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CAUSES FOR FLAKES APPEARANCE, PREVENTING WAYS AND REMOVING METHODS[1]

UZROCI POJAVE LJUSPANJA PREVENTIVA I METODE ZA UKLANJANJE

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ABSTRACT

Among the causes that contribute to flakes appearance, a special attention is accorded to tensile strength, which is created during hot plastic deformation and cooling after the deformation. According to this, for flakes appearance prevention is recommended that hot plastic deformation and the cooling after, to be executed on minimal tensile strength. In the case when the flakes appearance couldn't be prevented, these defects may be removed by welding. For flakes welding, the hot plastic deformation is necessary to continue, particularly forging, in condition of maximum weldability of materials discontinuities defects.

Key words: flakes, flakes appearance conditions, forging.

INTRODUCTION

Flakes are discontinuities in materials. They can be found only in some varieties of steel and represent rupture fuses. In most cases, with but few exceptions, research concerning flakes has mainly tried to establish the causes of appearance, without giving much thought to possible means of eliminating them after the have appeared. Among the factors that contribute to the appearance of flakes, special interest has been shown in the chemical composition of steel and its degree of purity, especially in the amount of hydrogen contained, as well as in the thermic tensions which arise during the

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cooling process of finished and semifinished products, after the hot moulding. The same thing cannot be said about the analysis of the way in which tensions that appear during the hot moulding process can influence the product.

EXPERIMENTATION

As an attempt to reduce the weight of rejects caused by flakes, we shall go on to present several considerations regarding the influence of tensions during the hot moulding process on the appearance of flakes, as well as the results of experimental research conducted to eliminate these flaws. It is an established fact that semifinished product forging, as well as the forging of square section pieces, are done according to the diagram in figure no. 1.

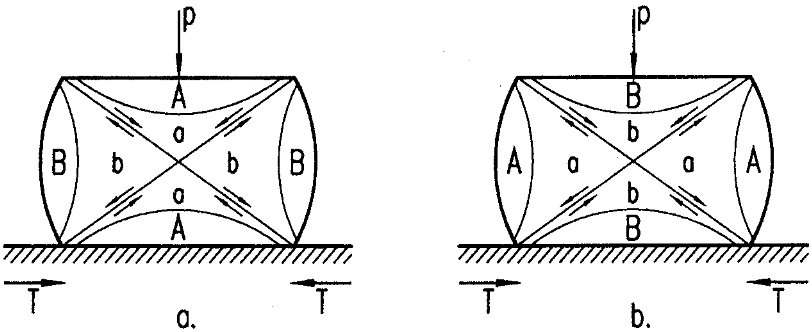


Figure 1 - The material flow at forging, according to the square - rectangle- square schema /7/

Due to exterior friction T that appears between tools and the semifinished product, heavily distorted zones are formed, that is zones A in figure 1a. and zones B in figure 1b. The tension in these zones is marked as S1, and the resistance to plastic deformation is higher than with the rest of the product. Under the influence of pressuring forces P caused by tools, these areas move from the exterior to the interior.

That is why discontinuities caused by stretching tensions during the forging process appear exclusively either on one diagonal, or on both diagonals of the cross section. Similarly, in the case of forge stretching according to the schema mentioned before, flakes appear particularly in the centre and in the neighbourhood of diagonals, that is, the areas where there is a high stretching tension during the plastic deformation process.

Figure 2 presents the aspect and distribution of flakes on cross section, for forged semifinished products.

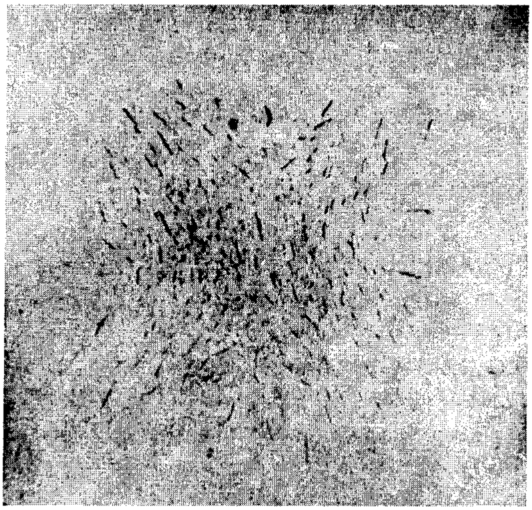


Figure 2 - The distribution of flakes in a forged semifinished product according to the square-rectangle-square schema.

In the case of round semifinished product forging with flat tools, areas ABC and $A^1B^1C^1$ are formed, due to exterior friction between tool and semifinished product. Inside these areas, tension manifests itself as spatial compression (S1), with small differences between extreme tensions $\sigma 1$ and $\sigma 3$.

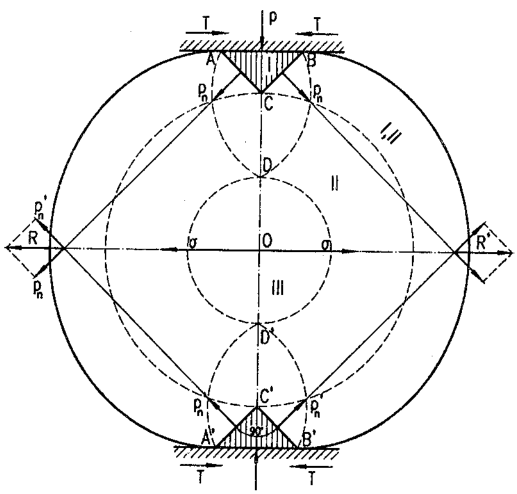


Figure 3 - Plastic deformation zones and forces that arise during the forging of round semifinished products with flat tools

Because of the tension state S1 which is created inside areas ABC and A1B1C1, the resistance to plastic deformation of the material in these areas, which we will further refer to as I, is much bigger than in the rest of the product. Because of the differences in resistance, heavy deformation zones I advance into the semifinished product like split pin and distorts the material by stretching and compression, in areas ABCD and A1B1C1D1, which we will further refer to as II. Flakes are the result of radial stretching tensions in the central area of the semifinished products, as in figure no.4.

The appearance of flakes in the areas where plastic deformation has occured under the influence of stretching tensions and the directing of these flaws towards the material flow direction, especially towards the longitudinal one, fully confirm the hypothesis that among the factors which favour the appearance of flakes there is also the tension state created during heat distortion. Consequently, to prevent the appearance of flakes, heat distortion, particularly forging, has to be done so that stretching tensions are kept at a minimum.

a.- in the polished sample

b.- in rupture

Figure 4 - The aspect and distribution of flakes inside round section semifinished products.

In order to reduce stretching tensions in favour of compression ones when forging square section semifinished products, the stretching process must be done with small widening and big lengthening. Therefore, the advance, expressed as the ratio between the length of the product that is caught between tools (l_0) and its width (b_0) has to be sub-unitary. The smaller this ratio gets, the widening decreases, which means that the opposite slippings in the diagonal plan also decrease, and so do stretching tensions in these areas and the neighbouring areas.

Unlike with square semifinished products, in the case of the forging of round semifinished products zone III is decreased up to zero as the degree of unitary deformation $\in_u$ increases, and the ratio between the value and the weight of tensions is modified in favour of compression tensions, as in figure 5.

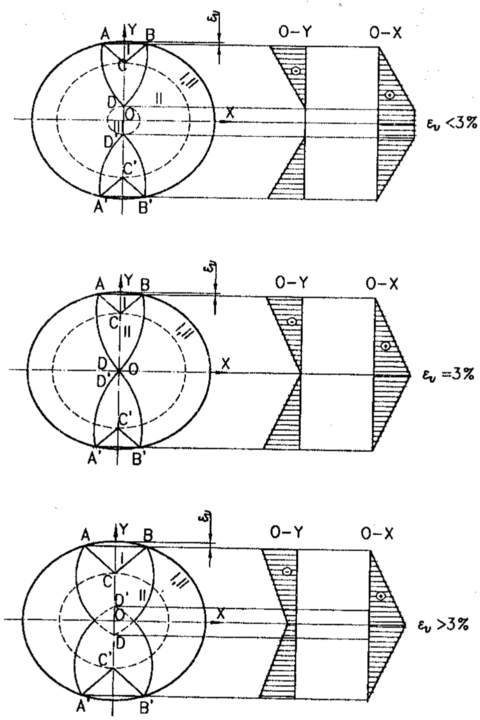


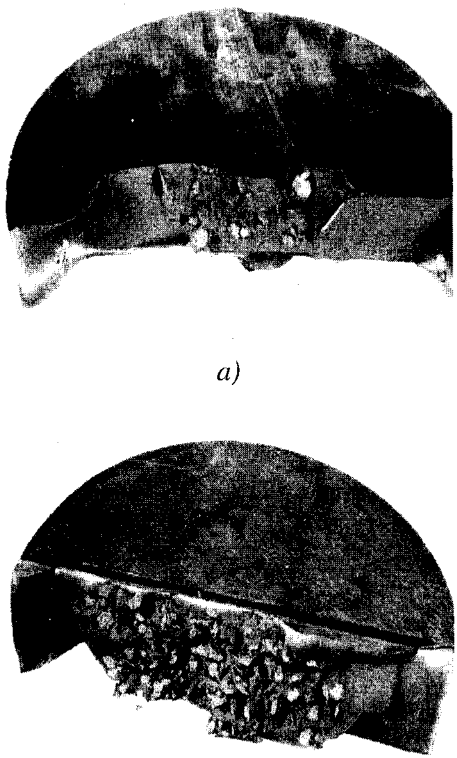
Figure 5 - The weight of plastic deformation areas and of stretching and compression tensions for several values of the unitary deformation degree

In order to establish if flakes can be removed by welding, a 1050 kg steel ingot with a 370 mm diameter, that has the following chemical composition: 0.93% C; 2.06% Mn; 0.22% Si; 0.25% Cr; 0.17% Ni; 0.22% Cu; 0.07% Mo; 0.04% W; 0.08%V; 0.37% Al; 0.01 S and 0.026% P.

It can be seen that this steel, named 90VMn20, is chemically equivalent to W.1.2842. The forging of this ingot was executed with a hydraulic press of 10 MN (1000 tf), under circumstances that favour the appearance of flakes, that is, according to the round - round schema, between flat tools with $\in_u \leq 6.0\%$.

After forging, in the thermic interval of 1100 - 900°C, bars with the diameter d = 170mm were discharged with the chisel at high temperature and lengths of about 1.0 m, and then cooled in air.

Of the forged mellow bars, a 30-35 mm thick rove was done. At the macroscopic control, flakes were found on the polished, Nital affected surface and in rapture, for all roves, as in figure 6.



a)

b)

Figure 6 - The aspect (a) and distribution (b) of flakes in bars used in experiments

In order to establish if flakes extend on the entire length of the bars, an ultrasonic control was also done, beside the macroscopic analysis and the section analysis. A Kraut Kramer USD 10 device was used, in three distinct areas of each bar. Flaws were noticed in all three areas. The section samples showed that the flaws found during the ultrasonic control are flakes.

The difference between one bar and another, as it is shown in figure 6, was mainly the size of the area affected by flakes. In most cases, flakes appeared only in the axial area (on a surface of about 25-30 mm, as in figure 6a), but there were cases when these expanded almost in the entire transversal section, as shown in figure 6b. The causes that led to these differences could be explained by the small and inerent nonconformities to the rules of forging and cooling, although there is also the possibility of a difference in the chemical composition and purity, especially in the amount of hydrogen contained.

Next, the bars with flakes of the size and intensity in figure 6 were forged under different circumstances. Beside temperature as a main factor that influences steel stability, several other things were taken into account, like the tension that is formed during heat plastic deformation and the deformation degree. Heat deformation was done by forging with a hammer of 3 tons, and the deformation degree was measured by decreasing the ratio between the initial transversal section and the final transversal section of the product, ratio that is called ratio of reduction by forging.

The first bars were forged according to the square - rectangle - square schema, at temperatures of 1200 -800°C, 1200 - 1000°C and 1000 - 800°C. It was noticed that the granulosity of the cooled forged bars in figure 7 was not influenced by the forging technique, and the welding of flakes was more complete between 1200 - 1000°C. Consequently, the interval 1200 - 1000°C was adopted for all other experiments, regardless of the initial and final temperature of forging.

The after-forging cooling occurred in all instances according to the graph in figure 7, the bars that were forged in several steps were introduced in the cooling furnace at 350°C and kept at this temperature for another three hours.

In the forging according to the square - rectangle - square schema at temperatures between 1200 and 1000°C, we experimented with two subtypes: first, with a l_0/b_0 advance of 0.6 - 0.8, and second, with the advance between 1.0 and 1.2. In both cases, the ratio of reduction by forging increased by 0.5 for each step in the interval 1.5 - 8.0.

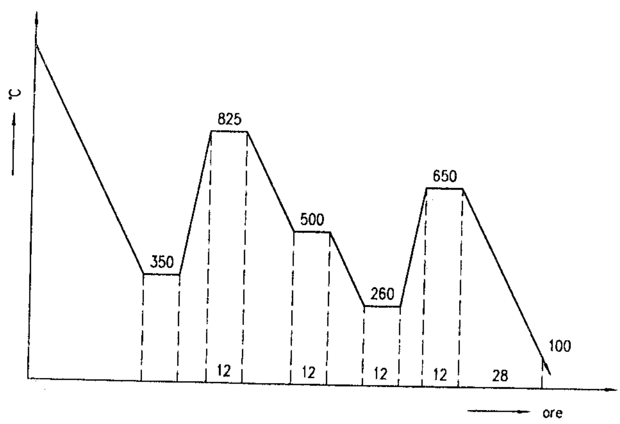
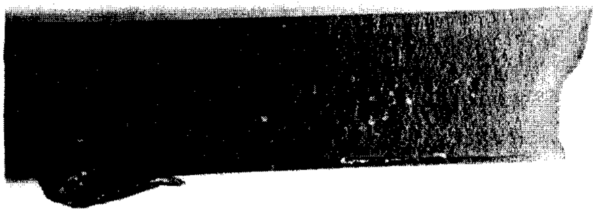
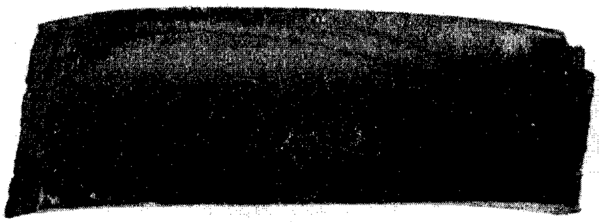


Figure 7 - The cooling graph of bars forged in several steps

After forging and cooling, two roves per stage were discharged, the first one for metallographic analysis, and the second for rapture control. For ratios of reduction by forging 1.5 and 2.0, the welding of the flakes was only partial. For C = 2.5, flakes were partially welded because of the forging with ratio l_0/b_0 = 0.6 - 0.8, figure 8a, and totally welded when the same ratio is 1.0 - 1.2, as in figure 8b.



Sl. 8a



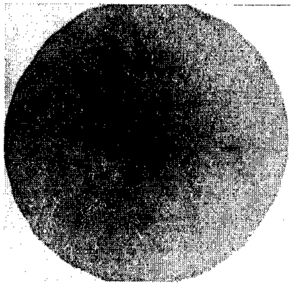
Sl. 8b

Figure 8 - The aspect of rapture samples after the C = 2.5 forging

The metallographic analysis and the ultrasonic control showed that on the Nital affected polished surface of bars forged with C = 2.5 and l_0/b_0 = 0.6 - 0.8, flakes were seen less easily than in rapture. The complete welding of flakes in the case of forging with l_0/b_0 = 0.6 - 0.8 was done at a C level of 3.5. When the value of the ratio of reduction by forging is bigger, flakes are completely welded in both forging cases. It is possible that in the case of steel that is more easily forged than 90Vmo20 steel, that contains 0.9%C, the welding be done at lower levels of the ratio of reduction by forging.

For the forging of round bars between flat tools, the degree of unitary deformation varied between 3 and 6% in the first case and 8 to 12% for the second. Since during the forging process the degree of unitary deformation was measured with a boundary marker only at the fist hammer strokes and then estimated visually, it is possible that there were slight differences among the approximate values and the real ones.

In the first case, $\epsilon_u \leq 6.0\%$, the flakes were only partially welded, more so at the periphery, and for C over 3.0% in the axial area, beside the unwelded flakes there were also cracks which developed pro rata with the ratio of reduction by forging as in figure 9.



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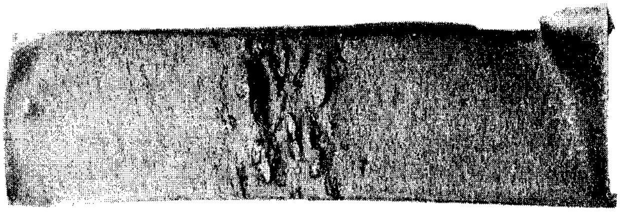
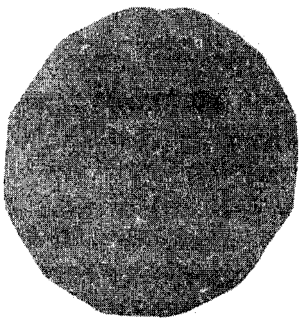


Sl. 9b

Figure 9 - The aspect of roves made of bars forged with $\in_u \leq 6.0\%$ and $C = 4.0$

In the case of forging with $\in_u = 8$ - 12%, the flakes were welded entirely for ratio of reduction by forging between 3.5 and 4, as in figure 10.



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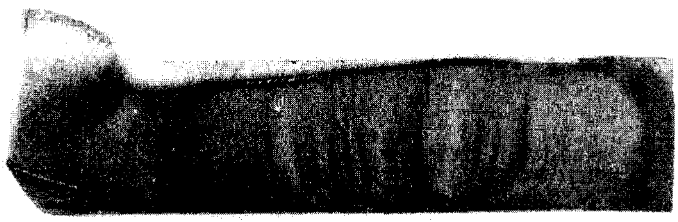

Sl. 10b

Figure 10 - The aspect of roves made of bars that were forged with $\in_u \geq 8\%$ and $C = 4.0$

It was established that for forging between flat tools according to the round - round schema, the welding of flakes is possible. To this end, the forging must be conducted with an $\epsilon_u \geq 8\%$ and ratio of reduction by forging of or over 4.0. If $\epsilon_u < 8.0\%$, the welding of flakes is the more difficult the less the ϵ_u is, and it becomes impossible for $\epsilon_u < 6.0\%$.

For V profiled tool forging at an angle of $\alpha = 130°$, or between mixed tools such as the flat breaking machine or the profiled anvil, the unitary deformation degree had less influence as compared to flat tools. In this case, the minimum ratio of reduction by forging necessary for welding the flakes was of 3.5.

CONCLUSIONS

The following main conclusions can be drawn from all that was discussed above:

- Flakes should not always be considered irreparable damage. In the case of semifinished products whose destination can be changed, such as die-blocks and rolling mill cylinders, flakes can be welded by proceeding with heat deformation.

- The welding of flakes by forging can be done both with flat tools and with profiled or mix tools. For square section semifinished products, where flat tools are compulsory, the minimum necessary ratio of reduction by forging is of 3.5 when the advance is between 0.6 and 0.8 and of 2.5 when the ratio is over 1.0. In both cases, forging must be done with light strokes, that is, with small degrees of deformation, at temperatures on the verge of the superior limit of the interval recommended for heat deformation. In the case of round section semifinished products, profiled or mix tools should be used, and the ratio of reduction by forging should be higher than 3.5.

- In order to prevent the appearance of flakes, beside a detailed analysis of circumstance, like chemical composition, thermal tensions, etc. special consideration must be paid to the state of tension that is created during the plastic deformation. To this end and regardless of the process used, heat deformation should occur with minimum values of the stretching tensions ascompared to compression ones.

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