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COMPUTER RESEARCH ON THE TOPIC OF PLASTIC DEFORMATION BEHAVIOR DURING HOT DIE FORGING

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ABSTRACT

A methodology for upgrading the hot die's technological forging processes was developed to increase forgings' economic efficiency based on computer modeling in QFORM and DEFORM-3D software packages. "Mounting Bracket" and "Disc" hot die forgings, made of aluminum alloys, were selected as the process for the upgrade. Meanwhile, the improved efficiency of technological process must not be connected to replacement of the utilized deforming equipment, considerable renovation of the pressing tool, or any changes in the form and size of the die forgings. Analysis of the existing technologies of the forgings' manufacture provided a basis to define an objective for computer research, namely, reducing the quantity of forging transitions via optimization of the contact friction, temperature, and speed conditions of metal deformation. As a result of forging with the use of new technology developed based on computer modeling, the forgings whose geometry and properties met the normative documentation requirements were produced in one transition in a factory environment. Meanwhile, the prime cost of their manufacture dropping by at least 10%.

Keywords: aluminum alloys, hot die forging, computer modeling, die forging.

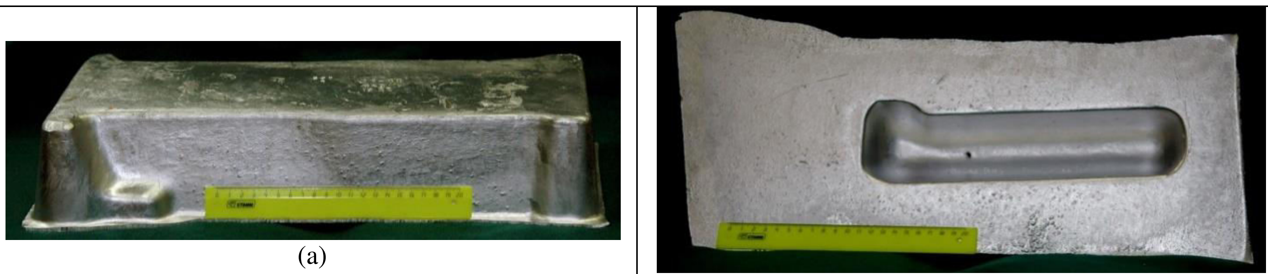
INTRODUCTION

Computer modeling is an effective tool for designing plastic metal works. In particular, the QFORM (Russia) and DEFORM (USA) software packages based on a finite element method (hereinafter - the FEM) are mainly used for hot die forging. The works [1-10] show that the use of computer modeling allows the picture of metal deformation to be virtually tracked, the limits of the energy, temperature, and speed parameter variations to be determined for forging process, the distribution of stress and strain to be shown according to the volume of the deformed metal, the causes of defects in manufactured products to be identified, etc. Meanwhile, the validity of the modeling results mainly depends on correctness of the selection, completeness, and accuracy of the initial input conditions. For this reason, modeling during the development of technological processes for hot die forging is of topical importance as it may reduce expenses for designing new technologies and upgrading those that exist, as well as prove their economic expediency. Meanwhile, it is important to follow a certain works procedure for this purpose.

MODELING OF A HOT DIE FORGING TECHNOLOGY IN THE QFORM (RUSSIA) SOFTWARE PACKAGE

Following the recommendations provided in certain published papers on modeling the hot die forgings made of different alloys, the authors carried out an analysis of the real technological process of "Mounting Brake" forgings manufacturing (Figure-1) made of an AK6 alloy to discover opportunities for increasing its economic efficiency.

The analysis has demonstrated the reasonability of using the QFORM software package to model this technological process.



(a) (b)

Figure-1. "Mounting Bracket" die forging: a - frontal view; b - bottom view.

To carry out a virtual experiment with help of the Unigraphics NX program, "Mounting Bracket" forging and open die 3D models were made using the drawings and were downloaded as files in the pre-processor of the QFORM computer program. Prior to turning on the processor, the rheological properties of the alloy, temperature, speed, and power deformation modes, the

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friction conditions were entered. As a result, a computer model for the forging process was obtained.

Figure-2 shows a model of a blank plastic deformation during the forging process under existing technology. The complex behaviour of the blank forming in the course of the first final forging is shown in Figure-1, where the upsetting, backward extrusion and bending processes run simultaneously. Such a deformation pattern failed to ensure proper forging execution and often was accompanied by such defects as underfilling, clamping, perforating, etc.

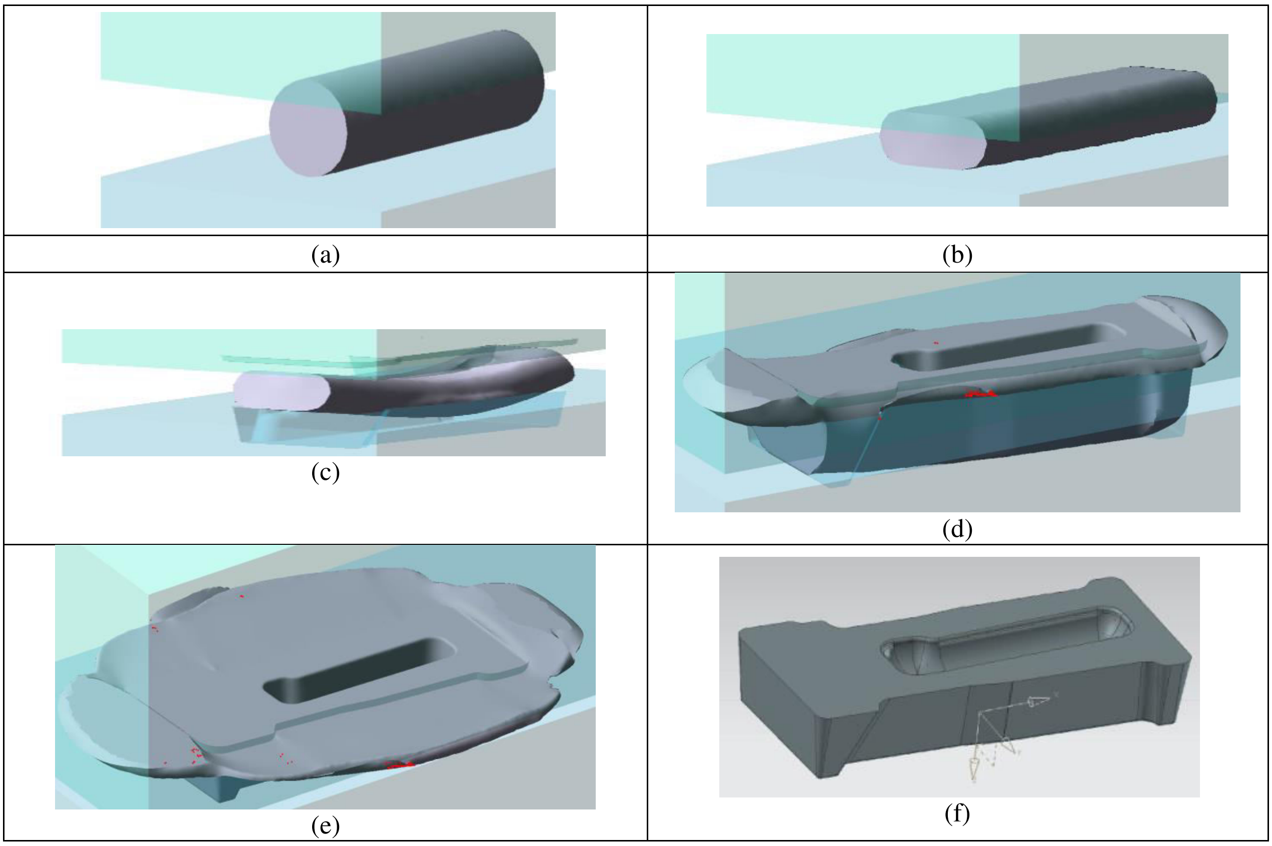

Figure-2. Successive forming of a blank in the course of the hot die "Mounting Bracket" forging made of an AK6 alloy under existing technology modeled in a QFORM software package: (a) initial blank; (b) flattening; (c) bending; (d) first final forging; (e) second final forging; (f) finished die forging.

For the technology's improvement, it was suggested to reduce the volume of the blank for about the volume of the flash that was cut after the first final forging that reduced the blank weight by about 12%. After adjustment, the blank length reduced up to a volume of 10-12 mm less than the die impression length, which considerably eased the blank's centering.

Having changed only the blank length, prior to turning on of the processor, the same temperature, speed, and power deformation modes were entered. As a result, a computer model of the process (new technology) was obtained in which flattening (Figure-2b) was excluded, while forging in the finishing die was completed in one operation. As follows from Figure-3, in this case forming of the blank is achieved by means of upsetting and extrusion.

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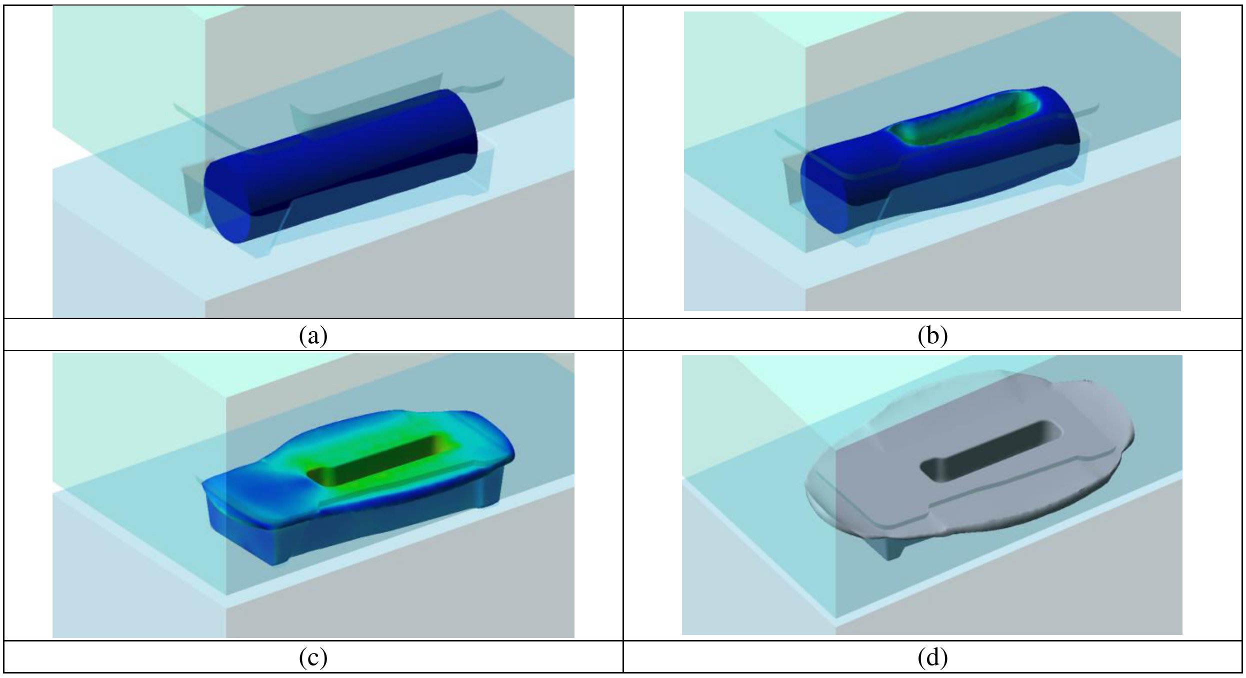

Figure-3. Successive forming of a blank in the course of hot die forging of the "Mounting Bracket" made of an AK6 alloy via a new technology modeled in the QFORM software package:
(a) initial blank; (b) groove formation via extrusion;
(c) flash generation; (d) forging completion

The program allowed for the forging power's design dependence to be designed on the press stroke and the deformation process to be shown in steps leading from the blank to the die's final form forging under the new technology (Figure-4).

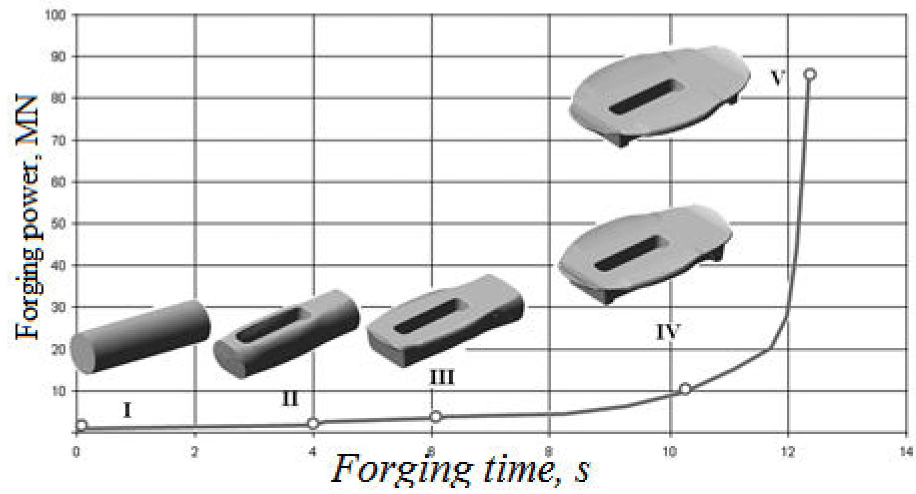

Figure-4. Changing the forging power and the blank form during the modeling of the "Mounting Bracket" hot die forging made of an AK6 alloy under the new technology (the point numbers at the curve correspond to the blank form numbers at this step).

It follows from the chart in Fig. 4 that forging under the new technology may be performed on the same press with a nominal force of 100 MN.

To prove the modeling results, the new technology was tested under industrial conditions. After the first forging, it was revealed that the edges of the forging were not formed and the final forging was made via double pressing to ensure it was fully filled. Meanwhile, die vent holes were made at bottom of the die impression to eliminate the air bulbs. After the said die improvement, the "Mounting Bracket" forging was retested and yielded positive results, i.e. the form and size of the die forging conformed fully to the drawing.

Thus, computer modeling provided a basis to substantiate changes in the technological analogue process. As a result of forging under new technology, the new forgings were obtained whose geometry and properties met the normative documentation requirements, and reduction in metal consumption amounted to 5% in the event of a decrease in the forging prime cost by about 30%.

MODELING OF HOT DIE FORGING TECHNOLOGY IN THE DEFORM (USA) SOFTWARE PACKAGE

The "Disc" die forging technology made of an aluminum AB alloy (Figure- 5) was used as a technological analogue process. Meanwhile, a condition was established that upgrading this technology shall ensure increased economic efficiency in the technological process and shall not be accompanied by replacement of the utilized deforming equipment, considerable renovation of the pressing tool, as well as any changes in the form and size of the die forgings.

An analysis of the existing technology was conducted with due regard to the above mentioned limits allowed to define an objective to reduce the number of forging transitions. It was suggested that the number of forging transitions can be reduced via the adjustment of the deformation speed and conditions of contact friction during forging.

Figure-5. "Disc" die forging made of an AB alloy.

The order of the technological process modeling went as follows. After analysis of the current technology, 3D models of the "Disc" die forging and the die (Figure-6) were made using the drawings and SolidWorks program that were then downloaded as files into the computer system pre-processor. After that, the temperature, speed and power deformation modes were entered, which, according to the factory technological process parameters, were as follows: die heating temperature 60-450ºC, blanks heating temperature 400-470ºC, forging speed 2-10 mm/s, and the resistance values to deformation for enlisted parameters were defined using the reference literature [11]. At the conclusion, a forging process database was obtained.

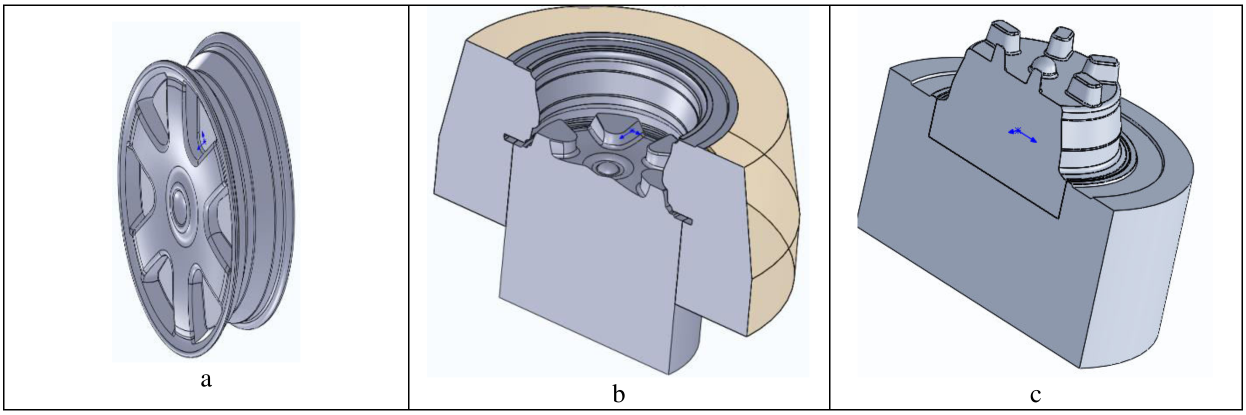

Figure-6. 3D models of "Disc" forging (a) and parts of the die (b, c).

With regard to imposed limits that do not allow changing the die tooling structure and temperature and speed parameters of deformation, the studies on the effect of Siebel friction parameter on efficiency of die impression filling during the forging were conducted. During production, greasing of the die impression (analogue technology) provides the means to ensure a friction value of about 0.7. This value was also used for modeling. To ensure forging in one transition, the experiments were carried out at different friction parameters on lateral and top end surfaces with their variation in the interval from 0.2 to 0.5. Meanwhile, the stroke speed of the press was changed from 3 to 5 mm/s. As a result, it was determined that die impression is uniformly filled in a single transition when the friction value for the top end and lateral surfaces is 0.3-0.4, and, meanwhile, the press stroke speed shall not exceed 5 mm/s.

The program capabilities also provided the means to study the metal flow during filling of the die impression with reference to the deformation force during different forging stages (Figure-7).

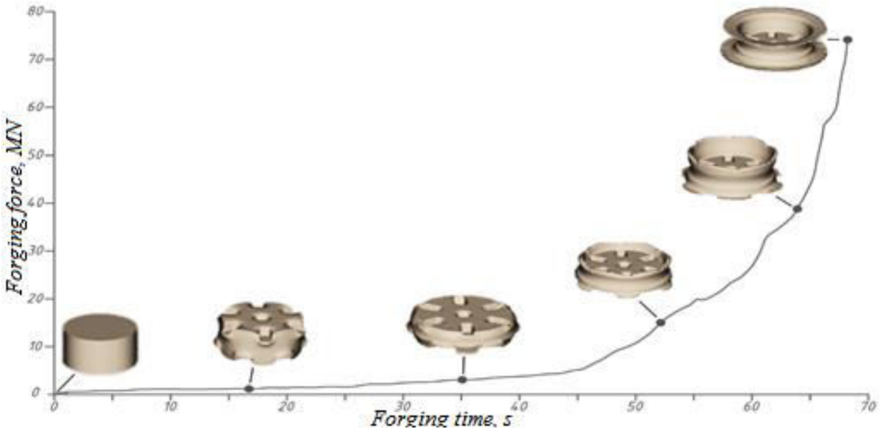

Figure-7. Change in the forging force and blank form during the virtual experiment.

CONCLUSIONS

Thus, computer modeling of the "Mounting Bracket" and "Disc" hot die forging processes provided a basis to substantiate changes in the technological analogue processes. As a result of forging in a single transition under industrial conditions, the forgings were obtained that met the requirements for the geometry as well as the normative documentation requirements with a reduction in the prime cost of their manufacturing of 10-30%.

It should be noted that an increase in the efficiency of the metalware's manufacturing based on computer modeling in the QFORM and DEFORM-3D software packages was also achieved for continuous metal works processes [12–16].

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