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Analysis of theoretic research of the ring tapered tool penetration with subsequent upsetting in the lining ring while manufacturing a disc with shoulder

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Abstract
In the present paper the results of mathematical simulation of metal form changing, deformation and temperature distribution obtained using the program product «Forge3», had been presented, as well as distribution of stresses in the forged piece section while using the ring tapered processing tool. The given processing tool is used for manufacturing forged pieces such as discs with shoulders by means of smith forging with following upsetting of obtained forged piece in the lining ring to form the final form of the forged piece.
Key words: quality, properties, dependence, forging, billet, upset, tool, ledge

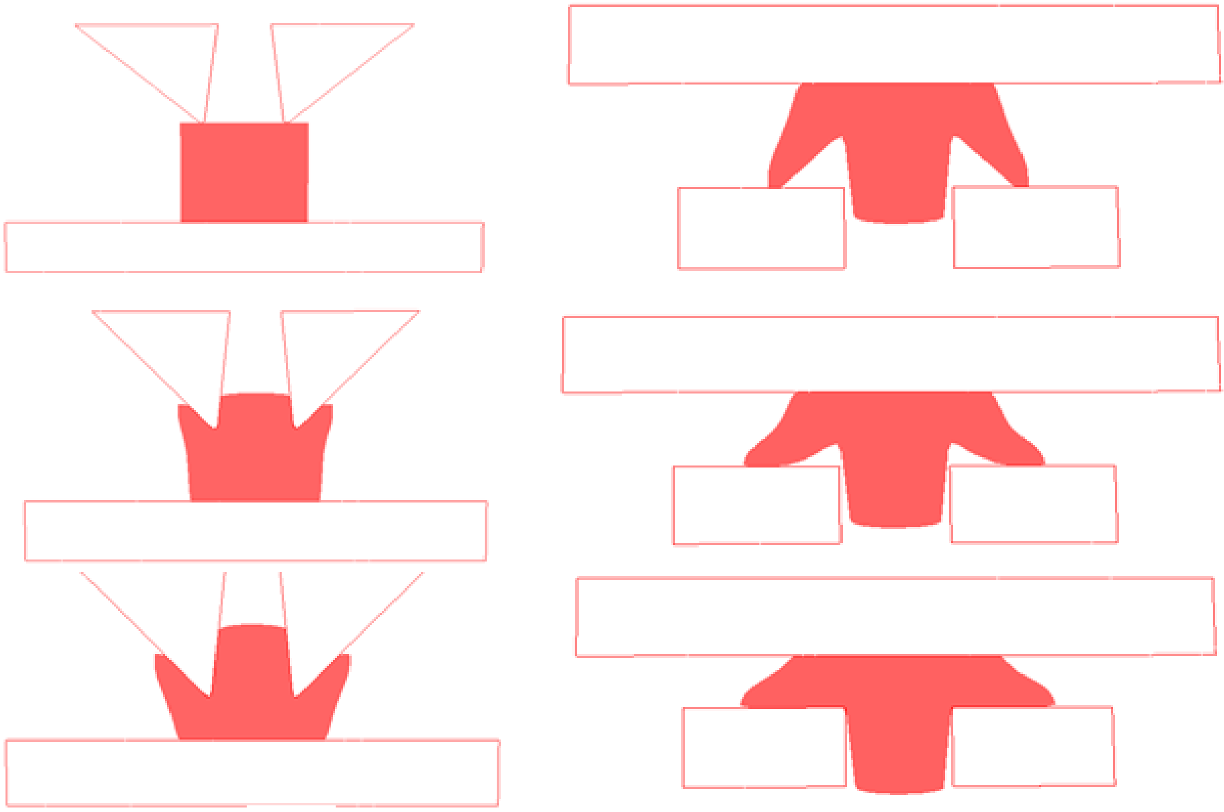
Forging of discs with shoulders falls into metal intensive operations what is caused with large values of tolerances and laps while manufacturing forged pieces of the given type. This results in turn in big waste of metal during the subsequent treatment (machining) of the given product. The main metal expendable operation is the removal of the forging lap, which is specified while obtaining a disc with shoulder in the case when the shoulder's height exceeds by several folds the height of the disc's blade. Then the part of shoulder, which can't be obtained by means of the extant technology, namely by upsetting in the lining ring, is covered with forging lap to be removed by machining. In this way, using the processing tool "cut–in ring" is actual, because it allows to obtain the form of a forged piece maximum close to dimensions to the finished product. This is possible at the expense of the rational changing of the forged piece's form during penetration of the ring what gives possibility not to specify the forging lap while manufacturing discs with shoulders of given type and to reduce metal consumption in production.

Presentation and analysis of the experimental investigations of using the processing tool "cut–in ring" were examined by authors of [1]. They described the influence of external angle of taper in "the cut–in ring" on the final height of a forged piece at the first stage of experiment. This stage consisted in penetration of the "cut–in ring" with different angles of taper. The experimental investigations, namely, investigations of the influence of internal angle of taper on the final height of the shoulder had been analyzed in [2].

The task of the research consists in estimation of results of mathematical simulation and comparing them with obtained data of experimental investigations. These experimental investigations had been carried out using the processing tool "cut–in ring" while manufacturing discs with shoulder of the height, which exceeds in several folds the height of the disc's blade, without specifying the forging lap.

The aim of the work consists in comparing the results of experimental and theoretic research on the base of metal form changing in the course of penetration of processing tool "cut–in ring" into cylindrical forged piece with subsequent upsetting of the latter in the lining ring. As a result of mathematical simulation a number of data was obtained, such as temperature, degree of deformation and stresses in the cross section of a sample after each stage of technology proposed for manufacturing the given discs type.

Transitions of the proposed practice of manufacturing discs with shoulder while using the processing tool "cut–in ring" are presented in the Fig.1.



a b

Figure1. Transitions of the new technology of manufacturing discs with shoulders [3]
a) the first stage (penetration of the "cut–in ring);
b) the second stage (upsetting in the lining ring)

The program of computer simulation "Forge – 3" of the company "Transvalor" (France) had been chosen for the further theoretic research of the metal form changing. Investigations had been carried out jointly with the colleagues from the Chęnstochowa Polytechnical University in the frame of the Contract about collaboration with NMetAU.

Description of the model for the process of metal form changing while simulating the set problem: in description Amonton friction law was used; the theory of plastic flow in the incompressible media by Saint–Venan – Levis – Misses was adopted; the problem is considered to be 3D (three dimensional).

The condition of stationarity for the functional of the mixed variation principle was used to obtain the solution in the program "Forge 3":

$$J = \frac{1}{2}\int_V \sigma_S\, \dot{\varepsilon}_j\, dV + \int_V \sigma\, \dot{\varepsilon}_0\, dV - \int_F \sigma_\tau\, u_\tau\, dF\,,$$

where $\sigma_S(\varepsilon_i, \varepsilon_j, t)$ is the dependence of the yield stress σ_S on the intensity of the strain rate ε_i, intensity of deformation ε_j, and temperature *t*; *V* – metal volume; σ_τ and u_τ - friction stresses and rate of metal sliding along the tool; F surface of the metal contact with tool.

Dependence $\sigma_S(\varepsilon_i, \varepsilon_j, t)$ is chosen for specific materials from the literary data or according to results of the plastometric tests.

The program uses the finite elements in the form of tetrahedrons with linear approximation of the average stress and piece–linear speed approximation (according to the angle nodes of the element and the node in its center of gravity [4].

The following indices were chosen as initial data: the heating temperature of the die forging: T=1200ºC; the temperature of tool: T=50ºC; dimensions of the die forging: D_f =400mm; H_f=400 mm; the speed of the tool lowering: V=60mm/s; the grade of the working piece steel is St45.

Figure2. The mathematical simulation of the "cut–in ring" penetration

The schema presented in the Fig.2 agrees with №9 of the complete factor experiment [2]. The "cut–in ring" used in the experiments had the following geometric form: αin – 6˚ (αвн. о - 6 о); αext – 45˚(αнар., о - 45 о); dopn – 25mm (dотв. - 25мм); h pen (hвнедр)– 2/3 of the die forging height.

Steel grades were chosen proceeding from condition of rheologic similarity, as in the course of experimental investigations they used lead of the grade S1. The reason is that the form changing of this material at the plastic deformation agrees with form changing of the steel St45 at the hot plastic deformation [5].

Figure 3. The comparison of geometry of samples obtained after the first stage
a – the appearance of a sample obtained by the way of mathematical simulation;
b – the appearance of a sample obtained by the way of experiment

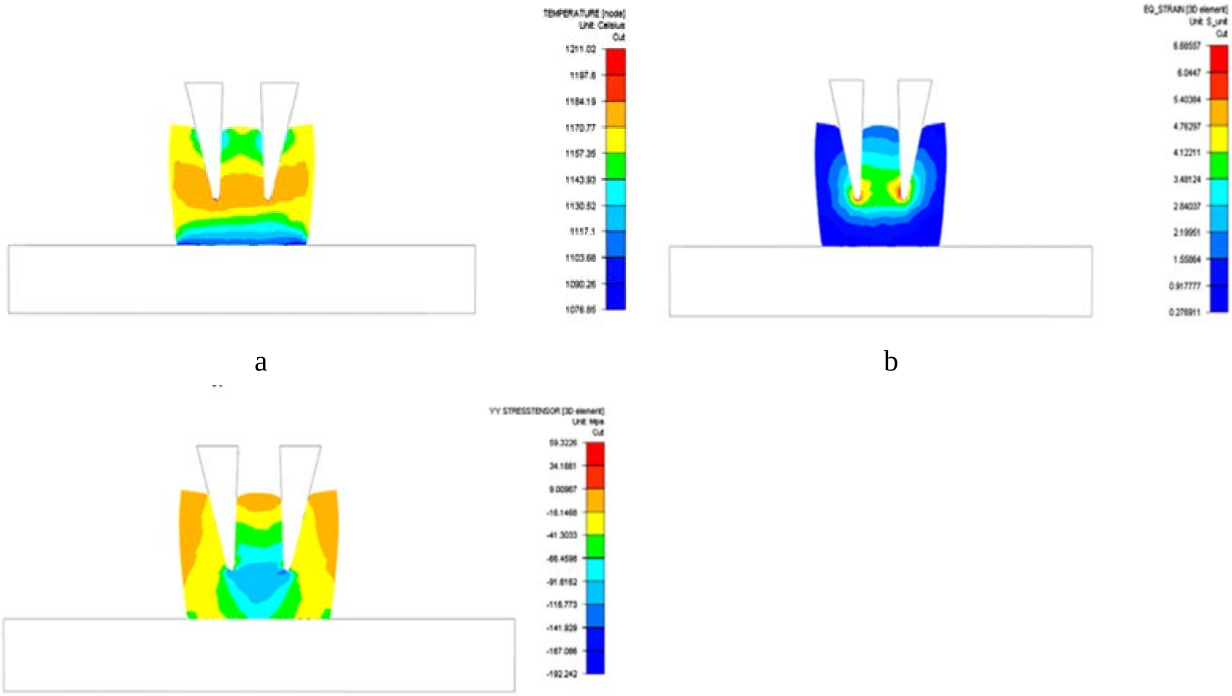


Figure 4. Results of mathematical simulation of the “cut–in ring” penetration
a – distribution of temperature;
b – distribution of deformation;
c – distribution of stresses

While analyzing Fig.3 one can state viewing the identity of geometric parameters in cross sections of samples obtained as a result of mathematical simulation and samples obtained by the way of experiment. In turn, this confirms the validity of the choice of boundary conditions in the course of simulation as well as the fit of software to be used.

Results of mathematical simulation for the first stage of technology during penetration of the “cut–in ring” are presented in the Fig.4. These results allow assessing schemas of temperature and deformation distribution in cross section of a sample.

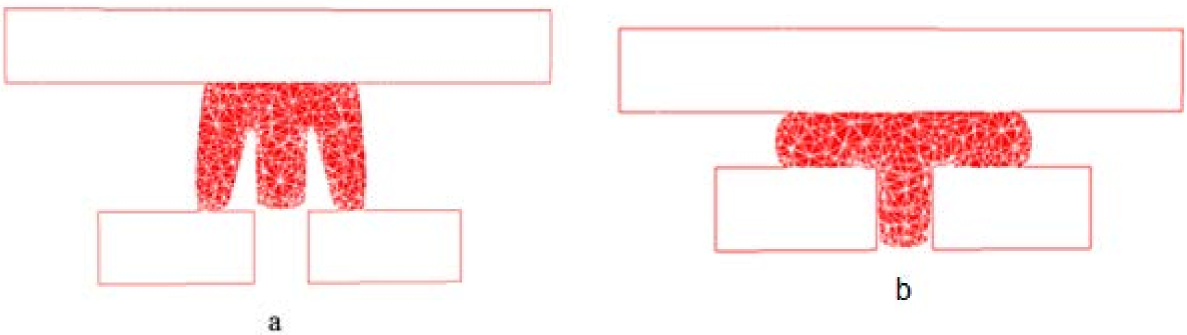


Figure 5. Mathematical simulation of upsetting the obtained sample in the lining ring.

While simulating the second stage, which is presented in the Fig.5, they introduced the boundary conditions only for the tool; these are: tool’s temperature, coefficient of friction and conditions of the heat exchange between die forging and tool. As to the die forging, all characteristics of the latter had been carried over after the first stage by means of the function of grid import. While using this function the die forging is carried over with all the changes appeared in consequence of the first simulation; these are: the carry of the grid, values of the temperature, deformation stresses, and so on.

Figure 6. Comparison of geometry of samples obtained after the second stage
a – appearance of a sample obtained by the way of mathematical simulation;
b – a sample obtained by the way of experiment

Analyzing Fig.6, it is possible to note that the resemblance between cross sections of obtained samples is also viewed in the course of mathematical simulation of the second stage of technology to be used. In turn, this also confirms the validity of the choice of boundary conditions while carrying out the simulation.

Results of the mathematical simulation of the second stage of technology are presented in the Fig.7. The second stage consists in upsetting an obtained die forging in the lining ring. Presented data allow also assessing the distribution of temperature and deformation in the cross section of a sample.

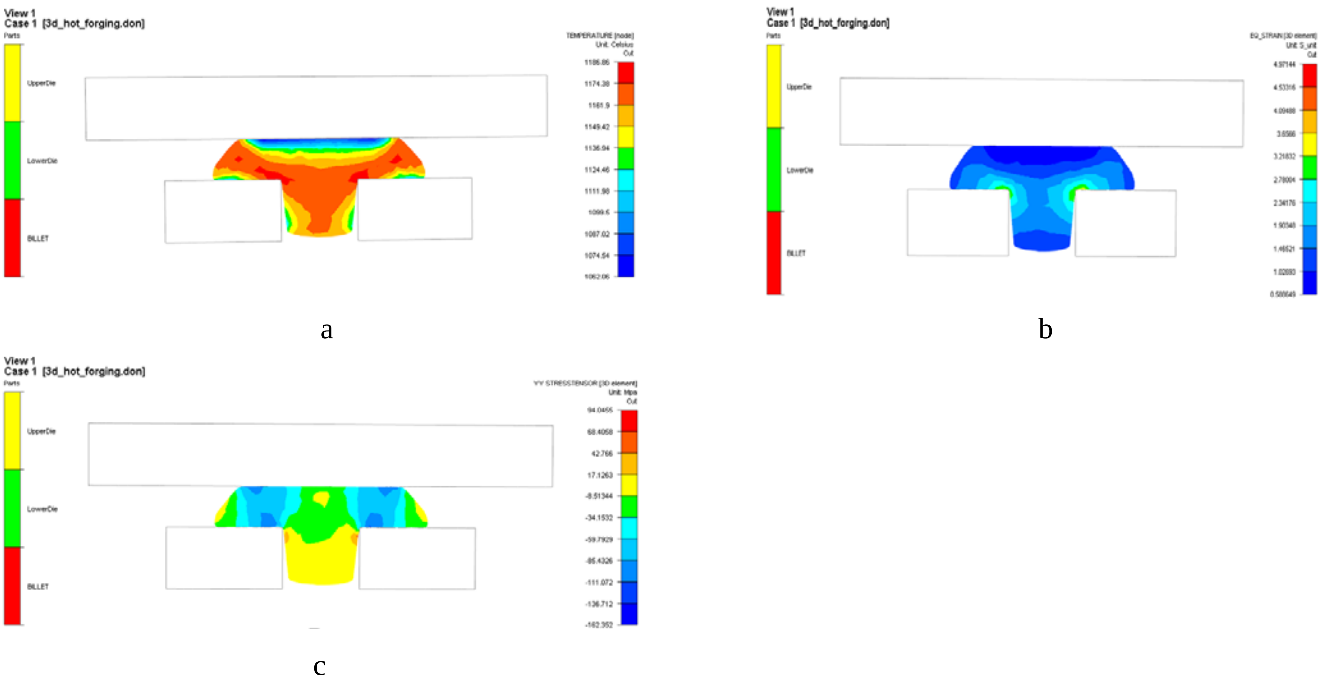


Figure7. Results of mathematical simulation of upsetting in the lining ring:
a – distribution of temperature;
b – distribution of deformation;
c – distribution of stresses

Conclusions

Manufacturing discs with shoulder while using the processing tool “cut–in ring” allows obtaining the die forging for such type of products with minimum forging lap. In this connection appeared necessity of performing the mathematical simulation for assessing the presented technology.

Comparison of experimental results of obtaining discs with shoulders while using the processing tool “cut–in ring” with subsequent upsetting in the lining ring with data obtained by the way of simulation using the software “Forge 3” shows good repeatability of results. This confirms the validity of chosen software and input of boundary conditions.

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