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Research of upsetting ratio in forming processes on a three – slides forging press

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ABSTRACT

Purpose: The purpose of the presented in this work research was determining the limiting conditions of upsetting in three-slide forging press (TSFP). The free upsetting process and upsetting process in cylindrical impression were analyzed.
Design/methodology/approach: The assumed purpose was confirmed in experimental research. For the case of upsetting in cylindrical impression, the research of limiting upsetting coefficients were made for different diameters and impression lengths.
Findings: The obtained results showed large variety of limiting upsetting ratio depending on the analyzed impression geometrical parameters. It was stated, that there are 3 phenomena limiting the upsetting process in the die. The main phenomenon is the bar upsetting outside the impression. The upsetting processes in the impression are limited also by bar buckling outside the impression and overlapping inside the impression
Research limitations/implications: The results of research allowed for stating that, besides the process geometrical parameters, friction conditions and type of the formed material influenced the limiting upsetting coefficients in the cylindrical impression. It is purposeful to make the further research determining quantitative and qualitative dependencies between these factors.
Practical implications: The obtained results are the basis for designing of forming processes in TSFP in which the upsetting dominates. Especially it considers the elongated forgings and elongated preforms with thickenings
Originality/value: The influence of the impression geometrical parameters on the limiting upsetting coefficients for the case of upsetting in cylindrical impression in TSFP has been analyzed in details. The dependencies, which should be used during designing of upsetting processes in TSFP were determined.
Keywords: Plastic forming; Three-slide forging press; Upsetting ratio

1. Introduction

Three – slide forging press (TSFP) has two coaxial horizontal slides and one vertical slide. This solution allows for the increase of the forging possibilities in comparison with forging in traditional presses or hammers [1÷5]. The important advantage of TSFP is the possibility of forming of elongated preforms and forgings with thickenings using a long bar charge - often with circular section. These types of forgings are made by cross wedge rolling process, forming in horizontal forging machines and other processes [6÷12].

The number of needed operations and tools shape in upsetting processes depends on geometrical parameters of the final part. Because of that, the significant aspect is determining the limiting conditions of bars upsetting. In the upsetting processes the different alternative methods: free upsetting, upsetting in the cylindrical impression or in the conical one are used. In this paper the results of the research of free upsetting and upsetting in the cylindrical impression are presented.

During free upsetting, in simple operation it is possible to upset correctly free end of the bar if the condition [13, 14] is fulfilled:

$$l \leq 3d_0, \quad (1)$$

where: l – the length of free end of bar, d_0 – the diameter of upset bar.

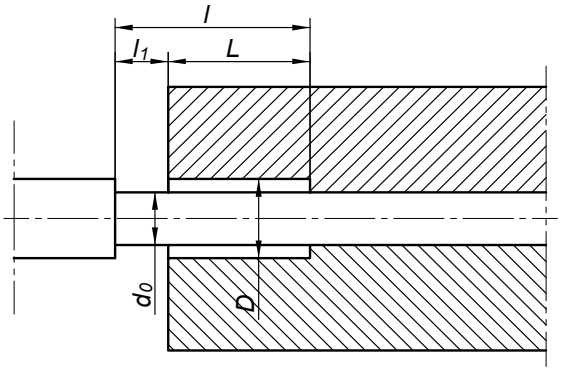

Fig. 1. The schema of bar upsetting in cylindrical impression

The dependency (1) concerns the conditions, in which frontal surface of bar is smooth and perpendicular to the axis. In real processes bar geometry is different from perfect, because of that it is assumed that the length l of the upset bar should be lower than $2{,}5d_0$ [14].

It is advised that upsetting of longer bar end, which does not meet requirements (1), should be realized in the cylindrical impression or in the conical one. The upsetting conditions in the cylindrical impression given in the literature are varied. In the work [14] the conditions of correct process course are described as follow (Fig. 1):

- if $l>3d_0$ and the impression diameter $D\leq 1{,}5d_0$ then bar part jutting out impression must fulfills the dependency:

$$l_1\leq d_0, \tag{2}$$

- if $l>3d_0$ and the impression diameter $D<1{,}25d_0$ then bar part jutting out impression must fulfills the dependency:

$$l_1\leq 1{,}5d_0. \tag{3}$$

In the work [13] is shown that the correct upsetting process in the cylindrical impression at single punch movement for $l>3d_0$ and $D\leq 1{,}5d_0$ is possible if the following condition is fulfilled:

$$l_1\leq L, \tag{4}$$

where: L is a impression length (Fig. 1).

The more strict conditions of correct upsetting in the work [15] are described as:

- if $l>2{,}5d_0$ and $D\leq 1{,}3d_0$ then $l_1<d_0$, (5)
- if $l>2{,}5d_0$ and $D\leq 1{,}25d_0$ then $l_1<1{,}5d_0$. (6)

2. Experimental research

On the basis of specialist literature presented in the introduction and dealing with the upsetting conditions it can be stated that the given descriptions show differences. This results from many factors e.g. differences in the used research methodologies, the applied simplifications, kind and technical conditions of research machines, types of analyzed materials or ways of billets preparation. Because of that, it is necessary to make research determining the limiting upsetting conditions in the process of forming in TSFP. Analysis of the process of free upsetting of a bar clamped with two dies and upsetting process in cylindrical impression was carried out. In the experiment extruded bar from lead of Pb1 type and with the diameter Ø20 mm was used. The bar frontal surfaces were made by means of turning which guaranteed their perpendicularity towards the axis.

2.1. Free upsetting

The research results of the free upsetting showed that a proper forging could be obtained for the upsetting ratio $m\leq 3$ (where: $m=l/d_0$). The example of this kind of forging is presented in Fig 2a. At the upsetting ratio $m>3$, in the initial stage a buckling appears and later upsetting. Due to that process course eccentricity is created (Fig. 2b), however, the bigger upsetting ratio results the bigger eccentricity of the formed thickening. Eccentric workpieces in some cases can be classified as the proper ones. They can e.g. constitute preforms at forming of which the main aim is to transmit the proper material volume and the eccentricity is not a factor excluding the further forming of forging. After exceeding the limiting value of the upsetting ratio $m=3.7$, the buckling of the bar is so large that at the further upsetting overlapping is formed (Fig. 2c). The obtained workpiece is a faulty part. Using it even as a preform leads to this disadvantage appearance in the forging.

2.2. Upsetting in the cylindrical impression

The second phase of research dealt with the upsetting process of a bar in the cylindrical impression made in a die. The aim of the experiment was to determine the limiting values of the upsetting ratio for various values of diameter D and length L of the impression (Fig. 1). For the research needs, special dies were used in which interchangeable semi-rings were applied allowing for changes of geometrical parameters of the impression (Fig. 3). The following conditions of the experiment were assumed:

- the values of the impression diameter D were changed every 1 mm within the range 25÷32 mm (hence within range $1{,}25d_0$÷$1{,}6d_0$),
- the values of the impression length L were changed every 4 mm within the range 30÷62 mm.

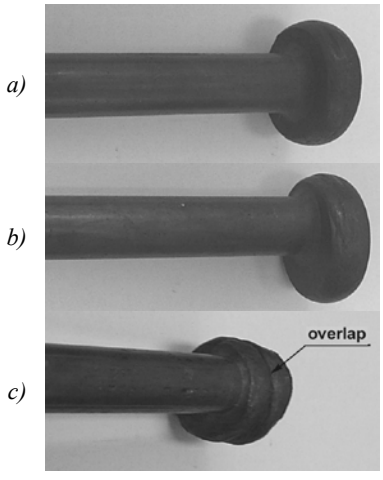

Fig. 2. The workpieces obtained at upsetting ratio: a) $m\leq 3$, b) $3<m\leq 3.7$, c) $m>3.7$

For the upsetting conditions at the given geometrical parameters of the impression, the limiting length l of the upset part of the bar (that is the maximal length at which the obtained forging was a proper one) was determined. The obtained results are shown in a graphic form in Fig. 4. In order to provide more general character of the results, the analyzed geometrical parameters were referred to the diameter of the upset bar. As it can be seen in the Fig. 4, the courses of the particular limiting curves have the form of power function. According to the expectations, the larger the diameter D and the length L of the impression are, the larger are the limiting values of the upsetting ratio m, which is connected with the impression larger volume.

On the basis of the obtained results it was stated that 3 main factors appear limiting the upsetting process in cylindrical impression made in a die. These factors include:

- upsetting on the outside of the impression,
- bar buckling before of the impression,
- overlapping in the impression.

It can be stated that main the limiting factor is upsetting of material on the impression outside (Fig. 5b). In the upsetting process in the impression, at the first stage free upsetting appears to the moment of material contact with the die walls. Then, the friction forces are present which prevent the material pushing into the impression. Friction forces increase together with the increase of the contact surface between the impression walls and the upset material. After exceeding the limiting value friction forces are so large and the material does not move into the impression inside, only the bar end jutting out the impression undergoes upsetting. If the diameter of the thickening outside the impression exceeds the diameter of the impression before the material is put in it, the obtained forging is a faulty one. In the carried out research, the upsetting on the impression outside was the limiting factor for all cases of upsetting in the impression of diameter $D=(1.25\div1.50)d_0$.

The second limiting phenomenon – bar buckling in front of the impression - concerns considerably large impression diameter ($D>1.5d_0$). The forging with that defect is presented in Fig 5c. It can be concluded that the length of the jutted out the impression part of bar l_1 cannot be longer than the impression L which is synonymous with the condition: $L\geq\frac{1}{2}l$.

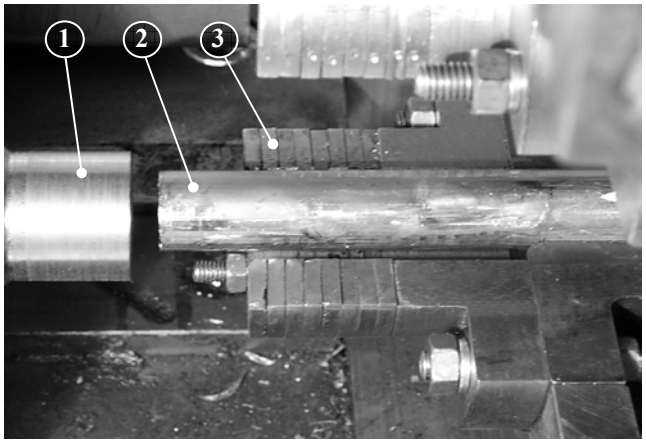

Fig. 3. The tools for research of upsetting ratio in die; 1 – upset punch, 2 – upset bar, 3 – interchangeable semi-rings regulating length and diameter of impression

Overlapping, the third limiting phenomenon, appears also at large impression diameter ($D>1.5d_0$). In this case the bar buckling is so big that at the further upsetting course in the impression the overlapping is caused (Fig. 5d). This phenomenon was present in all cases for the impression diameter $D=1.6d_0$ and in some cases, for $D=1.55d_0$ (marked in the Fig. 4 by black dots). Hence, it should be concluded that due to the overlapping phenomenon it is safer to realize the upsetting for the impression diameter D not exceeding 1.5 – times, the diameter of the upset bar d_0 ($D\leq1.5d_0$). Presented in the literature upsetting conditions (described in the introduction) determine the permissible length l_1 of bar part jutted out the impression. This parameter is limited by one condition for the wide range of the process geometrical parameters, while the results of research prove that it changes depending on the impression diameter D and length L. In Fig. 6 are presented the limiting conditions determined in stand tests and conditions given in the specialist literature determined by dependencies (2) and (4) (drawn by straight lines). From their comparison, it results that there exist considerable differences of limiting curves. The dependency drawn by horizontal line (dependency 2) is too restrictive even for the lowest impression diameters $D=1,25d_0$. Its

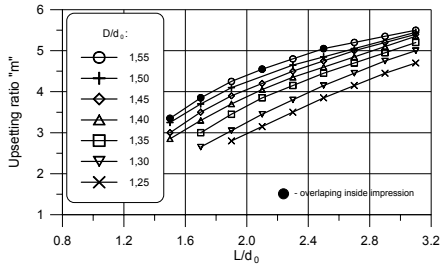

Fig. 4. The limiting values of upsetting ratio for the different impression geometrical parameters

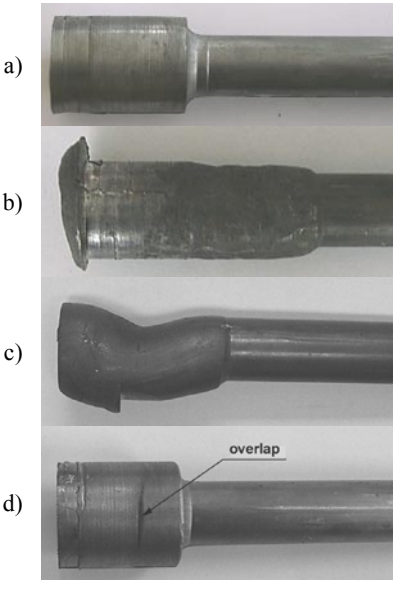

Fig. 5. The forgings obtained in upsetting process in impression: a) the proper forging, b) upset outside impression, c) buckling

application leads to non using the process technological possibilities fully. The second condition (dependency 4) is, however, for majority of cases too liberal. Its application in the cases of upsetting in impressions of lower diameters ($D \leq 1{,}35\ d_0$) leads to obtaining of faulty part, but for small L lengths and large impression diameters $D=(1{,}45 \div 1{,}5)d_0$ it imposes too firm limitations. Determined in the research limiting curves are between those two straight lines and show variety depending on the impression diameter D. Because of these differences, the assumption of the one condition for the whole range of the analyzed geometrical parameters is not correct.

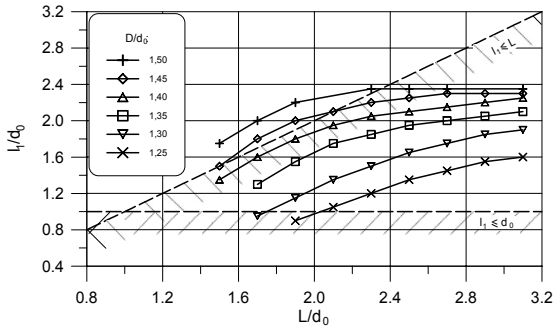

Fig. 6. The comparison of limiting upsetting conditions obtained in own research and given in the literature

3. Conclusions

The one of the main technological parameters of forming processes in TSFP is permissible upsetting ratio. It has a significant meaning during the correct designing of forging processes of parts with thickenings. From the conducted research it can be stated that, during the upsetting process into the impression, the main limiting phenomenon is upsetting of material near the punch outside the impression. Moreover, it should be observed: buckling and material flows outside the impression (in case of too long bar segments jutted out outside impression) and overlapping created because of too large impression diameters in comparison to the upset material.

The main limiting phenomenon depends on the friction conditions between the upset material and impression walls and on the properties of the upset material. The obtained results allow for supposing that larger individualization in determining the limiting dependencies is necessary. It will be useful for more effective technological applications of the given process for different material.

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