INVESTIGATION OF A NEW FORGING TECHNOLOGY IMPLEMENTING SHEAR DEFORMATION

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ABSTRACT

This work is devoted to the study of the forging process of round cross-section blanks in a new design crossing strikers, which ensures the additional shear deformation implementation in the entire volume of the deformable workpiece during the deformation process. This contributes to a better closure of internal defects and a more intensive and uniform processing of the initial metal structure compared with forging in the previously known design of crossing strikers, as well as compared with forging in conventional cut-out strikers. Moreover, the presence of an additional block of cut-out inserts in this design of crossing strikers allows to obtain forgings with an even cross-section, close to a circle, without additional processing of the forgings obtained in the cut-out strikers.

Keywords: forging, alternating deformation, crossing strikers, cut-out strikers, internal defect, microstructure.

INTRODUCTION

For more than a decade, scientists from all over the world have been paying special attention to such metal forming methods that allow realization of severe plastic deformations, and due to this the structure is crushed to an ultrafine-grained state. The latter makes possible to achieve an increased level of mechanical and operational properties in various ferrous and non-ferrous metals and alloys. It is possible to realize severe plastic both:

- with the help of simple processes that include one metal processing cycle in one deformation zone without changing the metal flow direction or load applying;
- with the help of integral (complex) processes that include several operations in one deformation zone, or a combination of operations with changing the metal flow direction.

Simple processes that allow implementing severe plastic deformations can include equal-channel angular pressing [1], including in an equal-channel step matrix [2], radial-shear rolling [3, 4]. Various combined processes, including the combined processes of “rolling-pressing” [5], “pressing - drawing” [6] and many others, can be attributed to complex processes that allow to implement severe plastic deformations. Unfortunately, using all mentioned methods, the long products with a small cross-section can be obtained, and with conventional equal-channel angular pressing, the resulting blanks even have limitations in length.

It is possible to obtain massive workpieces only by forging. Most often (except for comprehensive forging), by forging it is impossible to obtain an ultrafine-grained structure in the entire volume of the deformable metal. But at the same time, due to the implementation of additional shear or alternating deformations, it is possible to obtain workpieces with a uniform fine-grained structure [7]. The easiest way to achieve the development of additional shear or alternating deformations in the entire volume of the deformed metal is possible due to the special design of the working tool - strikers. Research in this direction is carried out all over the world, and in some countries, there are even specialized schools, for example, in Poland, Ukraine, Russia and Kazakhstan. Scientists from these countries have published a large number of scientific papers in this direction, in which they proved the advantage of forging technologies that implement shear or alternating deformation during deformation compared to current forging technologies in traditional forging tools: flat, cut-out and combined strikers [8 - 27].

This work is devoted to the study of a new technology for forging workpieces in crossed strikers of a new design, allowing additional shear deformations to be realized. To achieve this goal, the following tasks were set:
1) study of the blank shape change;
2) investigation of the internal axial defect closure;
3) analysis of the impact of the new forging technology on the microstructure evolution of steel 60.

EXPERIMENTAL

The difference between the proposed design of crossing strikers from the previously known design is that in the new one a working block is additionally provided in the form of flat or cut-out (combined) inserts (Fig. 1). The latter allows to obtain blanks of a given cross-section without additional compression [28]. Also there is a gap between the intersecting and flat or cut-out inserts, both of the upper and lower strikers, which will avoid cutting the workpiece during deformation process. Such defect was observed when deforming the workpieces in the crossing strikers, which did not have a gap between the inserts.

To study the influence of the tool shape factor on the blank shaping, lead blanks with dimensions D ´ L = 35 ´ 200 mm were prepared. The experiment was carried out on a hydraulic press with a force of 100 tons.

The deformation of the workpieces was carried out in crossing strikers of two designs:
- in crossing strikers of a new design, having an additional working block in the form of cut-out inserts (Fig. 1) with a cut-out angle 120°;
- in crossing bikes that do not have an additional working block in the form of cut-out inserts, but also have a gap between the crossing inserts.

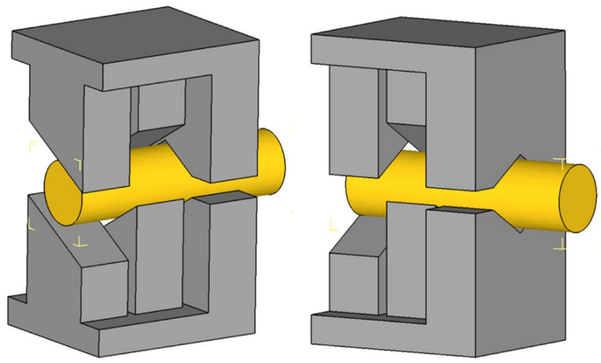


Fig. 1. Crossing strikers of a new design.

The deformation in the new design crossing strikers, having an additional working block in the form of cut-out inserts and without the block, was carried out in the following way: the workpiece was fed into the crossing strikers and broached with an absolute feed value equal to 20 mm and a relative compression of 6 %. When exposed to the workpiece by the side surfaces, a plastic shift of one part of the workpiece relative to the other occurs. After deformation along the entire length, the workpiece was turned 90° and a second pass was carried out with the same values of absolute feed and relative compression. Due to the presence of a section with a triangular cutout in this design, after several passes with a 90° edging of the workpiece, a forging with an even cross-section was obtained, close to a circle with a diameter of 28.7 mm. Square reduction when deforming cylindrical workpieces in crossing strikers of a new design, having an additional working block in the form of cut-out inserts with a cut-out angle of 120° was 1.49.

Similar workpieces were also deformed in the crossing strikers, which do not have an additional working block in the form of cut-out inserts, but also have a gap between the crossing inserts, with the same square reduction as in the strikers of the proposed design. But unlike the blanks forged in the crossing sides of the new design, these blanks had an uneven surface. Therefore, in order to obtain a round-section workpiece with a flat surface, the workpiece had to be additionally compressed in cut-out strikers with a cut-out angle of 120°, which led to an increase in deformation cycles by two or more times.

To study the influence of the tool shape factor on the axial defect closure, blanks of steel 60 with dimensions D ´ L = 35 ´ 200 mm were prepared, which had through-drilled holes with a diameter of 2.4 mm in the center, which is 6.86 % of the workpiece diameter. This through hole models one of the main ingot defects - axial porosity, the nominal diameter of which is 7 % of the ingot diameter approximately [29].

In this case, the deformation was carried out in the crossing strikers of a new design, having an additional working block in the form of cut-out inserts (Fig. 1) with a cut-out angle of 120°, and in cut-out strikers with a cut-out angle of 120°. The experiment was also carried out on a hydraulic press with a force of 100 tons, all the workpieces were pre-heated in a resistance furnace to a temperature of 1100 ± 50°C.

The deformation of the first batch of blanks with an internal axial defect in the crossing strikers of the new design was carried out according to the above deformation scheme with a square reduction of 1.49. The second batch of blanks with an internal axial defect was deformed in standard cut-out strikers with a cut-out angle of 120°, up to a diameter of 28.7 mm with a square reduction of 1.49.

The microstructure was studied using an OLYMPUS BX61 industrial optical metallographic microscope. The study of the microstructure was carried out on specially prepared micro-grinders. Preparation of micro-grinders was carried out according to the standard procedure: template cutting using a BRILLANT 230 cutting machine; obtaining a flat surface of the sample; grinding and polishing using a SAPHIR 520 ATM grinding and polishing machine; etching (4 % solution of nitric acid in alcohol).

Grain sizes were determined using the IMAGE-SP program. The results of the processed data on the images were displayed using tables. All samples at x200 magnification were examined.

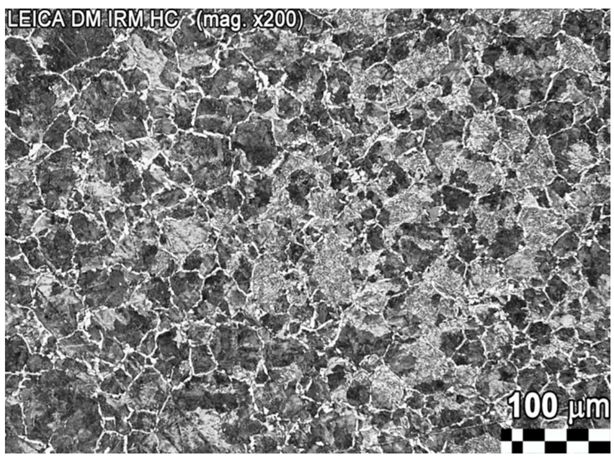
RESULTS AND DISCUSSION

The macrostructural analysis showed that when using crossed strikers of a new design with an additional working block in the form of cut-out inserts, with a square reduction of 1.49, the internal defect closed by 97 %, and when using conventional cut-out strikers with such square reduction, the defect closed by 82 %.

To solve the third task, another batch of steel billets of steel 60 with dimensions D ´ L = 35 ´ 200 mm was prepared, but without axial defect. This batch of blanks was formed according to the above schemes, but already in three different forging tools: in crossing strikers of a new design, having an additional working block in the form of cut-out inserts and not having this block, as well as in cut-out strikers, with a cut-out angle of 120°. Before deformation, all steel billets were annealed at a temperature of 780°C.

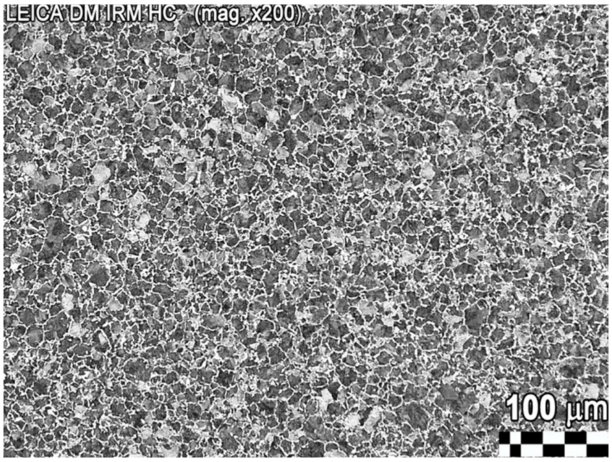
The microstructures of the initial sample and samples formed in three different forging tools are shown in Fig. 2. Metallographic analysis showed that the microstructure of the initial samples (after annealing) has a ferrite-pearlite structure, the average grain size is 45 microns (Fig. 2(a)). Perlite is characterized by a lamellar structure.

After forging in the crossing strikers of both designs, the structure of the samples demonstrates mainly a pearlite structure and a ferritic mesh along the grain boundaries obtained under the action of shear deformations (Fig. 2(b-e)). The grain size in the samples obtained after deformation in the crossing strikers of the new design is the same both in the transverse and longitudinal directions and is 20 microns (Fig. 2(b-c)). When deformed in crossing strikers, without an additional working block in the form of cut-out inserts, the grain size in

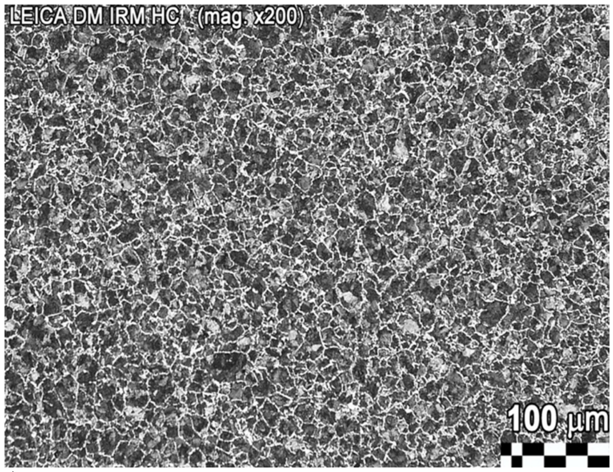


a)

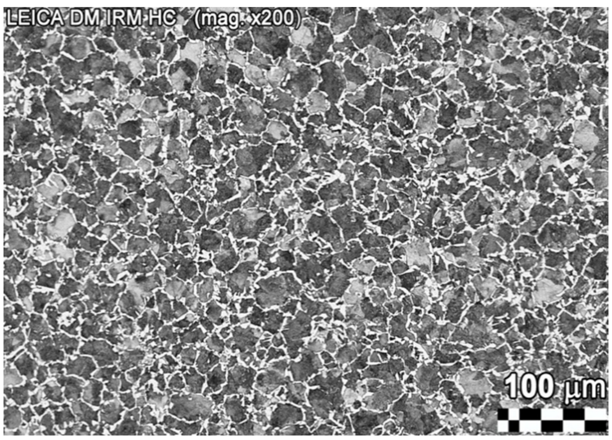
Fig. 2. Microstructure of steel 60: a - structure before deformation.



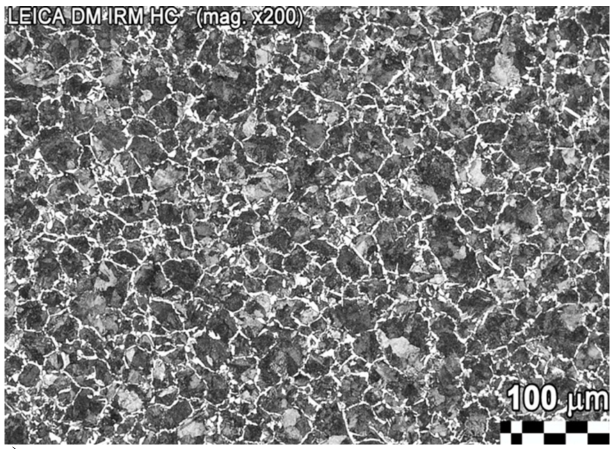
b)



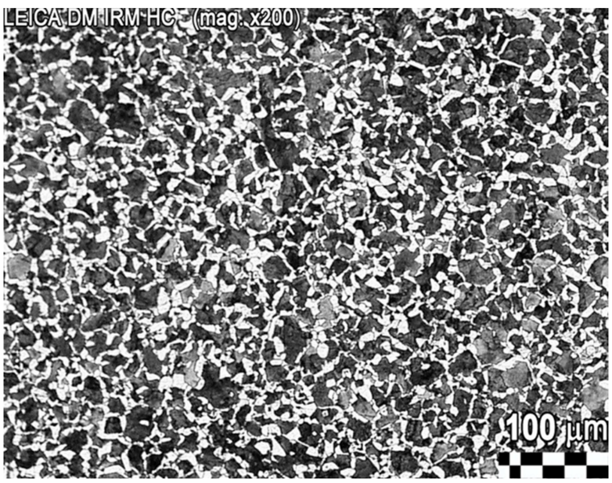
c)



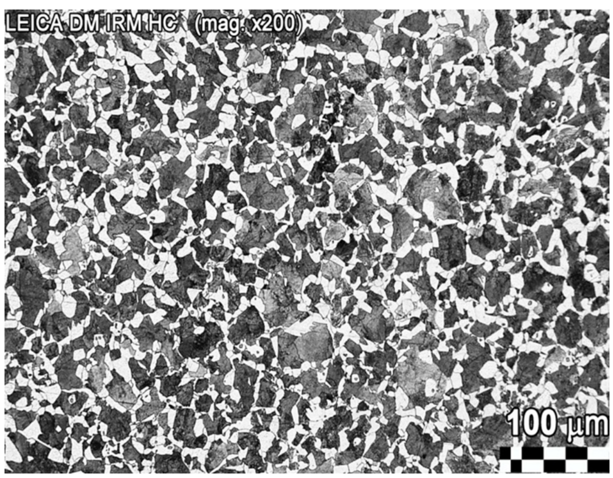
d)



e)



f)



g)

Fig. 2. Microstructure of steel 60: b, c - after deformation in the crossing strikers of a new design, having an additional working block in the form of cut-out inserts; d, e - after deformation in the crossing strikers; f, g - after deformation in the cut-out strikers, with a cut-out angle of 120 °; (b, d, f - longitudinal direction; c, e, g - transverse direction).

the longitudinal and cross sections is slightly different, in the longitudinal direction is 25 microns (Fig. 2(d)) and 30 microns in the transverse direction (Fig. 2(e)). The structure of the pearlite colonies have undergone changes, the cementite plates have become distorted and bent, and in some cases broken into separate parts.

Deformation in the cut-out strikers leads to the fact that the ferritic grains become a certain shape, and are not arranged in a grid along the boundaries of the pearlite grains. The average grain size in the longitudinal direction is 27 microns (Fig. 2(f)), and in the transverse direction 40 microns (Fig. 2(g)).

After analyzing the microstructure, it can be concluded that by forging in the crossing strikers of the proposed design, it is possible to obtain the most fine-grained and homogeneous microstructure over the entire volume of the deformable workpiece compared with forging in the previously known design of crossing strikers, as well as compared with forging in conventional cut-out strikers.

CONCLUSIONS

The paper presents the results of the study of the forging process of round cross-section blanks in a new design crossing strikers, which ensures the additional shear deformation. Such effect leds to better closure of internal defects and a more intensive processing of the initial metal structure. After laboratory experiment the microstructure change was investigated. Obtained results revealed that:

- the use of additional cut inserts in the crossing strikers design does not require additional compression of the blanks in the cut-out strikers to obtain forgings with an even cross-section close to the circle;
- using the crossing strikers of the proposed design, which has an additional working block in the form of cut-out inserts, provides the axial defect closure by 97 % with a square reduction 1.49, and using conventional cut-out strikers with a similar square reduction, provides the axial defect closure only by 82 %;
- forging in the crossing strikers of the proposed design provides the most fine-grained and homogeneous microstructure over the entire volume of the deformable workpiece compared with forging in the previously known design of crossing strikers, as well as compared with forging in conventional cut-out strikers.

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