopped are not due to the tensions resulting from the applied charge, but to the residual stresses already existent.

Residual stresses are definite as the stresses existing into a corps that is not exposed to exterior pressings. For many years we have only taken into consideration the negative effect of the residual stresses in different engineering constructions. Theses were responsible of the big distortions that appeared after the making process of the fragile breakouts or of the creak that would lead to their destruction. Yet, after a while, it was proved the good effect of the residual stresses in the case of the fretage tubes, pieces that are exposed to periodical variable works.

Many experimental records showed the important effect of the residual stresses on the reliability and the lifetime of the machines. This shows why we need to know the origins and the effect of these stresses.

1. GENERATING AND THE APPEARANCE OF THE RESIDUAL STRESSES

For explaining the making of the residual stresses, Middleton used the comparison of the spring plate bending loaded - figure1.

The stresses resulting from elastic field of loading (figure 1a) are balanced disappear after removing of the bending moment / load (figure 1b). Then the in the other direction, so that the bending stresses on its surfaces exceed the yield stress of the material (figure 1c)l.

After the bending moment removing the material that was plastically deformed tends to remain plat on the superior surface and compressed on its inferior part. Due to its elastic properties of materials we can observe how the material tends to came to its initial length. On the superior part of the spring plate, the material with elastic behavior layers compresses the plastic ones that are generating stretching stresses in the elastic layers (figure 1d).

There is the same for the inferior layers of the spring plate, in the plastic area loaded at the compression, the residual stresses appeared are stretching stresses, as in the elastic field residual stresses are those of compression.

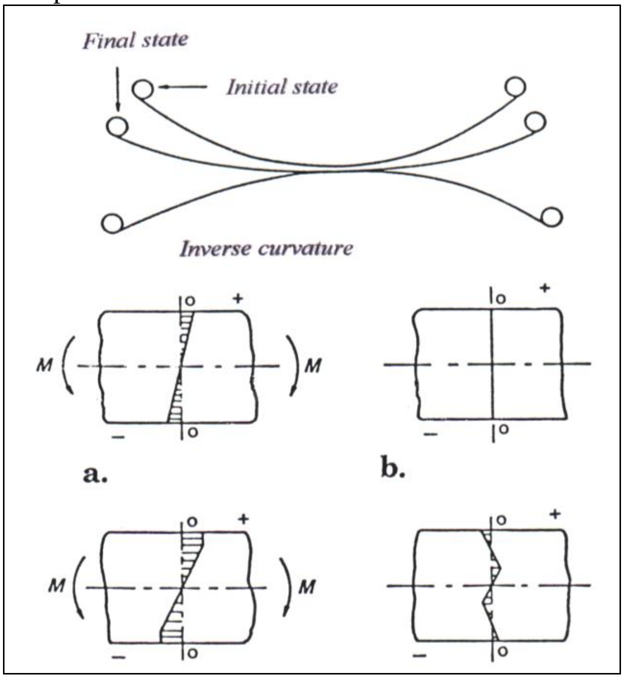

Figure 1. Bending of the spring plate.

The appearance of the residual stresses is due to the fact that the material is not coming in the initial position. It is exposed to a permanent set of deformations that verifies the compatibility equation of the solid deforming corps. The residual stresses appear as a consequent of the deforming process, will be self-equilibrated, resulting a system of forces inequilibrans.

For different working process you can se the origins of the residual stresses in table 1 (after [2]): mechanical, thermic or structural. You can se that for generating the residual stresses there can be one, two or three ways.

Using a single process of mechanical output: the rectification of a piece, J. F. Flavenot and N. Skalli [3], show the way of generating

Table 1 The origin of residual stresses

Origin / Procedure	Mechanic	Thermic	Structural
FORGING THROTTLING SAND-BLASTING ROLLING LASER SHOCK BENDING RECTIFYING SPINNING	*Nonhomogenous plastically deformation between the middle and the surface of the piece*	*No*	*No*
TURNING MILLING DRILLING REAMING GRINDING	*Plastically deformation due to splinter remouvement*	*Temperature gradient due to processing heat*	*Processing phase transformations, if the temperature is sufficiently high*
BLAST COOLING WITHOUT PHASE TRANSFORMATION	*No*	*Temperature gradient*	*No*
SURFACE HARDENING WITH PHASE TRANSFORMATION (INDUCTION, LASER, PLASMA, CLASSIC METHODS)	*No*	*Temperature gradient*	*Volume changes due to phase transformations*
CASE-HARDENING NITROGEN HARDENING	*No*	*Thermal incompatibility*	*New chemical element with volume variation*
WELDING	*Flange joining*	*Temperature gradient*	*Structural changes (ZAT)*
BRAZIER	*Mechanical incompatibility*	*Thermal incompatibility*	*New interface phases*
ELECTROLYTIC DEPOSIT	*Mechanical incompatibility*	*Thermal incompatibility*	*Low down composition, by baths nature*
CASTING	*No*	*Temperature gradient during cooling*	*Phase change*
HOT DEPOSIT WITH PLASMA SPRAY, LASER	*Micro cracking mechanical incompatibility*	*Thermal incompatibility, temperature gradient*	*Low down phase change*
PVD, CVD	*Mechanical incompatibility*	*Thermal incompatibility*	*Phase change*
COMPOSITES	*Mechanical incompatibility*	*Thermal incompatibility*	*No*

residual stresses in the case of the three causes interfering. At the rectifying of the steel appear simultaneous three mechanisms of residual stresses forming, but with different influences conditioning by applied rectification modalities.

1. Plastic and heterogeneous deformation in the superficial splinting layers due to the removal of the material (a consequence of the rectification process). The mechanism of the residual stresses (usually the compressed ones) and their variation with the thickness for the case of low depth splinting the correction and intense lubrication of a piece without orifices is shown in - figure 2.

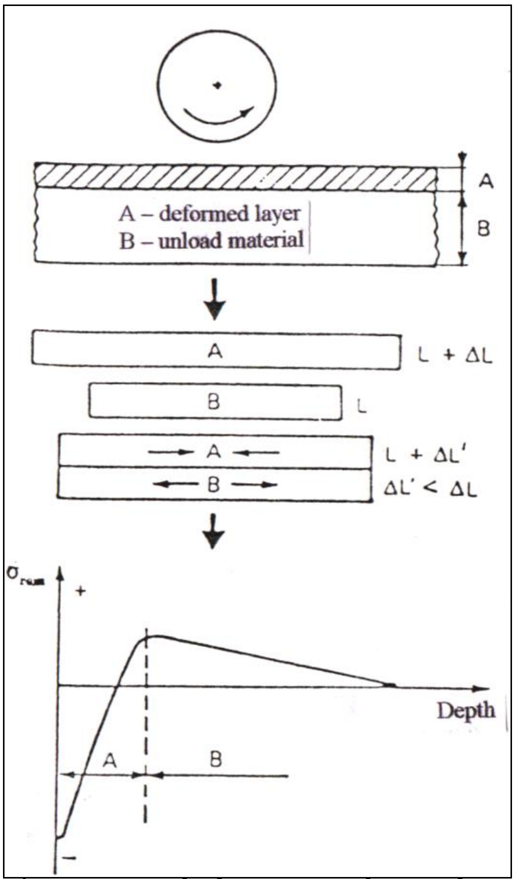

Figure 2. Residual stresses at the rectification with low depth splinting

2. The temperature gradient due to the heating up process during processing. In the case of an intense correction (high splitting depth, without cooling process) the superficial layer is exposed to a thermic gradient. The increased of temperature leads to a heterogeneous dilatation of the material and to a change in its mechanical features. If the thermal dilatations surpass the elasticity limits, then the dilatated layer undergoes a heterogeneous plastic deformation of compression, but stresses that appeared after the material has reached the initial temperature are stretching stresses - figure 3.

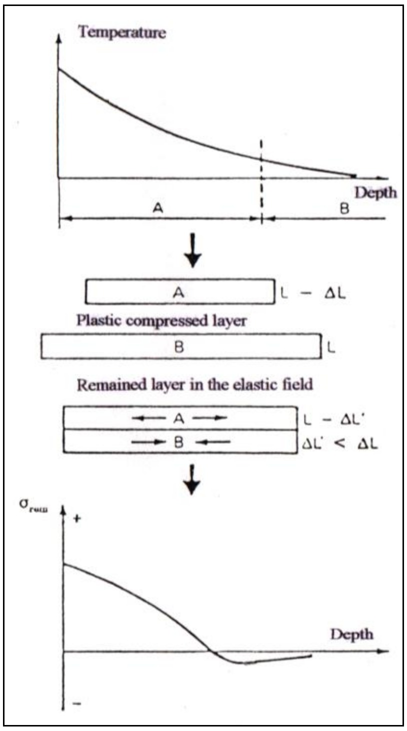

Figure 3. Residual stresses at the rectification with low big splinting

3. The changes of structural phase/ metallurgic during processing if the temperature sufficiently increased. During the correction at high splitting depth, the temperature of the superficial A layer can surpass the transforming A_3 temperature of the steel and the superficial layer became austenitic - figure 4.

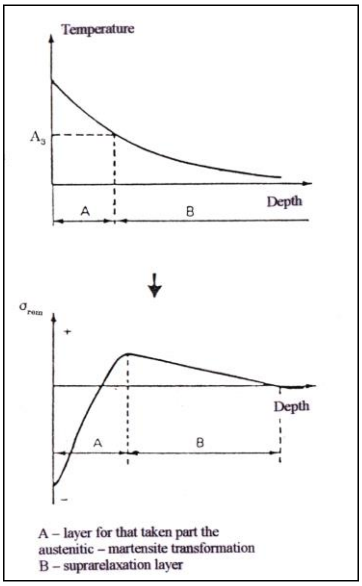

Figure 4. Residual stresses at the rectification with low big splinting (austenitic layer)

At a suddenly cooling process appears an increasing of volume as a consequence of the austenite transformation into martensite, the stresses that appear are those of compression. The temperature of B layer surpasses the returning steel's one. The extra recording is generally accompanied by metallurgical changes that leads to reduce of volume, attenuates the stretching effects and that will have residual stretching stresses.

2. THE INFLUENCE OF THE RESIDUAL STRESSES THE MATERIAL'S FEATURES

By their size and sign, the residual stresses differently influence the mechanical features of the material:

a. *Tension strength*. The material tension strength is influenced by the size and the sign of the residual stresses, especially in the case of the composite material made structure or when the thickness of the tensioned layers is superior when compared with the piece's thickness.

b. *Dimensional stability*. As a consequence of a series of mechanical processing operations, of the relaxing of residual stresses resulting from thermal treatments or of welding, it can appear dimensional changes of the pieces.

c. *The reaction at abrasion and wear out*. The effect of residual stresses on the abrasion and wear out features of the material was a little studied. The effect was fitted into a global parameter that is a result of the adherent lay down of a anti wear layer.

d. *The lay down adherence*. The material's covering have as purpose the improve of the basically resistance at corrosion and wear out as well as creating a thermal barrier for high temperatures. At the lay down part and the basically material appear residual stresses: grain scale micro stresses (generated during cooling process) and macro stresses created by cooling as well as by the thermal difference between the basic material, cover and exterior surface. The different construction of this layers leads to the appearance of the residual stresses in the two layers as well as at their interface. The residual tension stresses leads to the diminution of the laying down process, while those of compression have as a consequence the growth of the process. A diminution of residual stresses (by thermic treatments) leads to the improvement of the lay down adherence.

e. *The under tension corrosion*. The under tension corrosion is a chemical and mechanical phenomena of cracking that can lead to breakouts under the combined effect of the stretching stresses and the corrosive environment. The introduction of residual compression stresses leads to the increases of the functional time of the parts exposed to under tension corrosion.

f. *The fatigue behavior*. The residual stresses can be considerate as the overlapping of a medium tension or a static one and cyclical stresses. When the medium stresses increases the capability of fatigue resistance at decreases. The residual stresses stretching stresses together with the applied stress (even for small charges) reduces the fragile breakouts by cleavage. In the case of low temperature exposure of the steel, this reducing_propagates easily in the near by grains area, leading to suddenly breakout.

3. CONCLUSION

For knowing the level of residual stresses in different engineering constructions, in many levels of fabrication we must know its creation, its appearance, its influence and its evaluation. For this we can favorable conduct the material mechanical features in the making of resistant, reliable and low costs construction.

For example, pretension blast is a procedure that amplifies the fatigue resistance and corrosion of piece, inducing residual stresses of compression in the superficial layer of the material. The procedure consists of high speeded projection towards the piece in severely controlled conditions of small balls (0,2mm up to 2,0mm diameter) made by steel, cast, iron, glass or ceramics upon piece. In the case of welding more than one layer by using high plasticity electrodes we recommend that after every layer is applied knocking detention so that a part of induced residual stresses can be removed.

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