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THE VALUE OF THE STRUCUTRAL REMANENCE AND THERMIC TENSIONS IN THE FORGED PIECES

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ABSTRACT

The plastic deformation, the heating and the cooling of the pieces submitted to plastic deformations acumulate remanent tensions inside the pieces.

Knowing the environmental where they are produced and avoiding its superposition in an important problem for a specialist who aims to get through the forging process some pieces dimentionally corresponding and without defects. This works will analyse the value of the structural remanent and thermal tensions in the case of some forged pieces.

KEYWORDS: forged pieces, tensions, cracks

1. Introduction

At the end of the deformation process of the forged pieces, remanent tensions remain, tensions which type and size can be determined especially by suplimentary tensions which operated on the metal at the moment of the end of the deformation. Also, during the cooling process, in the forged piece structural transformations can be produced accompanied by the corresponding tensions. Finally, during the cooling process in the press thermal tensions appear too. Thus, the final stage of the forged press tension is determined by the sum of the above mentioned tensions. Each of the mentioned tensions or their algebraic sum may achieve the resistance tensile strength of the metal and provoke its distruction:

$$\sigma_i > \sigma_r \qquad (1)$$

$$\sum_{i=1}^{n} \sigma_i > \sigma_r \qquad (2)$$

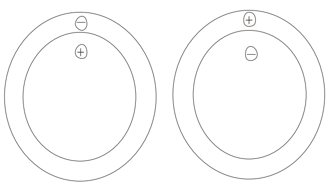

Fig. 1. *The possible diagrams of the tension state of the round forged piece after the ending of the forging process (the remanent tensions of the forging process).*

At the end of the deformation process in the forged pieces, the tension state can correspond to one of the following diagram of figure 1.

These tensions are provoked by the remanent deformation tensions.

The destruction of the metal starts inside the forged piece (in their breaks) or un their surface (superficial cracks).

At the forged pieces, from steels that do not have phase transformation, superficial cracks are possible which may become gradually deeper inside their body. At the pieces forged in a round shape these cracks orientate radially. The characteristics difference consists in the fact that yhey are visible during the cooling process of the forged piece up to 500^0C and are hardly to discover sfter its complete cooling. The cooling cracks after the quenching process start from the surface of the forged piece. They appear under the action of the structural tensions, the most frequently after the complete cooling of the piece.

We will analyse further on the variation of the tension state diagram during the cooling process of a cylindrical forged piece from the moment of the end of the forging process (T_f = 900-1000^0C) till the environmental temperature(T_0 = 20^0C), for both types of tensions described in figure 1, applicate for steels of three types:

a. without phase transformation
b. perlitic transformation
c. martensitic transformation.

The variation of the tension state diagram of a cilyndrical forged piece, having phase transformation is swown in figure 2.

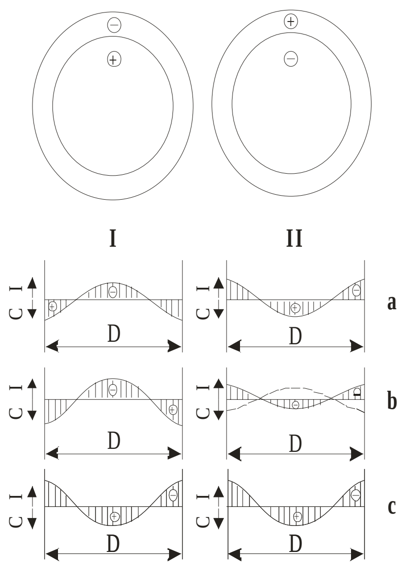

Fig.2. *The variation of the tension state of a cylindrical forged piece made of steel without phase transformations during the cooling process after the forging process with different remanenet tensions of deformation.*

a. the deformation remanenent tensions before cooling;

b. the diagram tensions before of the cooling piece surface up to 200-500^{0}C

c. the diagram of the tensions after complete cooling up to 20^{0}C.

In figure 2 one can notice the variation of the tension state during the cooling process of the forged piece, with remanent tensions of forging, of compression at the external side and elongation in the axial area.

From figure 2 in this case it results that maximum tensions of elongation, superficial can be obtained in case I b, and maximum axial elongations in I c and II c bodies.

In the last case all the other conditions remain equal, the extent of internal elongation tensions gets the maximum value. It results that the formation the interior cracks of cooling in the forged pieces of steel without phase transformations is possible in I c and II c bodies only after complete cooling.

The formation of the superficial cracks is the most probable only in case I b. in the II b case, at a sufficiently intensive cooling of the forged piece, the formation of the elongation superficial tensionsis possible (the dots line figure 2, II,b).

However under identical cooling conditions the value of these elongation tension is always smaller than in case I b.

The variation of the sign and tenisions value during the cooling process from 1000^{0}C to 20^{0}C of two forged pieces regarding the variants I and II from above, can be noticed in figure 3.

On the left side there are the remanent tensions of forging existent inside the piece before the beginning of the cooling process and on the right the final tensions obtained after the complete cooling process.

In conclusion, at both variants, after the complete cooling process, in the internal area of the forged piece, remanent thermal volumetric of elongation tensions are maintained, tensions that usually lead to the formation of internal cracks.

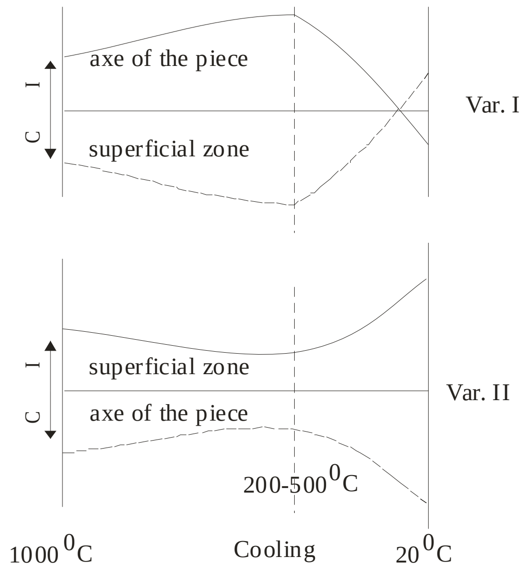

Fig.3. *The curves of the variation of the tension sign in different areas of the forged pieces analysed in figure 2, during the cooling process up to the room temperature.*

At the next heating process for a reheat treating in the axial area of this forged piece, radial internal suplementary tensions of elongation appear, tensions that are added to those thermal of cooling, with the same sign, which operates in the same area. That is why, the formation of the internal crack in the forged piece with volumetric internal remanent elongation is more probable during the heating than the cooling processes.

During the heating of these forged pieces, suplementary measures must be taken to aim at making the difference between the internal and pheripherical temperatures the smallest possible.

During the cooling and heating process in the forged pieces of steel without phase transformations, thermal tensions are appear to which the remanent tensions of forging with a sign or other are added.

The value of these tensions depends on:

a. the maximum difference between the axial area temperature and the superficial one of the forged piece during cooling and heating;

b. the coefficient of linear expansion of the metal.

The biggest the difference of temperatures and the coefficient of linear expansion of the metal which appear. Besides this fact, a significant importance for the possibility of formation of the intenal or external cracks has the reserve of the plasticity of the metal. The smallest the plasticity is, the smallest value of the tensions where cracks may appear is.

During the forged piece made of a steel with phase transformations, besides the thermal tensions, structural tensions appear, because the structural constituents of the steel: austenite, perlite and martensite have an unequal specific volume.

During the transformation of the austenite in martensite, the value of the local volumetric variations is incomparably bigger than the perlitic transformation. The value of the forged pieces tensions which bears a martensite transformation gets values. They often surpass the tensile strength of the hardened steel and produce the destruction of the forged piece.

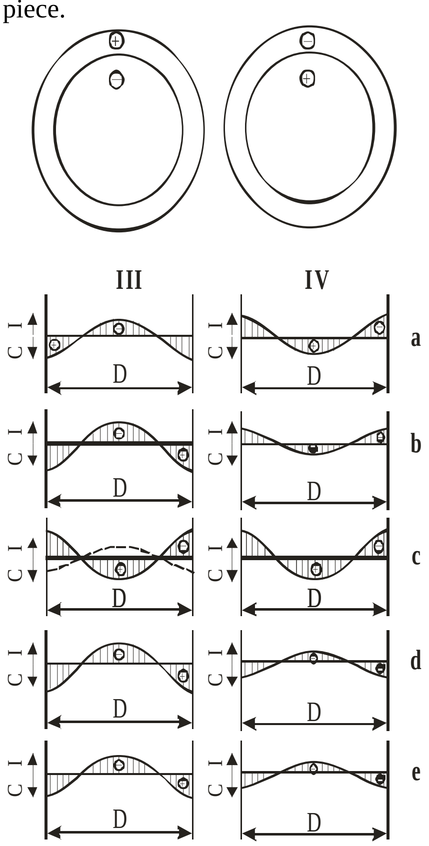

Fig. 4. *The variation of the strengthening state of the round forged piece of steel where a perlite transformation takes place.*

In figure 4 one may see that the round forged pieces made of perlite steel, variation while their cooling process from the forging temperature till that of the ambient temperature at different diagrams of the streighning state before cooling:

a. remanent tensions of deformation before starting the cooling;

b. diagram of the tensions before starting the perlite transformation in the superficial area;

c. diagram of the tensions after the perlite transformation in the superficial area;

d. diagram of the tensions after the perlite transformation in the centre.

e. diagram of the tensions after the complete cooling of the forged piece.

I-elongation; C-compression; S-diameter.

In the same case IV c, the highest internal tensions may be obtained, but into practice, they do not produce the formation of internal cracks. The maximum value of the strengthening superficial tensions may be noticed in cases III b, d,e. however the external cracks can be formed only in case III e.

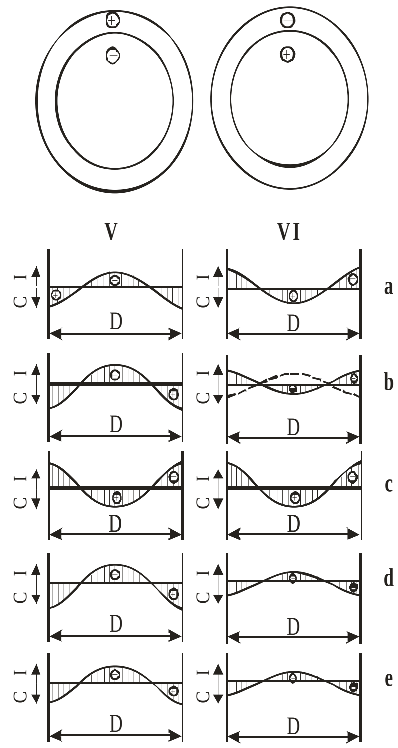

Fig. 5. *The variation of the tension state of the round forged piece made of steel where the martensite transformation takes place.*

In figure 5 the same thing is shown as in figure 4, but for forged pieces, where during the cooling process the austenite transformation in martensite is produced.

a. the remanent tensions of deformation before the begining of the cooling process;

b. diagram of the tensions before starting the martensite transformation in the superficial area;

c. diagram of the tensions after the martensite transformation in the superficial area;

d. diagram of the tensions after the perlite transformation in the centre.

e. diagram of the tensions after the complete cooling of the forged piece.

I-elongation; C-compression; S-diameter.

The principle on the whole developing period of the process of cooling, the tension state of the forged piece do not differ from the state of tension from the previous pieces.

Howver the tension state is here more evident. After the martensite transformationis higher and the hardness and the brittleness of the metal with martensite structure.

These circumstances condition a higher probability of the cracks. Usually, the elongation internal tension which appear in the forged piece at the cooling process after the variants V and VI do not produce internal cracks and inside the cooled forged piece, these tensions are absent practically.

During the cooling process, the elongatin tensions may reach high values in the superficial area of the forged piece, but practically they do not surpass the following limit of the metal because of the remanent formation.

The same tensions in the forged piece which was cooled (andd which has already a martensite structure) reach values that surpass the tensile strength of the metal and produce its breaking.

This type of cracks are usually called hardening cracks. The appearanceof these cracks starts from the surface of the forged piece and is the most probable in "V" and "U" bodies.

Conclusions

The formation of the hardening cracks may be eliminated by avoiding the possibility of developing the martensite transformation, creating conditions for obtaining the perlite transformation of the austenite, if the perlite transformation cannot be obtained, then by creating the martensite transformations conditions simultaneously an the whole section forged piece.

The tension state of the forged piece or the cooled semi-finished product has also a great importance during their following treating process.

At the heating process of the big forged pieces be established taking into account the cooling remanent tensions, in order to avoid the sum of tensions with the some sign.

At the cutting process of the forged piece or of the semi-finished product with circular saw or side milling cutters a gradual tightening of the disk or the side milling cutter takes place. This hapens under the action of the compression remanent tensions from the peripheric area of the forged piece. The more evident the tension state of the forged piece is, the stronger the disk may get stuck, and the cutting of the piece becomes more difficult. At the cutting process with the same saw or side milling cutter of the forged piece which has a diagram of the tension state in accordance with figure 1 b, the width of the cut grows gradually and the possibility that the disk get stuck is excluded.

The practical experiments show that at equal cooling conditions, in the forged pieces made of steel, the martensite of the remanent forging tensions with a sign or another, can accelerate or show down the formation of herdening cracks inside them. An important role regarding the kind and value of the remanent tensions at the forged pieces has the shape of the tools with which the plastic deformation is produced.

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