Investigation of the energy-power parameters of forging process in step-wedge strikers

Volokitin A.V.[1], Panin E.A.[2], Tolkushkin A.O.[1], Volokitina I.E.[1], Chigirinsky V.V.[1], Nurakhmetov D.D.[1]

[1] Rudny industrial institute, Rudny, Kazakhstan; [2] Karaganda industrial university, Temirtau, Kazakhstan
e-mail: cooper802@mail.ru

Abstract: *In this paper the deformation force of the forging process in step-wedge strikers was studied. At the first stage, the study of the deformation force using computer modeling in the Deform-3D software package was carried out. At the second stage, an experimental study of the deformation force during the broaching of workpieces in step-wedge strikers using thermometry was carried out. It is established that the experimental results have a high convergence with the simulation values. The increasing level of difference in results is associated with heat losses during intermediate operations, which are usually ignored during modeling.*

Keywords: FORGING, STEP-WEDGE STRIKERS, MODELING, EXPERIMENT, DEFORMATION FORCE.

1. Introduction

An important direction in the forging production development is to increase the mechanical properties of forgings made of ferrous metals by introducing new forging technologies into production that ensure the development of shear and alternating deformations throughout the volume of the deformed metal. This ensures the grinding of the cast structure to a fine-grained state and its uniform distribution over the entire volume of the metal. At the same time, one of the main effectiveness indicators of the new forging technology is the reduction of the energy-power parameters.

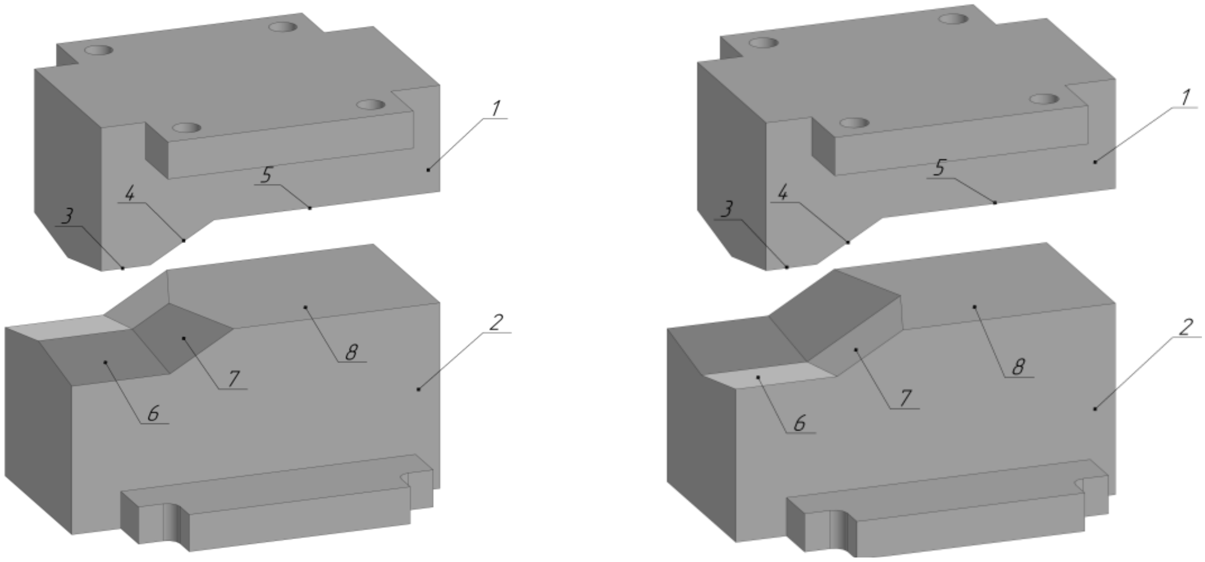
New forging technologies include the technology of forging forgings such as plates and plates in step-wedge strikers of two configurations:

- according to the first configuration, strikers with stepped and inclined sections are made with an inclination angle no more than 45° to the horizontal plane of the section between the steps and the width of the step of a greater length of at least 1.5 of the total length of the smaller step and the inclined section, while the inclined section and the smaller step in the cross section of the upper and lower striker are made in the form of a wedge [1] (fig. 1, a);
- according to the second configuration, the inclined section and the smaller step of the upper striker in the cross section are made in the form of a wedge, and the lower striker in the form of a similar wedge-shaped depression, and the length of the smaller step with the wedge-shaped depression of the lower striker is made longer than the upper one in order to avoid the formation of clips on the workpiece [2] (Fig. 1, b).

Earlier in work [3] it was shown that the use of step-wedge strikers is more energy efficient compared to the use of conventional step strikers, which formed the basis of step-wedge strikers together with wedge-shaped strikers, since the values of the forging forces in these strikers in comparison with conventional step strikers turned out to be on average less by 30-35%. The purpose of this work is to study the deformation force of the forging process of workpieces in step-wedge strikers.

2. Computer simulation

At the first stage, the study of the deformation force using computer modeling of the forging process of workpieces in step-wedge-shaped strikers (two configurations) in the Deform-3D software package was carried out. Two solid-state models of step-wedge strikers of the first and second configurations with a wedge angle of 160° were built. AISI-1035 steel was chosen as the model material for the workpiece. The cross section of the workpiece was 30x30 mm. Deformation was carried out at a temperature of 1100 °C with a deformation degree equal to 10% of the initial height of the workpiece.



a) b)

1 – upper striker; 2 – lower striker; 3 – smaller stage with a wedge of the upper striker, 4 – inclined section with a wedge of the upper striker; 5 – large flat stage of the upper striker; 6 – smaller stage with a wedge (a) and wedge depression (b) of the lower striker; 7 - inclined section with a wedge (a) and wedge depression (b) of the lower striker; 8 - large flat step of the lower striker

Fig. 1. *Step-wedge strikers*

Figure 2 shows graphs of the deformation force during broaching in step-wedge strikers of the first and second configurations, based on the values of maximum deformation force in each pass. It can be seen that when broaching the workpiece in the strikers of the first configuration (both strikers with a wedge) due to the compression intensificationf, the deformation force has higher values than when broaching in the strikers of the second configuration, this is especially noticeable when comparing the central areas of the graphs, which correspond to the presence of metal in the all three zones of strikers. In the last passes, when the workpiece is no longer in the first two sections, the force values become comparable.

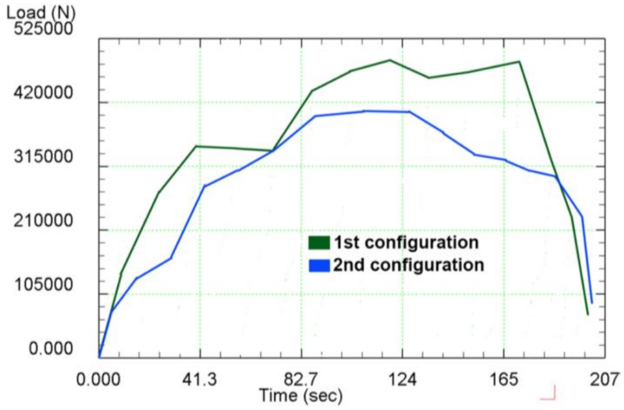


Fig. 2. *Values of the force during broaching in step-wedge strikers*

3. Laboratory experiment

At the second stage an experimental study of the deformation force during the broaching in step-wedge strikers was carried out. Experiment was carried out only for step-wedge strikers of the second configuration, i.e. with a wedge on the upper striker and with a wedge-shaped depression on the lower striker, since the main purpose of experiment was to confirm the results of computer modeling.

To measure the resulting deformation forces, it was decided to use a well-proven strain gauge method. The following equipment was used for this purpose: strain gauge station ZET-017-T8 (CJSC ETMS, Russia); strain gauges with TCFO1-2-200 resistors (CJSC ETMS, Russia).

The diagram of the sticker connection of strain gages is shown in Figure 3. This scheme allows to register the change in electrical resistance under the influence of force in the longitudinal or transverse direction, while the second sensor always acts as an element with the thermal compensation function, which is important dirung hot deformation. Since the broaching in these strikers is carried out in the longitudinal direction, the measuring strain gauge is glued across the striker, and the compensating strain gauge, perceiving only temperature changes, is glued along the striker.

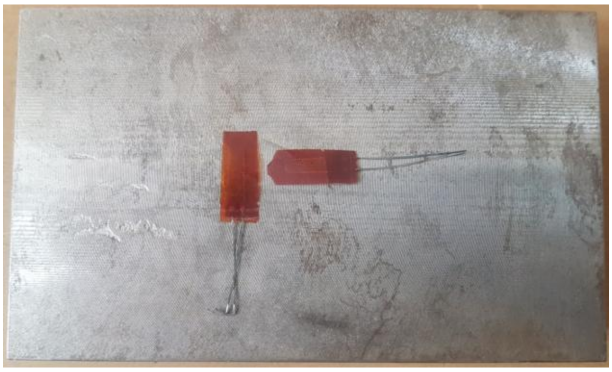


Fig. 3. *Load cell sticker diagram*

Before the direct test, the upper striker with installed load cells was subjected to compression tests on the torsion-bursting machine MI-40KU. The purpose of these tests was the preliminary calibration of strain gages. On this laboratory stand it is possible to develop forces up to 40 kN with accurate fixation of their values. The essence of pre-calibration is to change the stress-strain state of the strain gages under load, which causes deformation and linear change in the resistance of the strain gages. With a sequential change in the load in the range from zero to 35 kN with a step of 5 kN, the dependence of the electrical voltage in the circuit and the applied force is constructed. This dependence is always linear, so the result of calibration is a mathematical equation of the form Y = KX + B, where Y is the force and X is the voltage.

To improve accuracy, 3 passes were carried out over the specified range – up, down, up, or 21 measurements (when 5, 10, 15, 20, 25, 30 and 35 kN). The data obtained during the tests were statistically processed, and a linear regression equation was derived from them, linking the force applied to the instrument (P, N) with the voltage (U, mV) in the circuit. The equation for measuring the deformation force has the form: P = -4684.2U + 19625. The coefficient of determination $R^2 = 0.998$; the standard measurement error, according to the results of 21 tests, was less than 0.2%. The obtained data were entered into the program for recording and processing measurements of the ZET-017-T8 strain station to ensure the possibility of recording the signal in the form of a force graph.

After carrying out calibration settings, the striker with strain gages was installed on the upper plate of the press. When fixing the magnitude of the force, it was decided to carry out measurements on each successive feed of the workpiece, i.e. when the workpiece is crimped by one, two and three stages of strikers (stages 2, 4, 6 in Figure 4). This will make it possible to track the sequence of loading of the tool, as well as provide more opportunities for verification of measurement by comparing experimental values with simulation results.

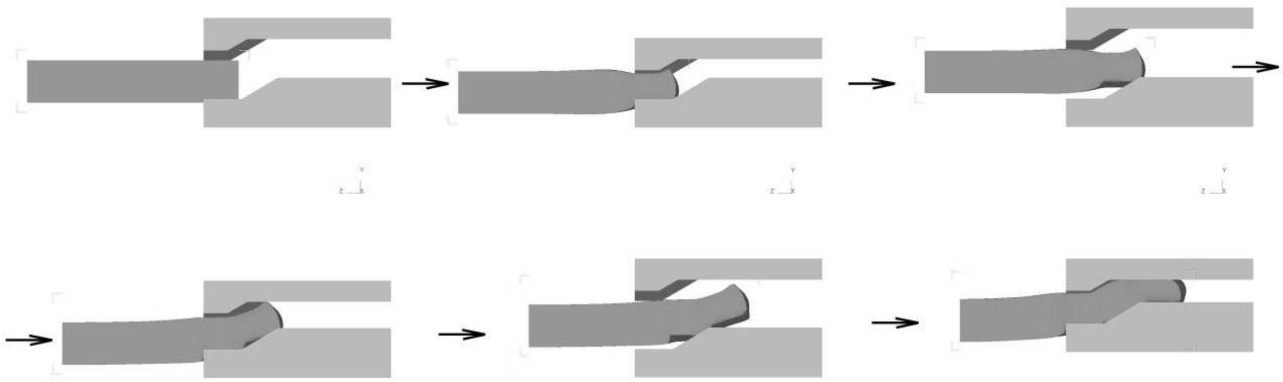
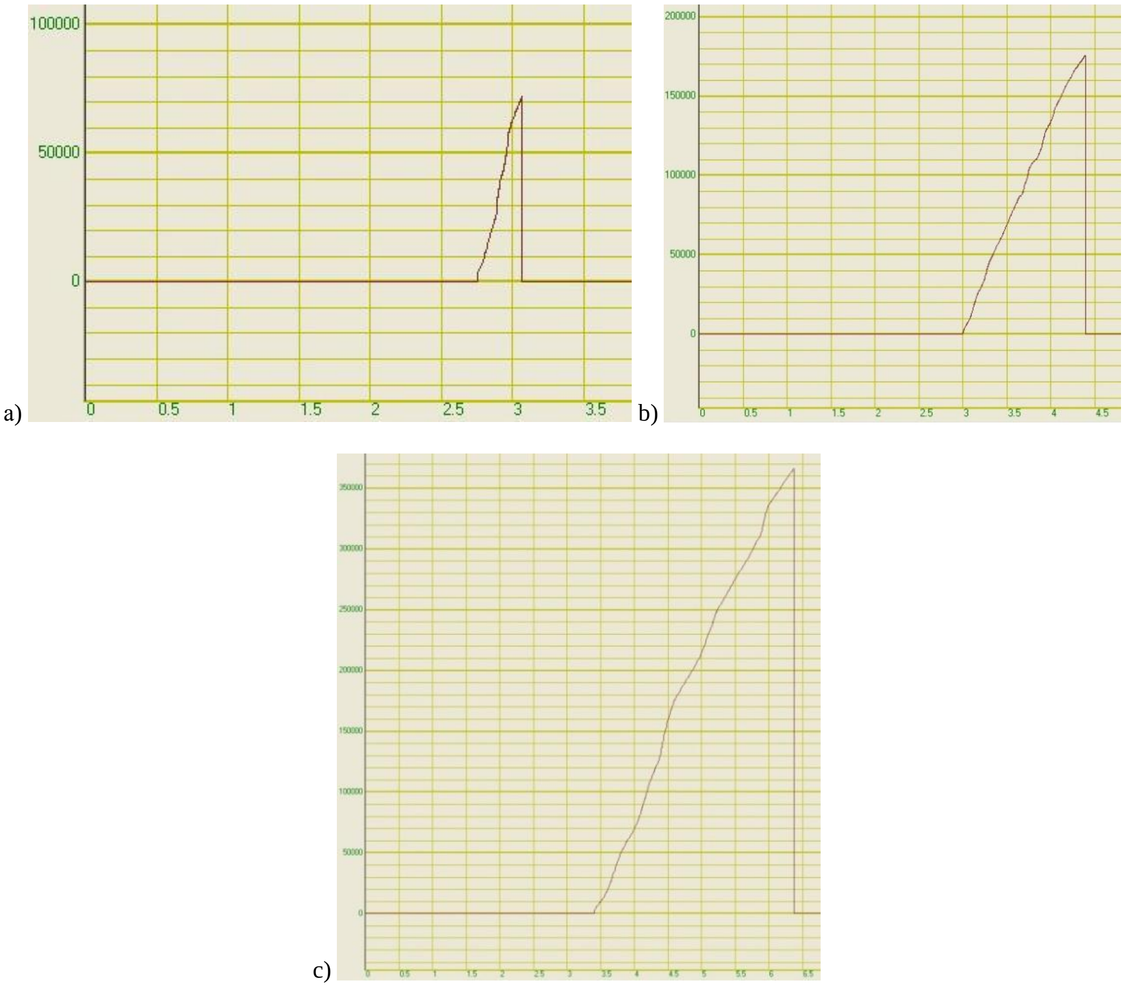


Fig. 4. *Deformation scheme in step-wedge strikers*

As a result, the following data were obtained (Figure 5).



a – compression by one step; b – compression by two steps; c – compression by three steps

Fig. 5. *Change in the force during broaching in step-wedge strikers*

When analyzing the results of the effort measurement, it was noted that at all three stages, the nature of the effort curve is monotonically increasing. With the identical nature (appearance) of the curve, they differ significantly in vertical amplitude, which is the result of a significant increase in the area of contact between the metal and the tool at each subsequent stage.

The force measurement data were summarized in Table 1. For each stage of the deformation process, the error values were calculated in comparison with the values obtained during modeling.

Table 1 – Force measurement results

	1st stage	2nd stage	3rd stage
Value of the force during the experiment, kN	70,5	173	367
Value of the force during modeling, kN	70	169	346
Error rate, %	0,7	2,36	6

In the course of the conducted studies, it was found that with each subsequent stage the error value increases, despite the fact that at the first stage the error is extremely small. This is due to some differences in the technologies of modeling and conducting the experiment. After each pass, the workpiece must be advanced by a certain amount of feed. In real conditions, this is done with the help of a manipulator (in laboratory conditions - manually with the help of ticks). These intermediate operations often take an average of 15 to 30 seconds, which is reflected in the additional cooling of the workpiece. When modeling, the movement of the workpiece between the aisles occurs instantly, so there is no heat loss here. As a result, the values of the force in the experiment are always greater than the force in the modeling.

4. Conclusion

The conducted studies have confirmed the energy efficiency of the forging process of blanks such as plates in step-wedge strikers with a wedge on the upper striker and with a wedge-shaped depression on the lower striker, compared with forging similar blanks in step-wedge strikers with a wedge on the upper and lower striker, and accordingly, compared with forging in conventional stepped strikers.

5. Acknowledgements

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6. References

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