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RESIDUAL STRESSES – QUALITY CONDITION OF THE PIECES

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ABSTRACT
The paper analyzes the residual stresses influence upon the mechanical properties of materials from which the parts are made. They are presented some types of removing non-useful effects of residual stresses upon the parts quality.

1. INTRODUCTION

Many defects of the strength structures or of the machines components both functioning and staying time result not from the stresses given by the applied loads, but from the residual stresses within them.

The residual stresses are the stresses that appear within the part without subjected external loads. Them presence create a state of equilibrium towards the generated system of forces. This deformation can be globally or locally one, depending on the kind of mechanical action. Some physics phenomena (toughness, ultrasounds, magnetic properties etc.), depend of the existing values of the residual stresses.

The first discovering related to the internal residual stresses (improper defined, because is not made any distinction between the produced stresses by the external loads and the existing stresses in them absence), was made by Heyn [2] he shows the differences between the internal stresses and hidden elastic stresses. From internal stresses, Heyn understood those stresses that produce dimensional modifying in the pieces, after removing a part of the pieces. From hidden elastic stresses, Heyn understood the stresses that occur only after pieces loaded in the elastic field and that produce modifying of them dimensions after removing a part of the pieces.

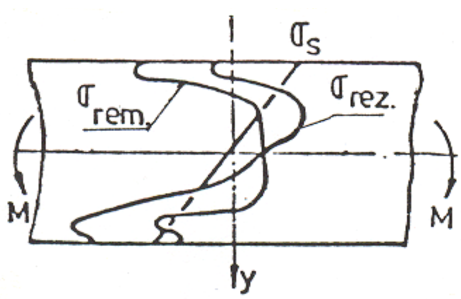


FIGURE 1. SUPERPOSITION OF THE RESIDUAL STRESSES WITH WORK STRESSES

Theoretical, the residual stresses can have values over fracture limit stress of the material, but because of the plastic deformations of the material, these have values less than elastic stress limit. In the case of the brittle materials, those values can exceed the fracture limit; those can conduct to the rupture of the materials. In many cases, even if the level of the stresses resulted by external loads, occurs the crack or though the destroying of the construction. That is happened because of the stresses produced by applied loads

σ_s, are overlay on the residual stresses σ_{rem}, existing in the piece during manufacturing process, resulting a final stress σ_{rez}, figure 1- according relation (1).

$$\sigma_{rez} = \sigma_{rem} + \sigma_s \qquad (1)$$

The resulted state of the stresses, represent a decision factor for the fatigue behaviour of the pieces. The origin, the nature, the level, and the sign of the residual stresses that occur in the solid parts influence this phenomenon [3].
Many times, is considered only negative effect of the presence of the residual stresses in engineering constructions, they occur after large deformations during manufacturing process, or appearing some cracks that can conduct to the failure of them. Afterwards, was observed the advantageous effect of the existing of the residual stresses (compression) in the pieces, stresses that increase them resistance after using (shafts subjected to variable loads, fretage tubes etc.). In some assembles are observed that in the region with compression residual stresses, the crack fatigue velocity decreases, so that the residual stresses effect can be insignificant considering. By blowing with shots, the compression residual stresses have a favourable effect upon the fatigue stresses, while the tensile stresses decrease the resistance.
By removing or decreasing the residual stresses, generally can invoke the relaxing processes: by natural aging process (relaxing for long time of the residual stresses), thermal treats of relaxing, vibration relaxing. The stage of relaxation is influenced by relaxing used process, by the piece complexity, by the respecting of the characteristic parameter of each process.
The numerous experimental data, give the important effect of the residual stresses upon the reliability and the time life of machines, which conduct to the necessity of the knowing the producing process of them, and the processes of the removal of the undesirable effect upon the pieces quality.

2. THE RESIDUAL STRESSES CLASSIFICATION

An important contribution in the residual stresses research area was made by Massing, which proposes a first classification since 1925. Later, the other researchers propose another 20 classifications.
A schematic representation of the residual stresses and of the appearing causes of them is shown in the figure 2.

3. 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 structure composite material made 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 ou*t. The effect of residual stresses on the property abrasion and wear out features of the material was a little studied and the effect was fitted into a global parameter that is a represented of the adherent lay down of anti wear layer.

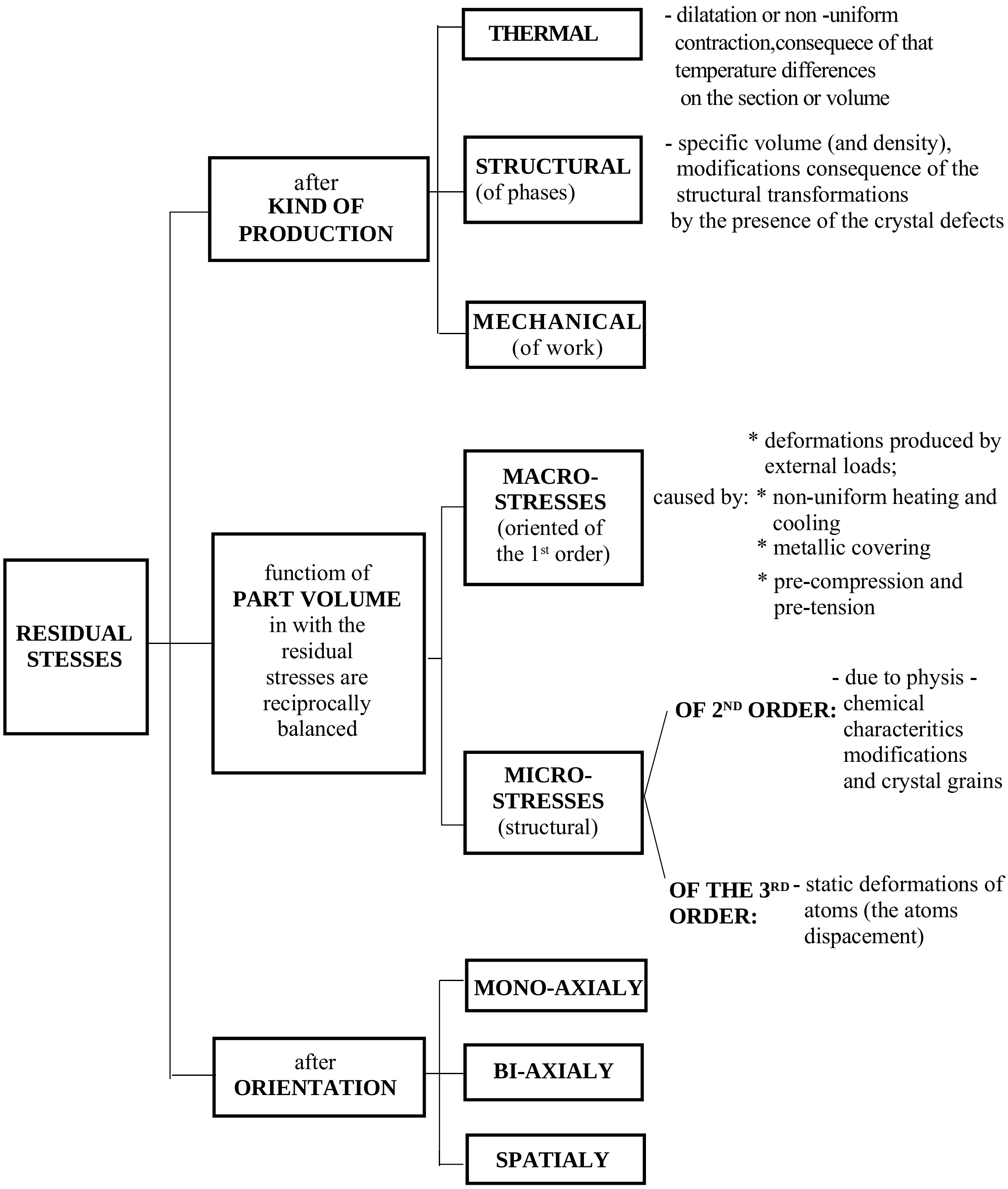


FIGURE 2. THE RESIDUAL STRESSES CLASSIFICATION

d. *The lay down adherence*. The material's covering have as purpose the improve of the 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 thermal 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 behaviour*. The residual stresses can be considerate as the overlapping of a medium tension or static one and cyclical stresses. When the medium stresses increase 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.

4. RELAXATION PROCESSES

As is known, the parts of machines relaxation have to be reduce the residual stresses induced by the last manufacturing (mechanical manufacturing, casting, welding, etc.). This decreasing is realized by modifying the field of the residual stresses, or by the thermal relaxation treatment, or inducing of a field of compression residual stresses (by locally thermal treatments, vibrations, applying static or variable loading, shot blasting, beat off and rolling). These treats decrease the tensile residual stresses values.

Thermal treatment of relaxation

The relaxation technique consist in heating of piece at the temperature 500-620 ^{0}C, and maintenance it at that temperature (two minute for each mm), after that is necessary to cool it with low velocity less than 220 ^{0}C/ h. By applying the relaxation thermal treatment for the welded sample (from steel, with the heating temperature 580-620 ^{0}C), S.J. Maddox [7] indicated a level of the residual stresses on 60 N/mm^2. K. Horikawa and his collaborators [5] was experimentally studied the heating temperature value influence on the residual stresses level, for the temperature included in 380-650 ^{0}C. It is observed a progressive decreasing with the increasing of the maintenance temperature. The decreasing of the stresses was more marked for the maintenance temperatures that do not exceed 500 ^{0}C.

The residual stresses decreasing by the locally thermal treatments

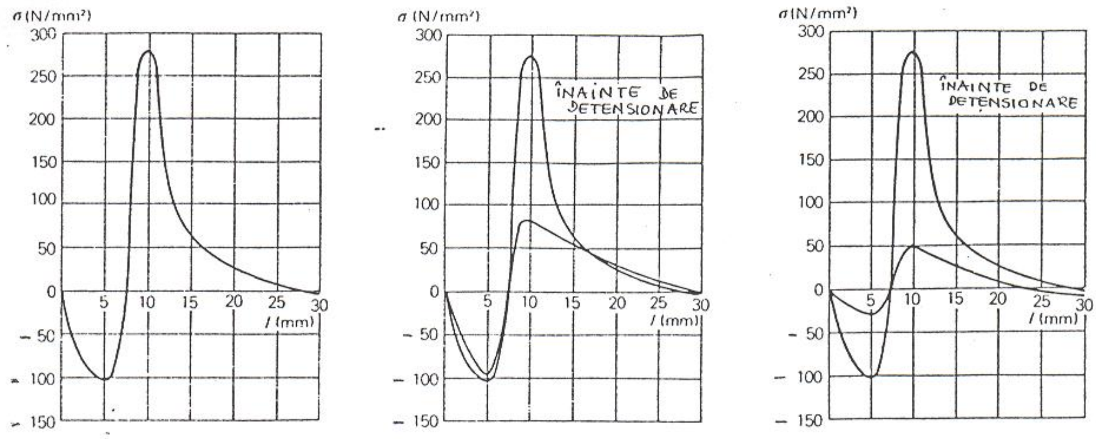
The compression stresses inducing by the locally thermal treatments is realized by the heating of the line welding to the 550 ^{0}C temperature, with the help of the radix heat, followed by the plump cooling with water spray.

The residual stresses reducing by vibrations

The hypothesis, which is used for the explanation of the residual stresses relaxation, is given by T. D. Kelsa [6]. So, the atomic inter-space in disorder can be put in the stabile state with help of the external energy. Therefore, it is produced a modifying of the residual stresses state, the same phenomenon occurs by heat or mechanical vibrations. It is said that the residual stresses amount and the vibration stresses exceed the yield stress, producing a plastic deformation at the same time with the residual stresses relaxation.

G. Gnires [4] proposes a theory related to the fatigue diagram. Under the effect of the residual stresses and the vibration stresses is producing (for an enough number of cycles N_1) a micro-plastic yielding, which under the vibrating effect ducts to the residual stresses relaxation. The bigger vibration amplitude the relaxation is better. It is recommended as the vibrations to stop

at the number of the cycles for avoid the fatigue risk.
The researches made by C. Bouhelier [1], got out seeing that the vibration relaxation (47 Hz frequency equally with the resonance frequency), causes the decreasing of the residual stresses with 70. The relaxation process applying by the thermal treat (for the same type of welding assembly) relieved that the residual stresses reducing by this process is higher than by – figure 3.



a) Initial residual stresses b) Residual stresses before and after vibration relaxation c) Residual stresses before and after thermal treatment relaxation

FIGURE 3. RELAXATION OF THE WELDING ASSEMBLES OF THE TWO-BAND STEEL

Supra-variable loadings and static
The experimental tests made by S. Berge and A.I. Edie [8] on some welded crosswise steel pieces (with yield point σ_c = 300 N/mm^2) pursue to determine the supra-cycling loadings on the residual stresses field. As a results of the pieces loading at $10^3...10^4$ pulse cycles of the constant amplitude ($\Delta\sigma = \sigma_{max}$ = 150 N/mm^2), was observed a decreasing of the residual stresses with over 50%. By the amplitude modifying, the residual stresses was removed when the tops of the stresses hit the yield point.

Sandblasting of pre-tensioning (cloudburst treatment)
Sandblasting of pre-tensioning is the process that increases the fatigue strength and the corrosion resistance, by inducing the compression residual stresses within the superficial layers of the material. This process consists in the blowing with high velocity of some steel balls (cast iron, glass and ceramics) on the line welding. The balls dimensions must be less enough for treating the line welding defects, and bigger enough (0,2-2 mm) for create a cold-hardening which hits 0,75 σ_r, on the deep of 0,1 mm.
By this process was obtained the fatigue resistance increasing of the welded assembles for $2 \cdot 10^6$ cycles with (20-40) % [5].

Hammering
This method was applied to the bottom of the line welding allowing inducing important compression stresses. For avoid the cold hardening it is recommended hammering during sedimentation of the line welding.

5. CONCLUSIONS

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 favourable 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 (0,2 mm up to 2,0 mm 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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