Influence of the forging process in step-wedge-shaped strikers on the destruction nature of the deformable metal

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Abstract: *The paper investigated the effect of cyclic deformation on the destruction nature of workpieces during broaching in step-wedge strikers. AISI 1020 was chosen as the workpiece material. According to the experiment results, the influence of turning and cycles number on the values of impact strength was carried out. Fractography analysis of the fracture surface structure was also conducted.*
KEYWORDS: *BROACHING, STEP-WEDGE STRIKERS, CYCLIC DEFORMATION, IMPACT STRENGTH.*

1. Introduction

At the present time, many energy-saving technologies are known in the world that allow to obtain high-quality metal products by rolling, forging, pressing and other methods of metal forming. When forging, this problem is successfully solved when deforming metals in special tools that implement shear and alternating strains throughout the entire volume of the deformed metal. Since it is the implementation of intense shear strains in the forging process of forgings from ferrous and non-ferrous metals that leads to a significant change in the initial microstructure and an increase in the physical and mechanical properties of the deformed metal. In this regard, the production of blanks by new forging methods with a significant reduction in energy and labor costs improving the quality of forgings is economically advantageous. One of the ways to achieve this goal is the use of deformation methods and tools that implement shear and alternating strains in the entire volume of the metal.

Previously, various investigations have already been conducted to study the stress-strain state, forces, mechanical properties and microstructure during broaching in step-wedge strikers [1-4]. The main purpose of determining the impact strength during bending is to assess the performance of the material under difficult loading conditions and its tendency to brittle fracture [5].

2. Experimental part

The experiment was carried out as follows: blanks of AISI 1020 steel with dimensions of 30x60x250 mm were heated in a resistance chamber furnace to a temperature of 1200°C, and then deformed in step-wedge strikers with an angle of inclination of 30° and with a wedge angle of 160° (Fig. 1) with different angles of turning.

The first batch of blanks was deformed without turning - workpiece immediately after alternating deformation in step-wedge strikers was fed to a flat section of these strikers for straightening. After the 2nd, 4th and 6th deformation cycles, standard samples were made from deformed workpieces for impact strength testing (GOST 9454-60).

The second batch of blanks was deformed in the same tool, but with 180° turning, i.e. after each pass, the workpiece was turned by 180° and alternating deformation was performed. Standard samples for impact strength and compression testing were also made from deformed workpieces. Impact strength tests were carried out using a pendulum.

The impact strength was calculated by the formula [5]:

$$a = A / F \qquad (1)$$

where F – the cross-sectional area of the sample at the incision zone before the test;
A - the work spent on deformation and destruction of the sample.

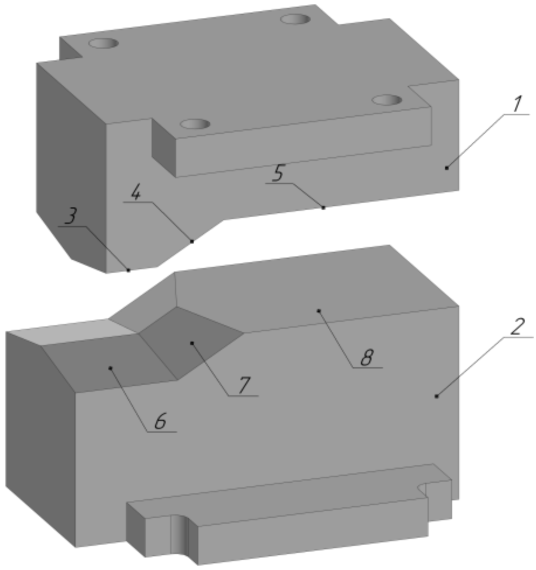
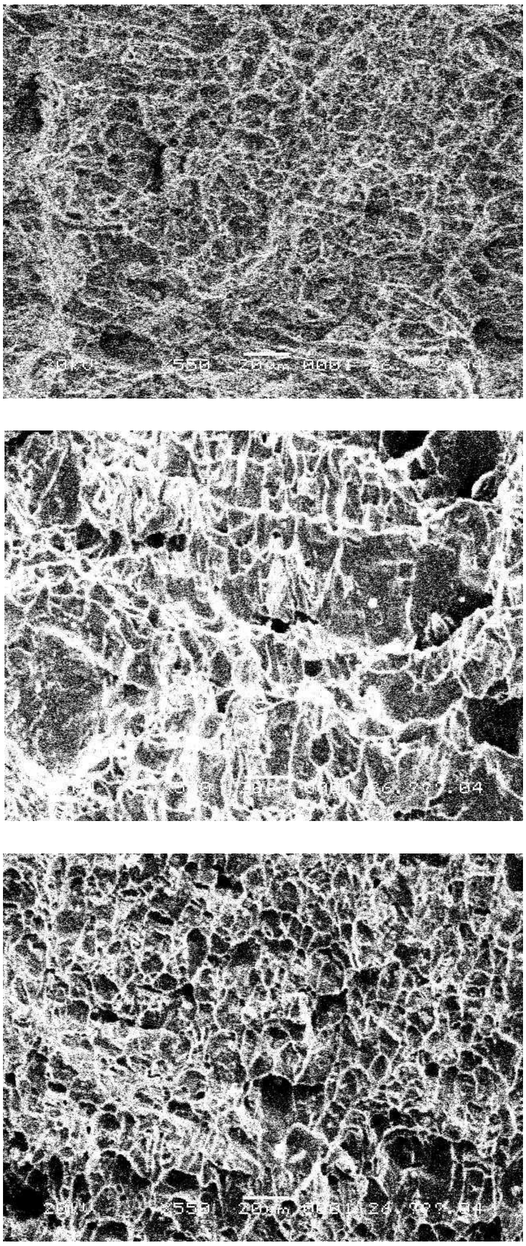


Figure 1 *- Step-wedge-shaped strikers*
1 - upper striker; 2 - lower striker; 3 - smaller stage with wedge of the upper striker, 4 - inclined section with wedge of the upper striker; 5 - large flat stage of the upper striker; 6 - smaller stage with wedge of the lower striker; 7 - inclined section with wedge of the lower striker; 8 - large flat stage of the lower striker

It is known from the works [6, 7] that the more dislocation sliding systems are simultaneously involved in the plastic metal flow, the higher the mechanical and technological properties of the material. The maximum increase in the number of dislocation sliding systems involved can be achieved with cyclic deformation of metal in step-wedge strikers due to the implementation of alternating strains, both in the longitudinal and transverse directions. In addition, the desired effect is achieved faster if the workpieces are deformed with 180° turning. Thus, with an increase in the number of deformation cycles of workpieces in step-wedge strikers according to the proposed schemes, the impact strength of the metal progressively increases. The results of the calculated values of impact strength are presented in Table 1.

Table 1 *- Results of calculated values of impact strength*

Method of deformation	Number of cycles	Average value of impact strength, N/mm
In step-wedge strikers without turning	2	176,69
	4	191,71
	6	206,61
In step-wedge strikers with 180° turning	2	188,03
	4	202,57
	6	212,56



a) b) c)

Figure 2 *- Fracture structures*
a –fracture structure after two deformation cycles; b - fracture structure after eight deformation cycles without turning;
c - fracture structure after eight deformation cycles with 180° turning

The experiment results were also confirmed by a fractography study of the fracture surface, which showed that at the initial stages of processing in step-wedge strikers (Figure 2a), the fractures of the samples, in addition to the fibrous component of the viscous fracture, have a sufficiently large proportion of the brittle component. As the deformation cycles increase (Figure 2b), the fraction of the brittle component decreases due to an increase in the plastic characteristics of the material [5]. The same effect is enhanced when deforming samples with edging (Figure 2c).

Conclusion

The test of workpieces formed in step-wedge strikers for impact strength was carried out. According to the experiment results, the influence of the turning and the number of broaching cycles on the impact strength values was investigated. A fractography study of the fracture surface of the workpieces showed that with an increase in the number of cycles, the plastic characteristics of the metal increase with a simultaneous decrease in brittle ones.

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References

1. S.N. Lezhnev, E.A. Panin, A.O. Tolkushkin, D.V. Kuis, G.A. Sivyakova, Development and computer modeling of a new technology of deformation of workpieces such as plates and plates made of ferrous and non-ferrous metals and alloys, VI International. Congress "Non-ferrous metals and Minerals-2014", Krasnoyarsk, 2014, 1213-1221 (in Russian).

2. A.B. Naizabekov, S.N. Lezhnev, A.O. Tolkushkin, Study of the effect of the deformation process of workpieces in step-wedge strikers on the microstructure and mechanical properties of steel 20, IV International. scientific and practical conference "Innovations in materials science and metallurgy", Yekaterinburg, 2014, 181-184 (in Russian).

3. A.O. Tolkushkin, E.A. Panin, S.N. Lezhnev, Study of the drawing process in a step-wedge dies, Materials Today: Proceedings, 19, 2019, 1883-1886.

4. A.O. Tolkushkin, S.N. Lezhnev, A.B. Naizabekov, E.A. Panin, R.M. Yordanova, D.R. Zhumagaliyev, Development and research of the new forging technology of billets in the step-wedge dies, Journal of Chemical Technology and Metallurgy, 54, 2019, 1337-1343.

5. A.A. Bogatov, Mechanical properties and models of metal destruction, Yekaterinburg: UGTU-UPI, 2002 (in Russian).

6. A.B. Naizabekov, Scientific and technological bases for improving the efficiency of forging processes with alternating deformations, Almaty, 2000 (in Russian).

7. V.A. Tyurin, Innovative forging technologies using macro-shifts, Forging and stamping production, 11, 2007, 15-20. (in Russian).