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NUMERICAL INVESTIGATIONS REGARDING NECESSITY OF PREFORMING STEPS FOR HOT CLOSED DIE FORGING OF AXISYMMETRICAL PARTS

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ABSTRACT

In this study investigations regarding necessity of preforming steps at hot closed die forging are conducted. Condition for necessity on the base of works done was used. Numerical simulations were carried out in order to confirm analytical calculations. The results show decreasing of tool wear and increasing of tool life by using of abovementioned condition.
Keywords: *preform design; closed die forging; finite element analysis*

1. INTRODUCTION

The recent development of the technologies, the economic situation, the continuous changing of costumers' necessities and expectations are factors which define the necessity of short terms for designing of more complex and more accurate products as well as low manufacturing costs. This require the improving both products and manufacturing processes in connection with technological, economical, ecological and ergonomic conditions.

Current investigations and developments in forging area direct their efforts towards searching of new materials, new system and technologies for processing, modern methods for die designing, numerical and model simulation of forging and computer-aided process planning.

On a worldwide scale, the main requirements for the forging products are determined from automotive and aircraft industry, which are their main consumers. These industries have big opportunities for development, but recently they define another trend line – middle and small-scale manufacturing. This fact put additional necessity of improvement of forging processes and ensuring of their flexibility.

Hot closed die forging is still one of the most frequently used for manufacturing of discrete metal parts. The process is also part of above mentioned trend line. The designers pay special attention to the opportunity to obtain more accurate forging parts and appropriate optimizing techniques for decreasing of tool-wear.

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2. NECESSITY OF PREFORMING STEPS

As it is known, the process of hot closed die forging of complex part is not always possible to perform at one step. Often this is possible, but not rational from the point of view to increase tool life and minimize manufacturing costs or to ensure adequate filling of forging die and the desired quality and accuracy of the workpiece.
In practice, engineers determine the necessity of preform steps on the base of the manufacturing experience, the expert valuation or the base of trial - error method.
In this article, the investigated forgings are selected according to the classification given in [1]. The necessity of preform steps was defined by shape complexity factor, proposed in [2] by Tomov and improved later in [3]. The shape complexity factor is based on the comparison of the work done during the forging in to the final die-impression when a forging part of revolution is forged, with the work done for forging of an imaged pancake preforging with the same volume but with a height determined under the condition of the volumes constancy. The necessity of preforming stages for die forging depends on the condition:

$$W_F^* = (1 - K_1).\varphi_A + K_1 > \varphi_H \tag{1}$$

If the equation (1) is satisfied, preform step is necessary. In the condition (1)

$$K_1 = V_{AD} / V_0 \tag{2}$$

$$\varphi_H = \ln (H_0 / H_{AV}) \tag{3}$$

$$\varphi_A = \ln\ (A_F / A_P)^2 \tag{4}$$

In the equations (1), (2), (3) and (4), K_1 describes the amount of the transformed volume during two arbitrary stages of forging, φ_H is the logarithmic height strain and φ_A is the logarithmic strain on the area of cross section. The other notations are:

W_F^* - dimensionless deformation work done;
V_{AD} - the added volume;
V_0 - the volume of the forging part (not including the flash amount);
H_{AV} - the average height of the forging part;
H_0 - the height of the initial billet;
A_F - area of the forging part;
A_P - area of the initial billet.

The work done is basic influential factor and it determines the tool wear and limit tool durability. For this reason using of work done as a criterion for complexity of specific forging is expedient and gives an account of the conditions for decreasing of wear of final die impression.

3. EXPERIMENTS AND RESULTS

In this paper eleven different forgings have been investigated, shown on the Figure1. Calculations according condition (1) was made for each investigated part. The values of the computed members of (1) and conclusions in respect of necessity of preforming steps for every studied part are shown in Table 1.

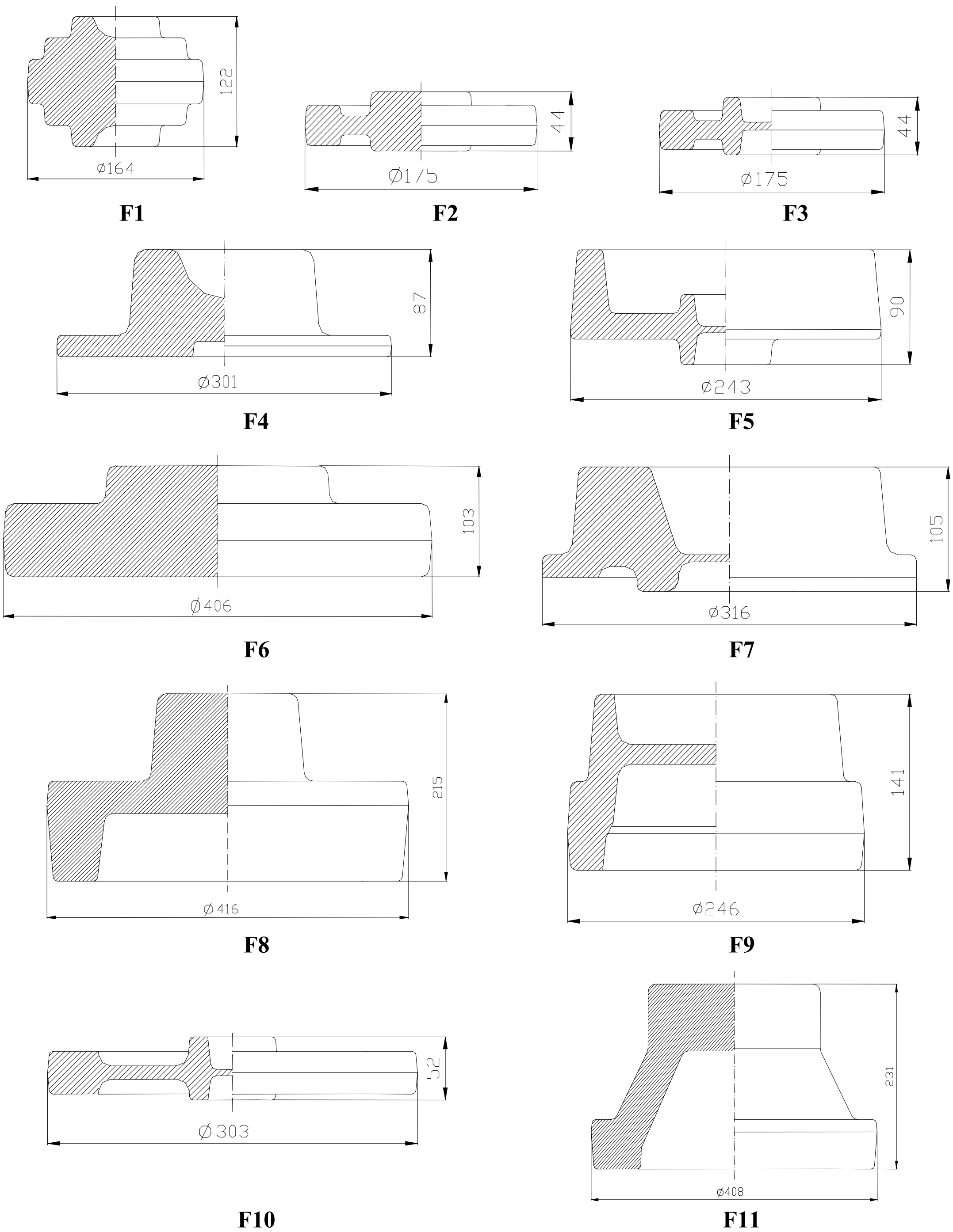


***Fig.** 1 - Investigated forging axysimmetrical parts*

The derived values and their comparison indicate the necessity of preform steps for seven forgings. For the other parts, upsetting prior to forging in final impressions is sufficient. Inclusion of the forging F6 is not an accidental choice. It is evident that this shape will not require preform step, but was used like an additional verification of the condition (1).
For the forgings that require preform steps, shape of these steps was constructed according to a broadly used rules, pointed out in [4]. Preform steps are shown on the Figure 2.

Table 1 *The values of the computed K_I, φ_H, φ_A and W_F*.*

Preform	K_I	φ_H	φ_A	W_F*	Necessity of preform
F1	0,440	0,452	0,0882	0,489	Yes
F2	0,491	0,446	0,0807	0,532	Yes
F3	0,440	0,435	0,435	0,684	Yes
F4	0,575	1,531	0,644	0,849	No
F5	0,873	0,836	0,673	0,958	Yes
F6	0,158	1,411	0,645	0,701	No
F7	0,601	0,468	0,382	0,753	Yes
F8	0,632	0,951	0,511	0,820	No
F9	0,951	0,989	0,833	0,992	Yes
F10	0,857	0,385	0,308	0,990	Yes
F11	0,341	1,230	0,512	0,678	No

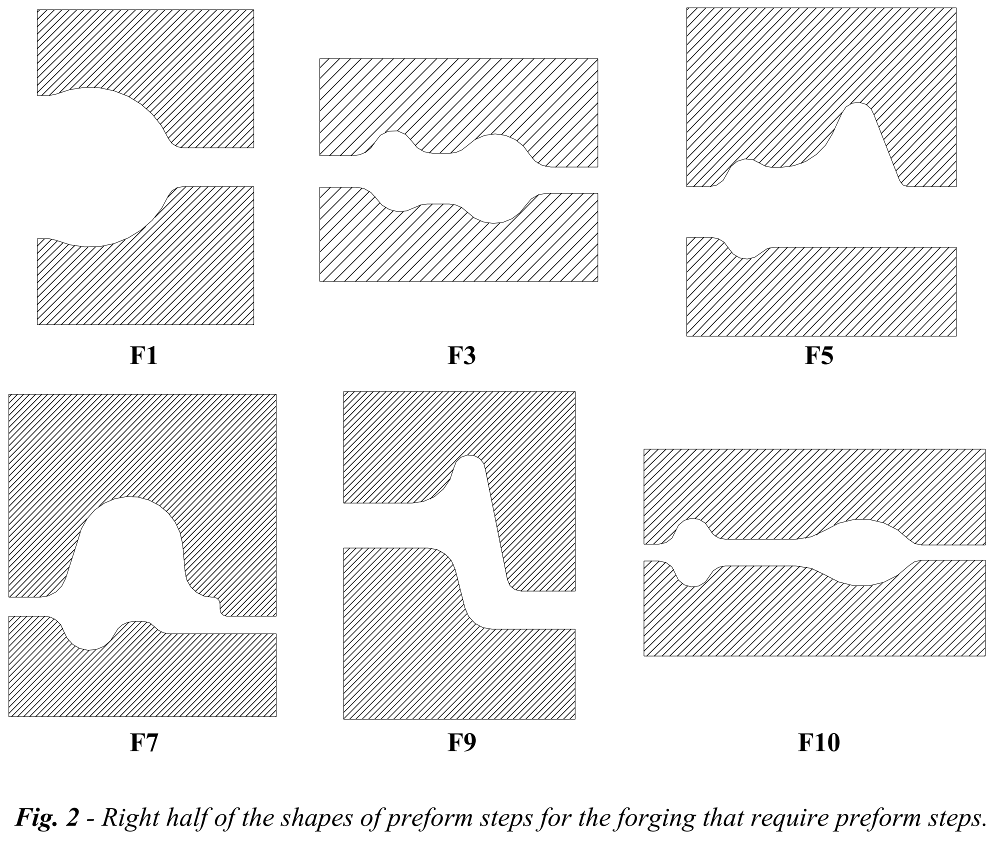
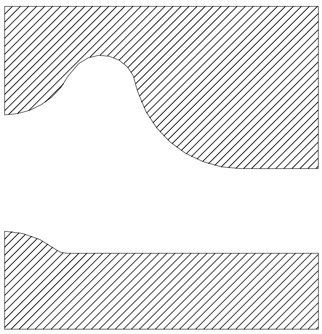


Fig. 2 *- Right half of the shapes of preform steps for the forging that require preform steps.*

In order to study correctness of used criterion for necessity of preform steps computer simulations by finite element method have been curried out. For the forgings F1, F2, F3, F5, F7, F9 and F10 two different cases were researched. The first one was simulation of hot closed die forging in final impression with preform, in correspondence with Figure 2. The second numerical experiment was forging in final impression after flat upsetting of initial billet. The simulations were performed using following initial conditions:

- Forged material – low-carbon steel C15;
- Initial forging temperature - T_F =1200°C;
- Temperature of the die - T_T=300°C;
- Lubricant - emulsion of graphite and water;
- Forging machine - hydraulic press;
- Deformation velocity - V_F = 15 mm/s.

In order to asses the effect of the different preform shapes (flat or according to Fig.2) on the works done of the final impression, data for their values have been calculated and shown in theTable 2. Although it is not necessary to employ a preform step for forging F4 in conformity with (1), preform step for this part was also designed. The shape of this preform is shown on the Figure 3.



F4

Fig. 3 - *Right half of the shape of preform step for the F4 forging*

Data for works done after the simulation of F4 forging have been also received and shown in Table 2.

Table 2 *Values of the the works done for different cases of die forging*

Forging	Work done in final impression for forging with upset billet (A) [kJ]	Work done in final impression for forging with preform step (B) [kJ]	B/A .100 [%]
F1	168,52	106,57	63%
F3	649,99	184,94	28%
F4	1027,15	973,39	94,8%
F5	794,26	575,82	72%
F7	569,36	266,88	45%
F9	966,50	429,15	44%
F10	874,78	551,35	63%

By comparing the works done in final impression for forging with upset billets (A) and works done for forging with preform steps (B) for different forgings, it can be concluded that the values of A and B for F4 forging are about equal (difference does not exceed 6%). This is the same forging that has not necessity of preform step accordance to inequality (1). It turned out that, using of preform step for F4 is not advisable in view of the fact that the presence of preform lead to the complication of forging dies and make them more expensive. In addition, at this case the using of preform does not lead to the essential decreasing of work done in final impression and, as consequence, decreasing of die wear. For other forgings, there are significant differences between values, shown on Table 2. For example, for F3 forging the difference is around 70%. This inevitably affects die wear of final impression and will increase the durability of the forging tools.

4. CONCLUSION

The results obtained by applying criterion for necessity of preform steps for hot closed die forging and additional computer simulations allow to conclude following:

(i) Condition (1), determining the necessity of preforming steps for axysimmetrical forgings can be used on the stage of designing of forging processes;

(ii) The using of criterion (1) allows decreasing of work done in the final impression of die, decreasing of die wear and increasing of forging tool life;

(iii) Additional investigations are needed about the applicability of the condition for more complex forging parts.

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NUMERIČKA ISTRAŽIVANJA POTREBA ZA PRIPREMNIM OPERACIJAMA ZA SLUČAJ TOPLOG KOVANJA AKSIJALNO SIMETRIČNIH OTKOVAKA

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REZIME

Rad elaborira problematiku toplog kovanja aksijalno simetričnih otkovaka i u tom kontekstu potrebu za predhodnim/pripremnim operacijama kovanja. Definisani su neophodni faktori koji utiču na tu potrebu. Glavni kriterijum je deformacioni rad koji se troši u procesu kovanja. Numerička simulacija je sprovedena sa ciljem da se verifikuje analitičko rešenje problema. U konkretnom slučaju analizirano je toplo kovanje nisko-ugljeničnog čelika C15. Početna temperatura kovanja je 1200C. Pri tome je temperatura kalupa 300C. Podmazivanje je sa emulzijom (vodom i grafitom). Proces je realizovan na hidrauličnoj presi sa brzinom od 15mm/sec. Nekoliko različitih geometrija otkovaka je analizirano ,uzimajući u obzir predloženi kriterijum. Zaključuje se da je još u fazi projektovanja procesa kovanja neophodno voditi računa o potrebi za pripremnim i prethodnim operacijama kovanja.
Kriterijumi definisani u ovom radu omogućuju smanjenje potrebnog rada (energije) za kovanje u završnoj gravuri što takođe vodi do smanjenja habanja alata tj. do produženja njegovog radnog veka. U budućem radu na ovoj problematici biće analizirani otkovci sa kompleksnijim geometrijama a ne samo aksijalno-simetrični
Ključne reči: *kovanje u zatvorenom kalupu;međufazni oblici, metoda konačnih elemenata*