The new forging process of a wheel hub drop forging

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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

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.

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](image)

Table 1.

<table>
<thead>
<tr>
<th>Element</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Ni</th>
<th>Zn</th>
<th>Ti</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>wt. %</td>
<td>0.7</td>
<td>0.7</td>
<td>1.8</td>
<td>2.6</td>
<td>0.8</td>
<td>0.8</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>5</td>
</tr>
</tbody>
</table>

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](image)

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
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]:

\[
\sigma_p = 369.13 \cdot \varepsilon^{-0.003} \cdot \exp(0.114 \cdot \varepsilon) \cdot \varepsilon^{-0.0044} \cdot \exp(-0.00364 \cdot t)
\]

where:
- \(\varepsilon\) – 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.
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.

References