Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 18
ISSUE 1-2
September–October
2006

The new forging process of a wheel hub drop forging

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Received 15.03.2006; accepted in revised form 30.04.2006

Manufacturing and processing

ABSTRACT

Purpose: The main purpose of the research was working out a new flashless forming process of wheel hub forging in three-slide forging press (TSFP). It was assumed that the new process would be more effective than the forging processes applied in typical forging machines.
Design/methodology/approach: The designing of the new process was based on the simulation by finite element method with the assumption of 3D state of strain. Calculations were made mainly for the analysis of the material flow kinematics and the process loads parameters. Experimental research were also made determining the dependency of clamping load in the function of forming load. On the basis of the analysis, the forming process of a wheel hub drop forging on the TSFP was worked out.
Findings: The results of research confirmed the possibility of flashless forming process of wheel hub forging in TSFP with axial cavities. The main parameters limiting the forming processes of wheel hub forgings are: permissible upsetting ratio and reciprocal relation of forming and clamping forces.
Research limitations/implications: The further research within the range of determining force parameters for different types of material and schemata of forming in TSFP were considered as purposeful. The works dealing with analysis of forming processes of different types of products in order to classify drop forgings possible to form in this press will be examined.
Practical implications: The comparison of the new forming process with the forging process on hammer showed majority of advantages which include: decrease of time and energy, decrease of drop forging weight and machining, decrease of material consumption.
Originality/value: The new process of wheel hub forging forming with axial cavities was worked out. The parameters important during designing of forming processes in TSFP were provided. The relations between forces of forming tools were also determined.
Keywords: Plastic forming; Wheel hub drop forging; Three-slide forging press

1. Introduction

The forgings of wheel hub type are often made by means of drop forging processes realized on hammers or presses. Due to the necessity of weight lowering, these forging types are often manufactured from aluminum alloys. Forming of parts from these alloys is a specific process and it differs from steel forming processes [1÷7].

The big changeability of aluminum alloys properties within the range of the applied forming parameters results in difficulties in the process design. The majority of aluminum alloys' forgings are made by means of forging process with flash. The degree of complex forging geometry decides about the amount of heating and type of the applied tooling. The forgings with a complex geometry, ribbed, which need a precise preforming, are forged in preforming impression, and next, after the damages removing and reheating they are forged in forming impression. In the forming process of less complex forgings, which are made in small series, the application of preforming impression is usually omitted. Preforming operation is made in forming impression with several millimeters of underfilling. After the damages removing and reheating, it is finally made in the same impression. In case of enlarged forgings, the preforms are rarely used despite difficulties in their obtaining. For the preforming of material, enlarging and rolling impressions are not applied. The operation of this type causes fast lowering of material temperature and the overlapping creation as a result forging with rotation at the same time. Because of that, workpiece in the form of a bar with the section close to the biggest forging section is used [1].

A significant value of material cost in the general cost of manufacturing of aluminium alloys' forgings causes that main directions of modernization of their forming technology aim at looking for material saving solutions. In the case of elongated forgings the effective solution may be the application of three – slide forging press (TSFP). This press is equipped with three slides independent in case of movement and force driven by hydraulic cylinders. One of these slides moves in vertical direction the other two move in horizontal direction. This TSFP design makes it useful for forming of elongated forgings with thickenings in a chosen areas and with the axial cavities. Due to these possibilities, a bar of section size adjusted to the shank section of elongated forging can be used as charge. Certain types of elongated forgings can be finally formed in one working cycle of the forging press. An example of this type of forging is wheel hub drop forging which forming process on TSFP is described in this paper.

2. Chosen aspects of designing of new technology of wheel hub drop forging

2.1. Applied forging technology

InFig. 1, shape and dimensions of the wheel hub forging formed on hammer are presented. Drop forging is made of AlCu2SiMn aluminum alloy. Chemical constitution of this alloy is given in Table 1.

As a charge for forging of part presented in Fig. 1 is a bar of circular section of dimensions Ø45x115 mm. The schema of a line. —··— and dimensions in brackets concern the final part.

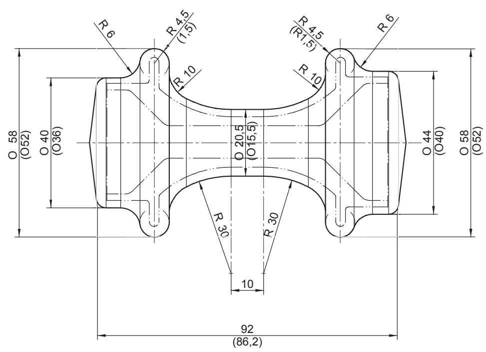

Fig. 1. The wheel hub forging made by means of forging on hammer; forging inclinations 7°, not given radii R3

Table 1.
Chemical constitution of AlCu2SiMn alloy (wt. %)

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Inne	Al
0,7-1.2	0.7	1.8-2.6	0.4-0.8	0.4-0.8	0.2	0.1	0.2	0.1	≤0.15	rest

In Fig. 1, shape and dimensions of the wheel hub forging formed on hammer are presented. Drop forging is made of AlCu2SiMn aluminum alloy. Chemical constitution of this alloy is given in Table 1.

Fig. 2. Other phases of the wheel hub drop forging forming process on hammer: a) charge, b) upsetting, c) forging in preforming impression, d) forging in forming impression, e) final forged parts, f) flash

As a charge for forging of part presented in Fig. 1 is a bar of circular section of dimensions Ø45x115 mm. The schema of a typical forging process on hammer of the discussed forging consists of the following phases (Fig. 2):

- initial upsetting of a bar charge of circular section (Fig. 2b),
- forging in preforming impression (Fig. 2c),
- forging in forming impression (Fig. 2d),
- flash trimming.

2.2. Design of drop forging formed on TSFP

The presented forging process of wheel hub drop forging can be evaluated as time and material consuming. In order to lower the manufacturing costs the forming process of the discussed forging can take place in TSFP. A new shape and new dimensions of the wheel hub drop forging possible to make in TSFP were designed (Fig. 3). The introduced differences in the forging design, lowering its weight in comparison with the weight of forging made on hammer, are as follow:

- smaller technological allowances due to the precise tool guiding,
- forging inclinations were omitted,
- forming of two axial cavities were taken into consideration.

The shape of forging imposed also adding technological allowances in the shrank part. The head diameters equal Ø38 mm and Ø42 mm are too big to realize the process by means of upsetting in impression. Using as a charge a bar with diameter Ø20.5 mm, which is equivalent to the diameter of shrank forging necking presented in Fig. 1, the condition of upsetting in cylindrical impression $D/d_0 \leq 1,5$ is considerably exceeded (D – diameter of impression, d_0 – diameter of charge) [8, 9]. Because of that it was assumed that the diameter of the formed on TSFP shrank forging was Ø24 mm. Using a charge of the same diameter, the upsetting ratio for forgings heads do not exceed 2.6. These geometrical parameters meet the limiting conditions of upsetting which guarantee the process stability. During forging design the shrank part of reel shape was changed into cylindrical shape, which considerably improves the stability of charge position in the impression. For the designed forging a charge in the form of a bar of diameter Ø24×155 mm should be used.

2.3. Forces in the forging processes on TSFP

Very important technological parameters in the forming processes are forming forces especially on TSFP [10÷14]. At the inadequate relations of values of horizontal and vertical forces a flash is made because of the material squeezing between dies. Hence, the experimental research were made, in which dependency between the forming and spacing forces was determined for the case of one side free upsetting of a circular section bar. The experiment was based on measuring of horizontal force (upsetting force) F_h and vertical force clamping the dies F_v, for limiting cases in which there was no flash. In Fig. 4 the obtained results are presented. The measuring points were marked by circles which show the linear dependency. In the result of approximation of experimental results by means of linear equation the following dependency was obtained:

$$F_v = 1,411 \cdot F_h \,, \qquad (1)$$

which for the analyzed case is the limiting condition (full line in Fig. 4).

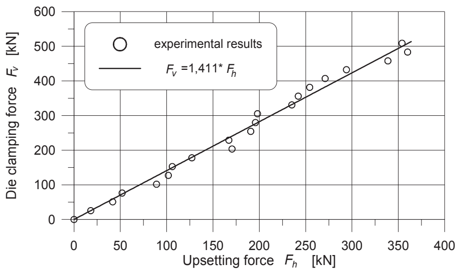

Fig. 4. Upsetting force vs. die clamping force for the case of one side bar free upsetting on TSFP

This means that the die spacing force F_s is of about 40% bigger than horizontal force F_h upsetting the bar. However, it should be noticed that during designing of technological processes a certain coefficient of safety should be considered and a bigger value of vertical force F_v than the value determined by Eq. (1) should be applied.

2.4. FEM model

Designing of a new technology of the wheel hub drop forging manufacturing is based on the FEM simulation. Taking into consideration theoretical results, the tools were designed and process force parameters were determined. The material model of AlCu2SiMn was made basing on the modified inverse method of calculations. Using their results, the Eq. (2) (describing relation between flow stress and strain parameters) was determined [15]:

$$\sigma_p = 369,13 \cdot \varepsilon^{-0,003} \cdot \exp(0,114 \cdot \varepsilon) \cdot \dot{\varepsilon}^{0,0044} \cdot \exp(-0,00364 \cdot t) \qquad (2)$$

where:
ε – equivalent strain,
$\dot{\varepsilon}$ – strain rate [1/s],
t – temperature [ºC].

The friction conditions during hot forming for the pair of materials: aluminum – tool steel were described by the constant friction model, with the assumption that friction factor m=0,5 [1]. The kinematics of material flow, its values and course of forming forces were analyzed.

3. Description of results

In the Fig. 5, the shape of forging in the final stage of process obtained by means of FEM simulation is shown. The calculations confirmed the rightness of the process course and tools design.

The designed forging process was verified in experimental way. In this research, the clamping force equal 500 kN and the forming forces equal 200 kN were applied. The force pressure of horizontal punches forming axial cavities were calculated by FEM. Yet, the spacing force was calculated with the Eq. (1), as the sum of spacing forces created by both horizontal punches pressure. In the result of the experiment, the drop forging with proper shape and without lacks was obtained (Fig. 6).

The applied technology improved the economic factor of this process due to the following advantages:

- decrease of energy, time and work consumption due to the elimination of upsetting, preforming and flash trimming,
- decrease of forging weight more than 34% and decrease of machining time due to the smaller technological allowances and axial cavities forming,
- decrease of material consumption more than 62% thanks to the mentioned above advantages and flashless forming together with diminution of cutting losses more than 71% and increase of cutting productivity connected with diminution of charges diameter,
- decrease of tools cost due to smaller dies overall dimensions and elimination of tools for flash trimming operation.

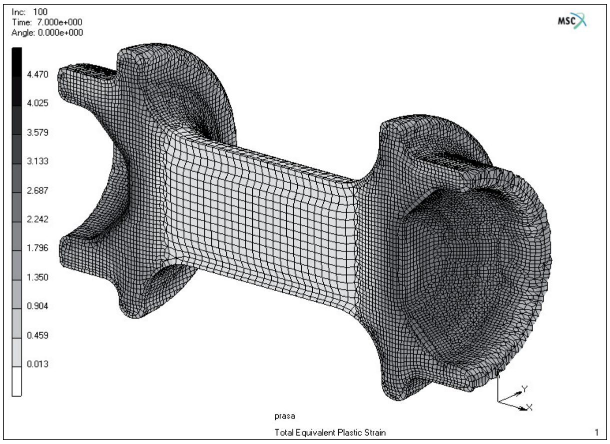

Fig. 5. The section of wheel hub drop forging with equivalent stress distribution – result of FEM simulation

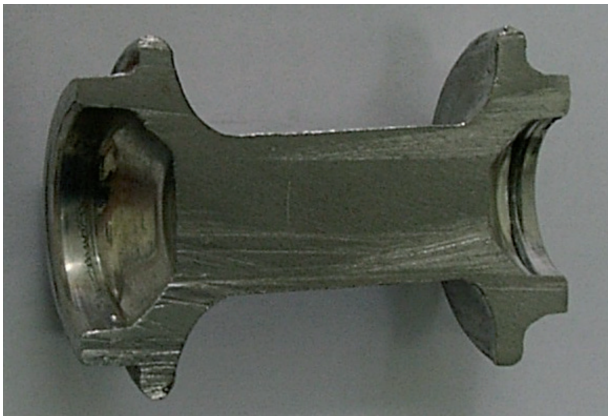

Fig. 6. Section of wheel hub drop forging obtained in experiments

4. Conclusions

On the TSFP is possible realization of the effective forming processes, which have worse economical effectivity in other machines. The TSFP application allows for forging of typical elongated forgings with thickenings and axial cavities at the ends of these parts. The results of made research show significant position of reciprocal forces relations, caused by particular forming tools. The relations between these forces values decide about the precise impression filling and correct clamping of particular tools, which counter-act the flash creation. In the analyzed upsetting process it was stated that die opening forces are about 1.4 times larger than the upsetting force. This condition is a base for determining of force parameters for forging with the assumed quality forming, in which the upsetting process is dominating.

Basing on presented forming process of wheel hub drop forging on TSFP it should be stated that obtaining of good economical effectivity is caused by many advantages of TSFP. First of all, the possibility of thickenings and cavities forming in both sides of the forging allows for application of lower technological allowances, than in other processes. Besides material saving, it causes a significant decrease of machining time and increase of mechanical properties of drop forgings. Moreover, the process is realized without flash during one working cycle of the press, which decreases time and energy consumption. Additional cost lowering is obtained by the application of charge with smaller diameter, which results losses of material and operation time diminution and increases tools durability.

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