STRUCTURAL ASPECTS OF INNER THREADS MADE BY PLASTIC DEFORMATION

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***Abstract*:** Phenomena that occur during the technological process of inner threading by plastic deformation are multiple (modification of the structure, fibre etc.) and they lead to increase of the qualitative index of parts. Cold plastic deformations are accompanied by elastic deformations of the metal layer; therefore, crystals dislocation and sliding phenomena that occur during processing, by displacements and partial springback of metal, cause a state of residual stresses within the plastic formed layer. The residual stresses are very different and unsymmetrical on the depth of formed layer, but they have the same values and distributions on the part length. Even if the force value can vary within very large limits, the residual stresses keep the same distributions in all cases.

***Keywords*:** inner threads, plastic deformation

1. LAYER MICROGEOMETRY

Phenomena that occur during the technological process of inner threading by plastic deformation are multiple (modification of the structure, fibre etc.) and they lead to increase of the qualitative index of parts.

Threading by plastic deformation is usually performed to a temperature that is smaller than the recrystallization temperature (710 – 720 ^{o}C) and, consequently, all the modifications produced into the structure after threading can be easily recognized due to the plastic deformations [4].

It has to be noted that the structural modifications of the formed metal layer represent one of the most important indexes that influences the physico-mechanical and physico-chemical properties of the processed parts. Also, there are cases when the plastic deformation of the superficial layer leads to destruction of the structural networks into the formed layer, fact that has negative consequences on the quality of the processed parts. This phenomenon is determined by an inadequate working regime material state, tool state etc.

There are differences between the structure of the formed layer and the base metal (Fig. 1); the first one is finer, because by plastic deformation crystals lose their globular form and elongate on the direction of the surface processing. In this way, a surface having a fibre character is obtained, which, in many cases, coincides with the fibre that the parts must have it.

Such thickening and orientation of the crystals are superior to the initial structure, where crystals were irregularly distributed. The orientation of crystals on direction of the part fibre is superior to the deformation and orientation of crystals on transversal direction of the part fibre. This phenomenon has to be taken into account during design and development of technological process.

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The process of thread deformation leads to a bigger concentration of pearlitic grains of steel under the forming pressure. Therefore, a general deformation of the crystal lattice of formed layer occurs, fact that influences directly the part quality [1].

By analyzing in section the formed layer it was observed that the deformation of the crystalline network decreases gradually in depth, and then completely disappear, the initial structure of metal prevailing. Regardless of the way the deformation is performed, the structure modifications occur on longitudinal, transversal and perpendicular direction on the work surface. Therefore, the structural modifications depend greatly on the constitution of material. For instance, in the case of steel with a ferrite-pearlitic structure, the plastic deformation will be bigger for the ferrite grains than for the pearlitic grains.

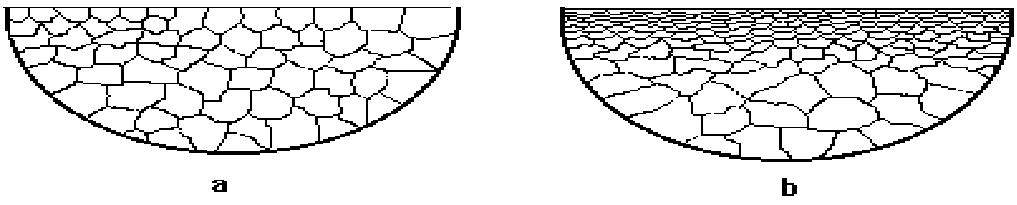

Fig. 1. Crystalline structure of the superficial layer in the case of steel:
a – boring sample; b – rolled sample [1].

2. RESIDUAL STRESSES

Cold plastic deformations are accompanied by elastic deformations of the metal layer; therefore, crystals dislocation and sliding phenomena that occur during processing, by displacements and partial springback of metal, create a state of residual stresses within the plastic formed layer. This state of stresses has a positive influence on the strength of the processed part. However, in the same time, the elastic deformations of the superficial layer influence the dimensional stability of the processed part and the unscrewing moment of the tool. Performed tests emphasized that even the non-ferrous alloys have significant elastic deformations, close to those of steels.

By analyzing the diagrams presented in Figure 2 [3], it can be observed that in the case of a M 12 thread made from laminated steel and an aluminium alloy, the unscrewing moments are fairly high and perceptually closer, (≈50-60%) from the forming moment of thread, due to the presence of the elastic deformation.

Also it can be seen that between the maximum threading moment and the maximum unscrewing moment an angular displacement exists, due to the cumulating of the elastic deformations of the material and to the torsion of the threading tool. The value of this angular displacement is $C_{max}= 15^o$ in the case of aluminium alloy and $C_{max}= 17^o$ in the case of steel.

Due to the plastic and elastic deformations that occur during thread processing, different slides occur into the formed material, simultaneous or successive, depending on the used procedure or method, which determine a state of residual stresses. In the case of splintered threads, these stresses concentrate at the turn of screw base, constituting fracture blasting, both in the case of shearing and especially in the case of fatigue load. On the other hand, in the case of threads made by plastic deformation, these stresses are very important because they improve the physico-mechanical properties of the processed threads.

The superficial metal layer which is compressed by plastic deformation represents, generally, a small volume compared to the part volume. The state of residual stresses which is created as well as the improvement of the roughness and micro-hardness, lead to high qualitative index of the processed surface, fact that has a direct influence on the part quality.

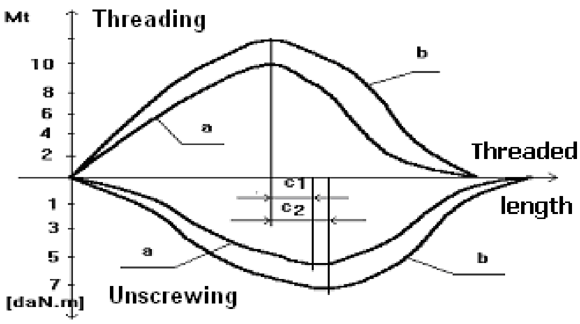

Fig. 2. Threading moment for:
a – AlSi5Cu alloy; b – OL38 steel.

The distribution on depth of the residual stresses that occur during a steel threading process, on the three principal directions, axial (σ_a), tangential (σ_t) and radial (σ_r), can be observed on the Figure 3 [3].

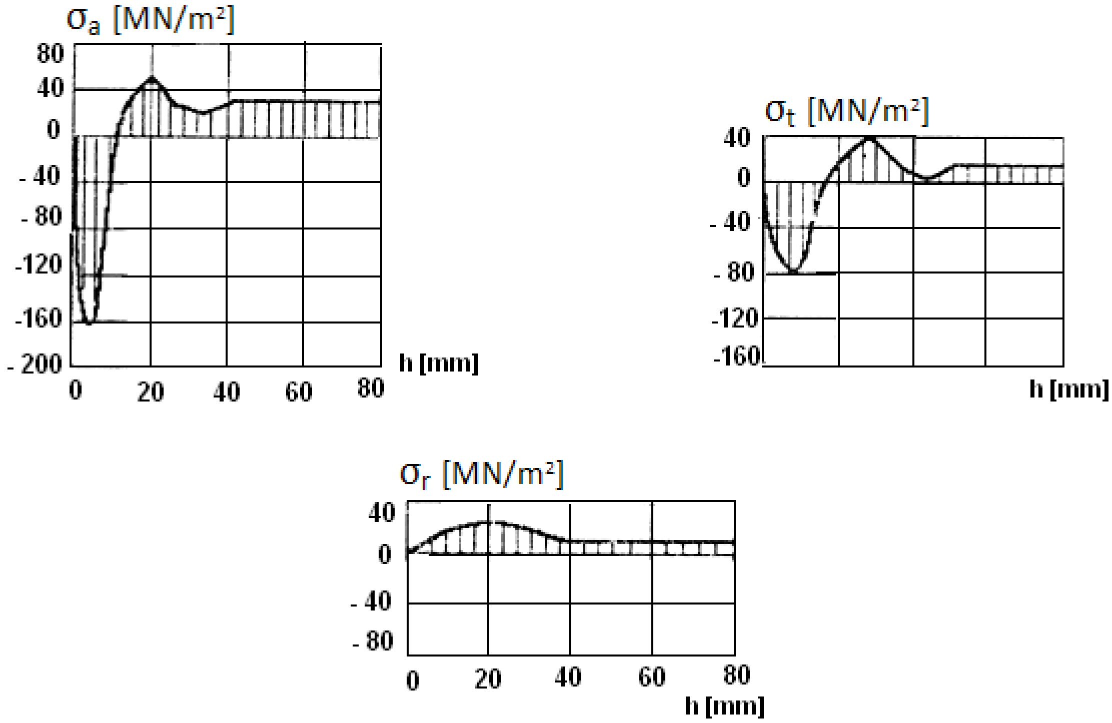

Fig. 3. Distribution on depth of the residual stresses.

3. COLD-HARDENING OF THE SUPERFICIAL LAYER

The cold-hardening phenomenon is close related to the presence of the large residual stresses in the deformed superficial layer. Through cold plastic deformation, the material suffers a cold-hardening phenomenon due to the obstruction of the dislocations displacement on the sliding planes and the setting-up of new dislocations, which determines the intensification of the stresses field.

From the whole energy used for deformation, the largest part is turned into heat, because of the frictions, and only 20-25% is stored in the network, increasing the internal energy of the deformed layer of material [5].

The deformation degree of the crystalline network in the cold-hardened layer and its thickness, mostly depend on the specific average contact pressure, as well as of the characteristics of the material.

Depending on the main purpose for which the rolled threads are made, and its material, different values of the specific average contact pressure are chosen, the action levers for this being the attack angle and the number of screw tap's edges, as well as the number of passing which from the thread is realised, the latest one being typical for threading rolls.

The material layer where the value $\sigma(t) = \sigma_c$ was achieved is situated in the vicinity of a deeper layer, where the deformations are elastic. These elastic deformations will determine a state of residual stresses in the cold-hardened layer, σ_0. After the time t_c and the achievement of a flow state, this state of stresses could be maintained, accentuated or diminished (Fig. 4). After the achievement of the flow limits in the point P (Fig. 5), the stabilization of the cold-hardening phenomena needs an imperturbation time t^*, this being the time between two deformation edge of the tap.

The evolution of stresses according to one of the curves a, b, c (Fig. 4 and Fig. 5) [2] was determined by studying the monotony of the following functions [2]:

$$\sigma(t) = e^{-bt}\left[\frac{A\cdot E\cdot\omega}{b\left(1+\frac{\omega^2}{b^2}\right)} - \frac{\sigma_c\cdot E}{b\cdot\lambda}\right] + \frac{\sigma_c\cdot E}{b\cdot\lambda} + \frac{A\cdot E\cdot\omega}{b\left(1+\frac{\omega^2}{b^2}\right)} \quad (1)$$

$$\sigma(t) = e^{-bt}\left[\sigma_0 - \frac{A\cdot E\cdot\omega}{b\left(1+\frac{\omega^2}{b\cdot\lambda}\right)} - \frac{\sigma_c\cdot E}{b\cdot\lambda}\right] + \frac{\sigma_c\cdot E}{b\cdot\lambda} + \frac{A\cdot E\cdot\omega}{b\left(1+\frac{\omega^2}{b^2}\right)} \quad (2)$$

where: σ – static stress in the rolling process; σ_0 – initial static stress owed to the preview processing; A – lubricate section; ω – tools rotated speed; E – elasticity modulus; b – whirl section; λ – coefficient of dynamic friction.

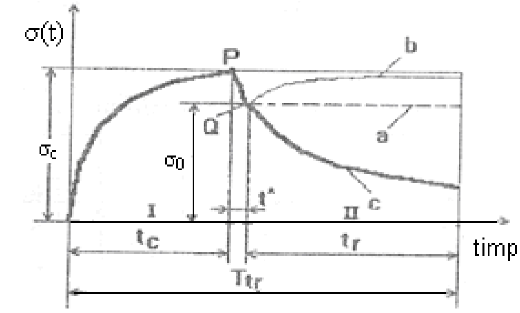

Fig. 4. Evolution of the residual stresses in the case of threading with rolls.

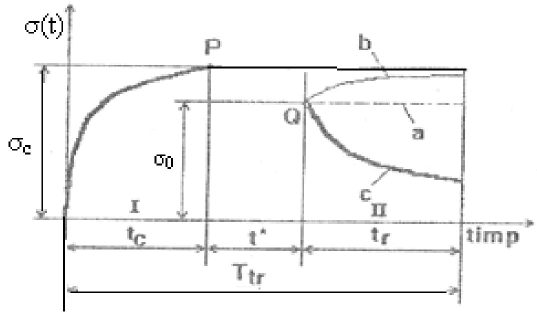

Fig. 5. Evolution of the residual stresses in the case of threading with taps.

4. CONCLUSIONS

The residual stresses are very different and unsymmetrical on the depth of formed metal layer, but they have the same values and distributions on the part length. Even if the force value may vary within very large limits (5000 – 22000 N), the residual stresses keep the same distributions in all cases.

Because the forming speed is direct proportional with the angle of incidence and the tap pitch as well as with the working speed, the residual stresses directly depend on these elements according to the diagrams presented in Figure 6, Figure 7 and Figure 8.

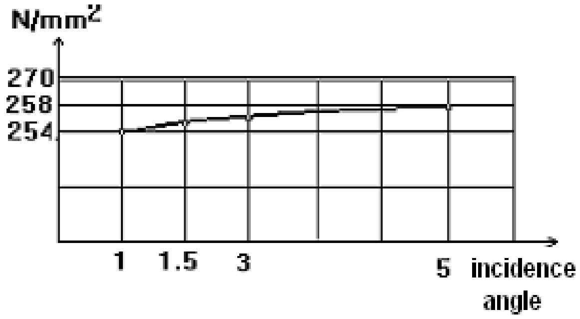

Fig. 6. Variation of the residual stresses with the incidence angle.

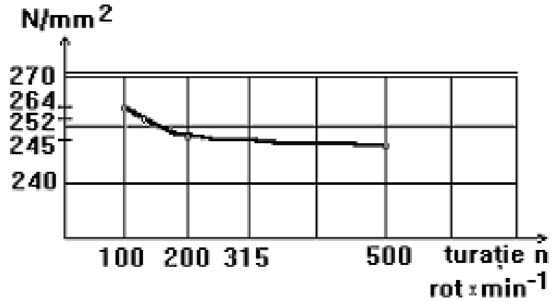

Fig. 7. Variation of the residual stresses with the working speed.

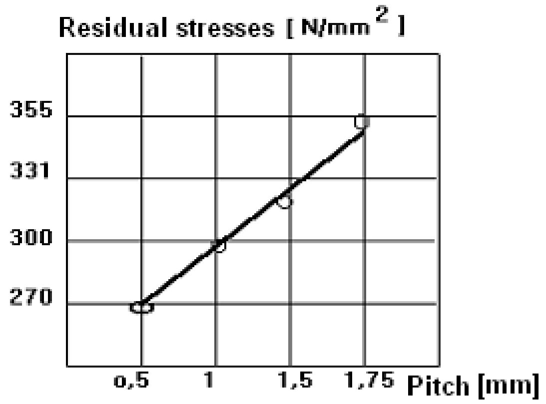

Fig. 8. Variation of the residual stresses with the pitch.

These diagrams were done by the combination of the experimental data with data taken from the spatial diagrams of stresses and deformations (Fig. 9) obtained by using the finite element method.

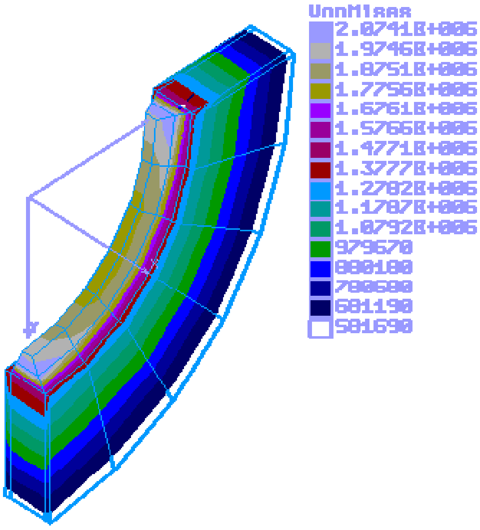

Fig. 9. The state of deformation obtained using the finite element method.

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