UDC 621.73

Analysis of die-forging variants of geometrically complex forgings in Deform 3D package

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Abstract
Analysis of the technological transition, technical and economic indices of three variants of forging a flat forging "Support" with the presence of the cross-sectional differences (material – steel 40 GOST 1050-88) in the Deform 3D package without preliminary profiling, with implementation of a preliminary profiling by upsetting by elongated convex dies with eccentricity and multi-piece forging was carried out. It is found that the introduction of this technology will reduce the stress intensity by 5% and the deformation intensity by 25% in the die of final impression; improve the cavity fill and reduce waste in metal burrs up to 22%.
Keywords: UPSETTING, PRE-PROFILING, CONVEX DIES, DEFORMATION, FORGING, STRAIN RATE, STRESS INTENSITY

Introduction

In modern mechanical engineering and metallurgical industries sufficient attention is paid to the issues related to the modernization of the old processes and the development of new technological processes, which can achieve maximum energy and resource saving with improvement of indices of product quality. In hot bulk forging, the maximum approximation of the workpiece shape to the form of a finished product, that is preliminary profiling, can significantly reduce the loss of material into flash, reduce expenditures for subsequent machining, as well as increase the resistance of forging tools. Issues of workpiece profiling are the most relevant for these technologies, since dies, subjected to intensive impact and abrasion wear, high temperatures and pressures, run in very erroneous conditions [1].

In works [2-4] the authors studied and illustrated the advantage of using upsetting by convex die-tool as a profiling operation before the subsequent forging. However, the nomenclature of currently forged semi-finished products produced by this operation is rather limited, that requires the selection of suitable die configuration and the development of technological transitions taking into account the equipment used. The study of stress-and-strain state and form changing at upsetting by convex radial dies with eccentricity of load was performed by the authors in articles [5-7]. One of forgings, which forging technology improvement is expedient by the usage of workpiece profiling by upsetting by convex die with eccentricity, is a product "Support" (Fig. 1).

Objective

The objective of this work is the development and analysis of variants for forming a flat forging with the presence of differentials (irregularities) of cross-section with the usage of analysis finite element package Deform 3D on the example of forging "Support".

Research

The specified forging is used in mechanical engineering designs. It is experiencing the strain of bending and stretching. Material - Steel 40 GOST 1050 - 88, the weight of part – 3.188 kg, the weight of forging (with machining allowances and overlap of hole designated in accordance with GOST 7505) - 3.4 kg.

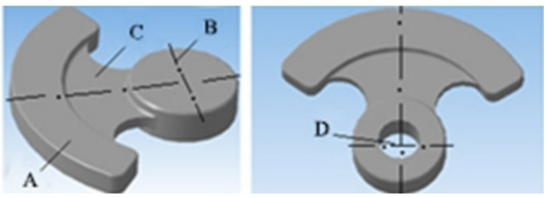
Forging of such forging can be made on the steam forging hammer and crank press for hot forging.

Depending on the variants of production and the equipment used, it is possible to use multiple-impression forging methods. Variants for stamping on steam forging hammer haven't been considered as less rational, from the point of view of material consumption as well as in terms of workshop layout, equipped with crank press for hot forging.

Three variants for producing the forging "Support" were analyzed:

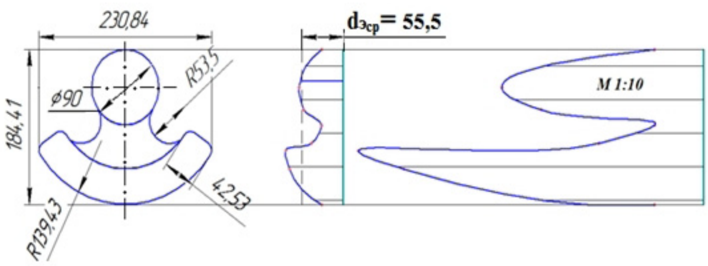
1. The workpiece is subjected to forging without pre-profiling.
2. The workpiece which is profiled with eccentric upsetting by convex die is subjected to forging
3. The workpiece with radial positioning of four forgings is subjected to multiple-impression forging method.

To develop technological processes of the considered forging, the diagrams of its diameters and cross sections were built (Fig. 2).



(a) (b)

Figure 1. Forging "Support" (a) and an part with a hole (b):
A – supporting portion;
B – coupling (fixing) component; C – transient portion; D – the hole in the part

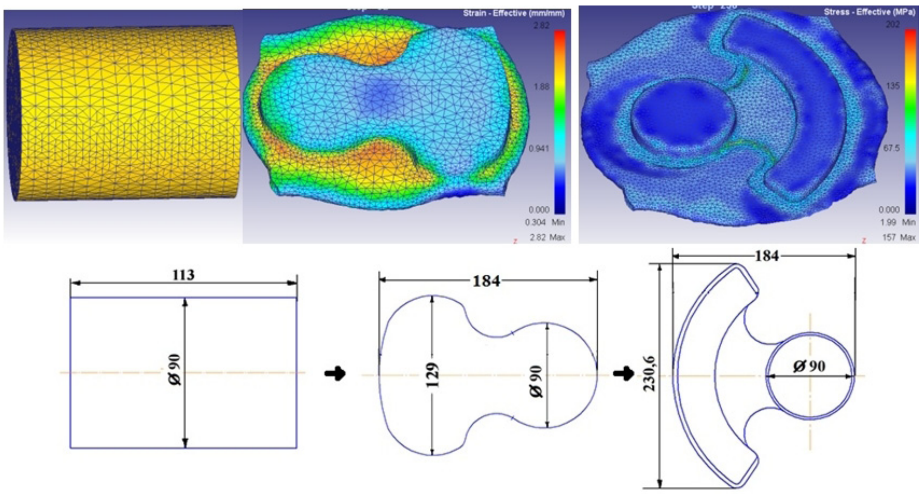


(a) (b) (c)

Figure 2. Forging "Support" (a), diagram of diameters (b) and diagram of cross sections (c)

All simulation variants were performed in a finite element analysis Deform 3D package (license No 8145). Model of hardening, as well as the boundary conditions, was taken in accordance with the terms proposed by the program. The temperature conditions taken isothermal deformation temperature 1100 °C (induction heating). The models were simulated in the software package KOMPAS - 3D.

The first variant of the production of forging "Support" (Fig. 3) includes cutting off the rod with cylindrical workpiece dimensions ∅ 90× 113 mm (weight 5.49 kg), heating, horizontal installation in the blocking impression, preliminary and final forging in the open groove with subsequent flash trimming in hot state at trimming press with tonnage of 6.3 MN. Forging with flash delivery from crank press for hot forging to trimming press is performed by a carrier.

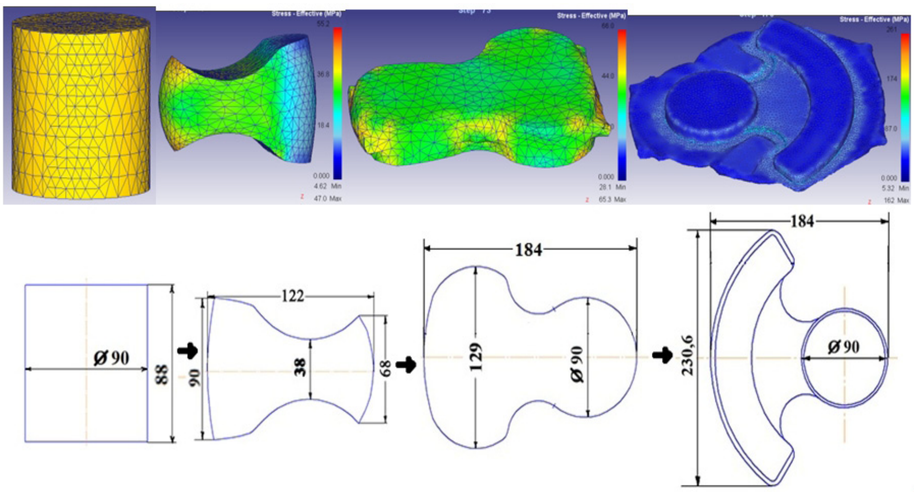


(a) (b) (c)

Figure 3. Forging technology without pre-profiling: a – workpiece; b – preliminary forging; c – finish-forging

The technological process was accompanied by unstable final size of forgings in the supporting portion border area due to under-forging to the desired size. This is explained by the fact that forgings "Support" with a thin blade and the cross-sectional differences require high specific strength (pressure) application on gravure. This is explained by the fact that forging "Support" with a thin blade and the cross-sectional differences require high specific strength (pressure) on the engraving to complete the final design dimensions of the product and the lack of intermediate approximation of workpiece form to configuration of forgings leads to an unfavorable distribution of pressure on the engraving. Large reduction rate and rapid cooling of the blade of a flat forging in the die results in a significant increase in deformation resistance of the metal, which increases the proportion of elastic deformation of the press frame, and results in not finished forging and overestimated thickness of flash.

The second variant included profiling operation of upsetting by convex dies for the approximation of workpiece shape to the geometry of the blocking impression gravure (Fig. 4). This made it possible to reduce the weight of the workpiece from 5.49 kg to 4.277 kg, i.e. to achieve economies of metal of 1.21 kg for each forging 22%. At the same time partial not finished forging was excluded and full design of the blade of the forging was provided.



(a) (b) (c) (d)

Figure 4. Technology with preliminary profiling of upsetting by convex plates with eccentricity: a – workpiece; b – profiled workpiece; c – preliminary forging; g – final forging

To localize the pressure in the area “A” (Fig. 1), to reduce the elastic deformation of the frame press, and to improve filling die impressions, it was suggested to perform upsetting of workpiece by convex elongated (radial) plates with providing of eccentricity of convex axle of plates to the vertical axle of the workpiece (Fig. 4). Similar profiling allows to redistribute the amount of metal on the estimated length of the workpiece (curve diameters) and to provide the distribution of metal volumes between the areas which form areas “A”, “B” and “C” (see. Fig. 1).

The third variant is multi-piece forging of a workpiece with the diameter of 300 mm and the height of 60 mm in a die at a cruciform arrangement of impressions (see. Fig. 5).

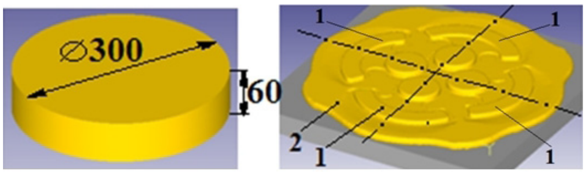
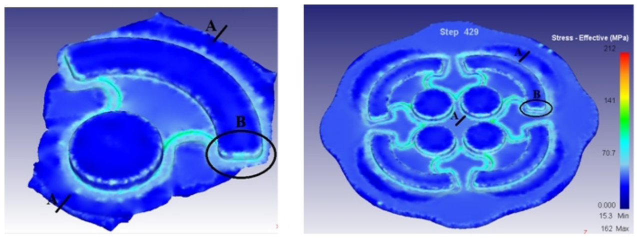


Figure 5. Multi-piece forging:
a – workpiece for multi-forging, b – model of multi-forging;1 – forgings; 2 – flash

Finite-element simulation of the plate forging in the final stage of forging with the scheme of measuring the intensity distribution of the stress-and-strain state in the longitudinal and cross-section is shown in Fig. 6.

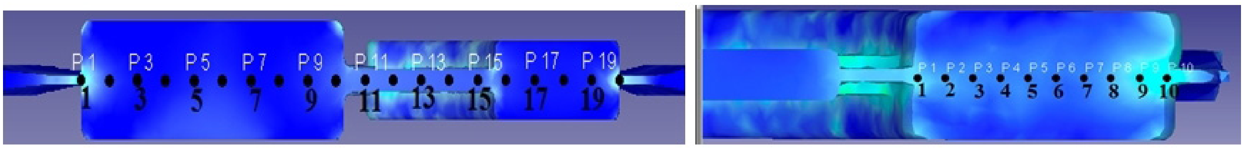
For building a graph of stress-and-strain distribution in cross-section A-A of the forging in the final impression there was selected 20 control points (Fig. 7, a) for measuring and in section B-B - 10 control points (Fig. 7, b) to determine the stress intensity and strain rate.

According to the results of the simulation the graphs of intensity distribution of stress and strain rate in the longitudinal direction (A) and section B on three technologies (Fig. 8-11).



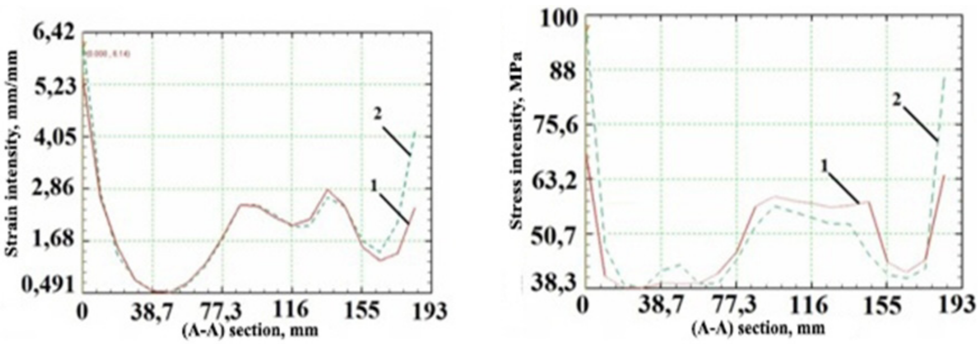
(a) (b)

Figure 6. Finite-element model of final forgings and longitudinal A-A cross section and B-B cross section, which were analyzed for stress-and-strain state:a – single forging; b – multi-forging



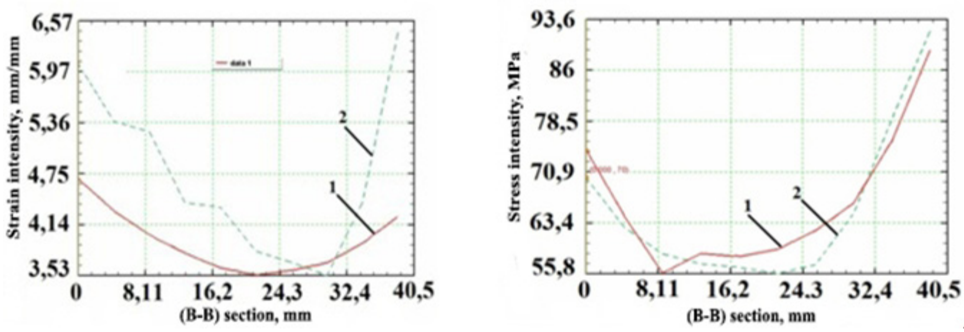
(a) (b)

Figure 7. The point pattern for measuring of stresses and strains in the indicated cross sections:
a – cross section A-A; b – cross section B-B



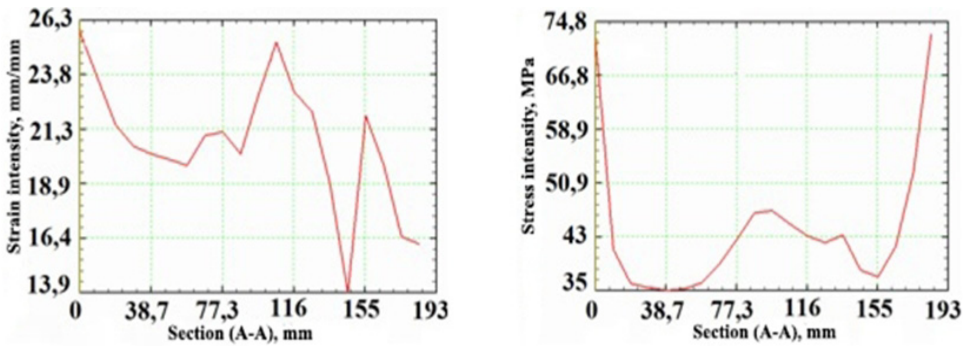
(a) (b)

Figure 8. The distribution of strains (a) and the stresses intensities (b) in the section (A-A) without preliminary profiling (1) and with the preliminary profiling by convex plates with load eccentricity (2) after forging



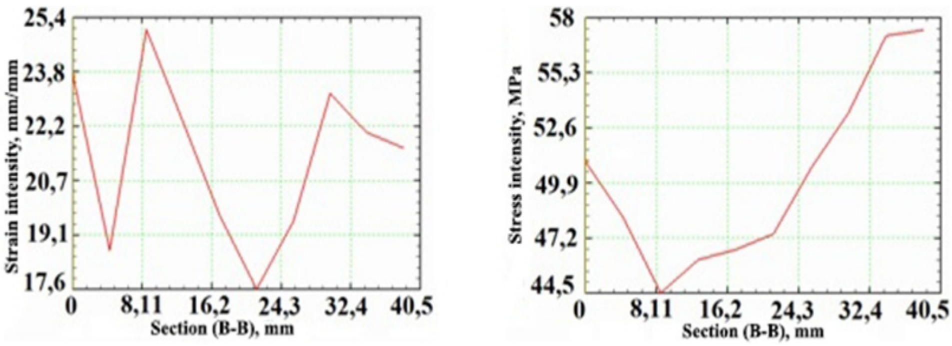
(a) (b)

Figure 9. The distribution of strains (a) and the stresses intensities (b) in the section (B-B) without preliminary profiling (1) and with the preliminary profiling by convex plates with load eccentricity (2) after forging



(a) (b)

Figure 10. The distribution of strains (a) and the stresses intensities (b) in case of multi-forging in section (A-A) after forging



(a) (b)

Figure 11. The distribution of strains (a) and the stresses intensities (b) in case of multi-forging in section (B-B) after forging

The graphs show the drop of stress intensity indices and strain rate in the transition area of the forging (cross-section A-A) by 8% final forging by convex plates with eccentricity of load as profiling operations. In the section B-B one can see the increase in the stress intensity at 5% and strain rate at 25% in the place of flash formation in forging with preliminary profiling by convex plates with eccentricity of load variant, which means better filling of the cavity impression with metal. In the case of multi-forging, on the final stage of forging the highest strain intensity is observed in the coupling section of the forging of 26 mm / mm, and the stress intensity in the supporting portion is 74 MPa.

According to the simulation results, the graph of required force for forging “Support” article according to three variants was built (Fig. 12).

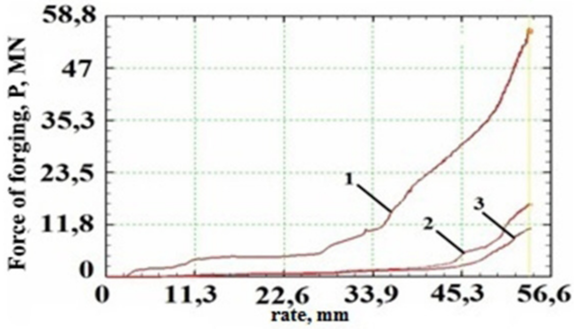


Figure 12. The graph of force required to final forging of «Support» forgings:1 – multi-forging; 2 – forging without preliminary profiling; 3 – forging with application of profiling by upsetting by convex dies

The graph (Fig. 12) shows that the maximum force of 57 MN for the final forging is necessary when multi-forging, and the minimal force is 11.5 MN when preliminary profiling by upsetting with convex dies with the eccentricity of load. According to the results, a table of technical and economic indices of forging "Support" formation was built (Table 1).

Table 1. Technical and economic indices

Indices	Variant of forging technology				
	Forging without preliminary forming (basic)	Forging with forming	% of basic	Multi-forging	% of basic
Mass of a workpiece (Mz),kg	5.49	4.277	77.9	32.39	590
Number of operations (n)	3	4	133	2	66.6
Number of forgings in final impression (m), pieces	1	1	100	4	400
Required force (P), MN	13.7	11.5	83.9	57	416

Thus, stamping with preliminary forming has advantages both in terms of metal economy of forging, and in the usage of less powerful and more energy efficient forging equipment.

Conclusions

Analysis of the technological transition and technical and economic indices of three variants of forging a flat forgings "Support" with the presence of the cross-sectional differences (material – steel 40 GOST 1050-88) in the Deform 3D package without preliminary profiling, with the implementation of a preliminary profiling by upsetting with convex elongated dies with eccentricity of load and multi-piece forging was carried out.

As a result of the simulation it was revealed that the implementation of a preliminary profiling by upsetting with convex dies with eccentricity of load before the forging operation reduces the stress intensity by 5% and the strain intensity by 25% in the gravure of the final impression, improves the filling of die gravure and reduces metal waste flash by 22%.

The implementation of upsetting by convex dies with the eccentricity of load as profiling operation before the subsequent volumetric forging made it possible to reduce required forging force by 17%.

Metal saving when using profiling was 22% of the base technology, the cost of forces is reduced by 16% of the base technology, and the number of operations is increased by one unit. Multi-piece forging requires more force in contrast to forging with profiling. Therefore the cost of equipment increases, but in the final impression we obtain 4 times more of the forged pieces than with the help of base technology.

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