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Prediction of the Variation of the Form in the Processes of Extrusion

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The theoretical analysis of dimple formation in direct, radial and combined extrusion processes was made. By the theoretical methods of analysis of radial, direct and radial-back extrusion processes, the problems on the determination of geometric parameters of extruded parts without dimples have been solved. Was found the parameters which has influence on defect formation in radial, direct and radial-back extrusion processes. Graphic dependence for determination of geometric parameters of parts extruded without dimple have been constructed.

Keywords: HOLLOW PARTS, DIRECT EXTRUSION, RADIAL EXTRUSION, RADIAL-BACK EXTRUSION, DEMPLES, RELATIVE PRESSURE, FINITE ELEMENT METHOD, METHOD OF BALANCE OF POWER

Introduction

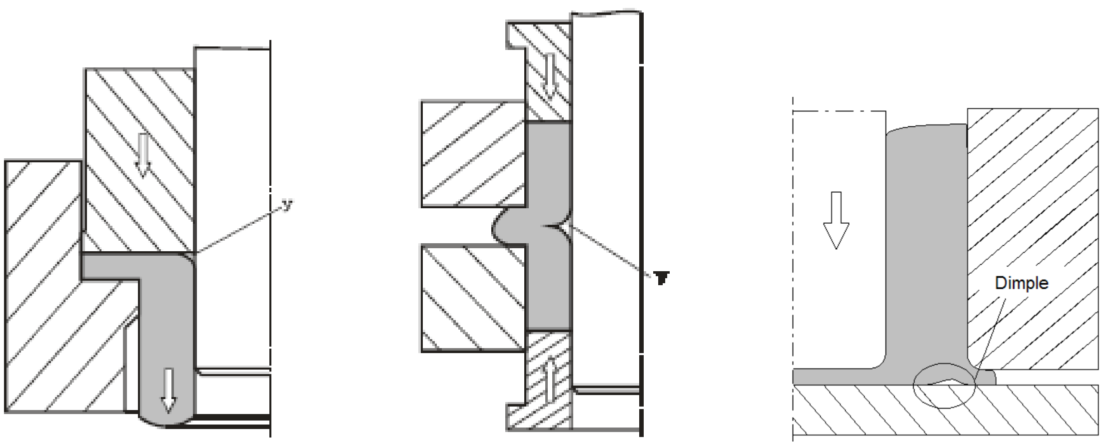
During the development various machines and mechanisms frequently used the hollow parts as the bushings and cups with the flange. Such details is the integral parts almost of all machine and mechanism.

On the machine building factories the hollow parts with the flanges are frequently made by the machining. This method of processing are characterize by low mechanical characteristics of details that obtained through-cut fiber and low utilization of metal. The latter feature is a defining of the manufacture of parts made of expensive materials [3, 4].

The alternative to mechanical processing is the metal forming by pressure and cold extrusion occupies special place in it (because of economical and ecology benefits).

This type of processing characterized by the favorable macrostructure of metal because of it elaboration (possible to replace the materials because of rise of mechanical characteristics) and absents the cut fibers, high utilization of metal.

Radial, direct and combined radial-backward extrusion is the major methods of obtain bushings and cups with flange. Bushings and cups with flanges obtained by extrusion these schemes have a internal, axial and vertical dimples. Schemes of dimples shown on the **Figure 1**.



a b c

Figure 1. Schemes of dimples in direct (*a*) radial (*b*) and combined (*c*) extrusion

Prediction of dimples in extrusion is important in manufacturing of quality and precise details. Solution of this problem by theoretical modeling is appropriate.

The aim of this paper is to develop recommendations on technology processes of stamping by direct, radial and combined extrusion of bushings and cups without dimples.

Radial extrusion

In direct extrusion on the mandrel sometimes dimples occur on the internal side of the workpiece (**Figure 1a**).

Theoretical investigations of dimple occurrence were made by means of power balance [1, 2]. The design scheme of direct extrusion with dimples shown in **Figure 2**.

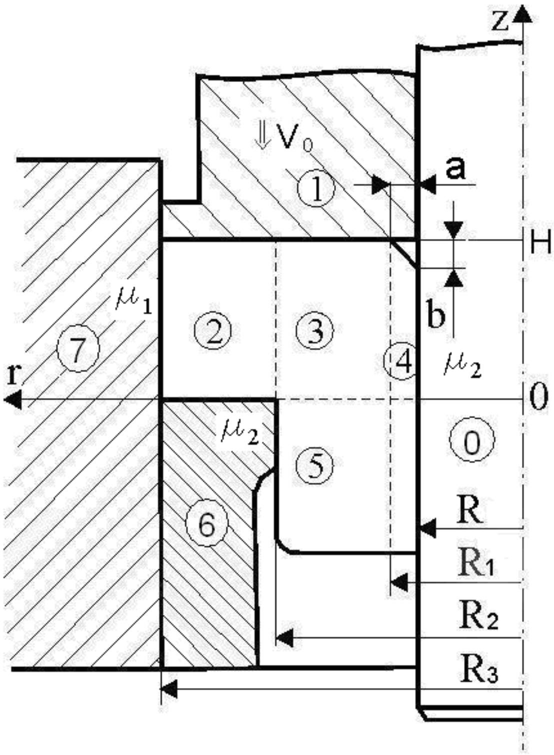


Figure 2. Design scheme for the analysis of direct extrusion on the mandrel with the formation of holes

Using the method of power balance [1, 2] the reduced pressure for direct extrusion on the mandrel in parametric form has been received. It can be expressed as:

$$\overline{p} = p/\sigma_s = f(R, R_1, R_2, R_3, H, a, b) \quad \text{(Eq. 1)}$$

In the reduced pressure formula the value $y = R_1/R_2$ is the variable value which is determined by the minimum of reduced pressure $\overline{p}$. The developed mathematical model was processed in the MathCAD. According to the results of theoretical research build the graphic dependence flange height $\overline{H}_0$ (where will be formation the dimples) from relative wall thickness R_2/R of bushing and mode of friction in **Figure 3**.

Formation of dimple will be in ratio thickness of flange and wall $H/(R_2 - R)$ more then 1. an increase coefficient of friction thickness of the bottom H (where will be formation the dimples) decreased. Friction of metal on the wall of die prevent the emergence of dimple.

To assess the occurrence of dimple and identify factors and modes of deformation preventing the emergence of dimple were conducted experimental studies. Experiments were made on the alluminium billets. Results of experiments are shown on the **Figure 4.**

Found that the presence of lubricant on the mandrel decreases the value of the critical height (where will be formation the dimples) of the flange. Lack of lubrication on the mandrel and degreasing of the contact surface mandrel significantly affect delay the appearance of defects (**Figure 4a**).

Direct extrusion

In radial extrusion of flanges when the relative thickness of flange h_1/s is more than 1, a dimple is formed on the internal side of the bushing wall (**Figure 1b**).

Theoretical analysis of dimple forming in radial extrusion is made by the method of power balance. The scheme with the deformable triangular element with the parabolic "hypotenuse" [5, 6] (**Figure 5**) is used.

The reduced pressure of radial extrusion in the parametric form was obtained by the famous method of power balance:

$$\overline{p} = p/\sigma_s = f(R, R_0, h_1, y) \quad \text{(Eq.2)}$$

In the reduced pressure formula the parameter y is variable. The value of this parameter is determined from the minimum of the reduced pressure. This mathematical model is processed in the program MathCAD.

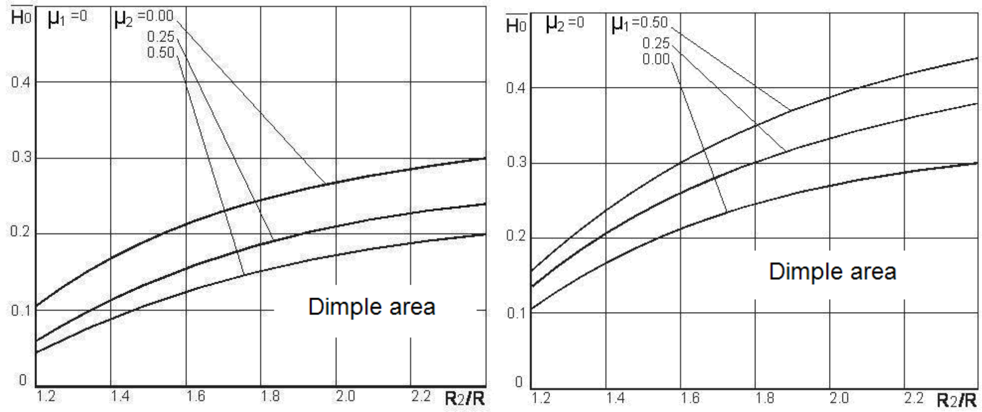
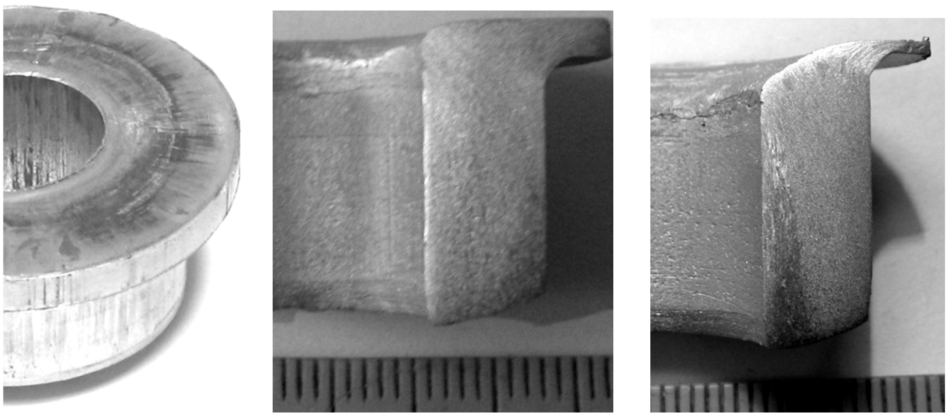


Figure 3. Dependence of flange critical height on relative radius of billet and friction mode



a b c

Figure 4. Dimple formation in direct extrusion of bushing from alluminium (experiment)

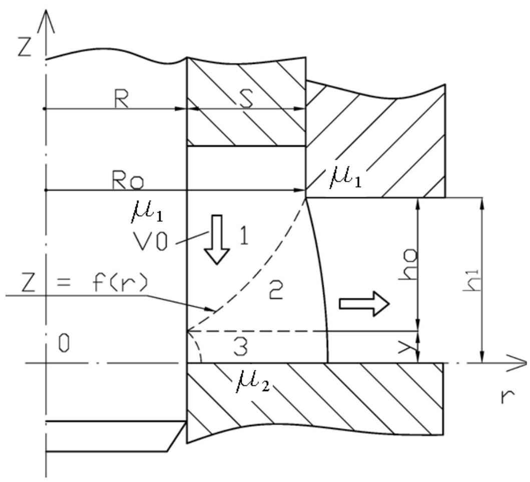


Figure 5. Scheme for modeling of dimple formation

In this model, the graphical dependence of the critical values of extruded flange (where dimples are formed) on the relative thickness of the work piece (**Figure 6**) and the graphical dependence of the relative values of the dimple on the relative thickness of the flange (**Figure 7**) were constructed.

The analysis of the graph dependence critical value of the flange height h_1/S shows that with an increase of friction coefficient μ_2 the area of the critical values increase too, and on the contrary, with an increase of μ_1 it decreases. Thus when $\mu_2 = 0$ the change of μ_1 in the range from 0 to 0,5 reduces the maximum permissible value of parameter h_1/S from 1 to 0,71.

Analysis of the graphic dependence gives the possibility's to come to the next conclusions. When the value of relative height $\bar{h}_1$ and the friction on the die μ_2 are low and friction on the mandrel μ_1 is rise the value of dimple becomes low.

Radial-back extrusion

In combined radial-back extrusion the formation of the dimple occurs on the bottom side of the part as shown on the **Figure 1c**.

Research of the regularity of the dimple formation in the combined extrusion was made with the aid of the Q-Form 2D which is based on the finite element method [7].

The extrusion of a cup with a flange (**Figure 8**) with the following dimensions R_1=22,5 mm; h = [1…6] mm; S = [3,5…14,5] mm was simulated.

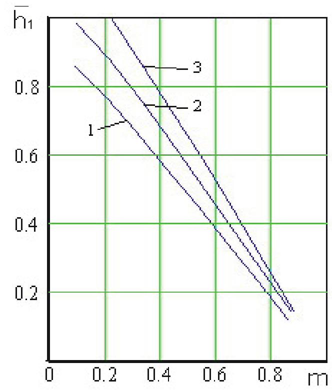


Figure 6. Dependence of relative height of flange (where dimples are formed) of the relative thickness of tube billet wall: 1 – μ_2 = 0.082; 2 – μ_2 = 0.253; 3 – μ_2 = 0.50; y = 0, μ_1 = 0.08

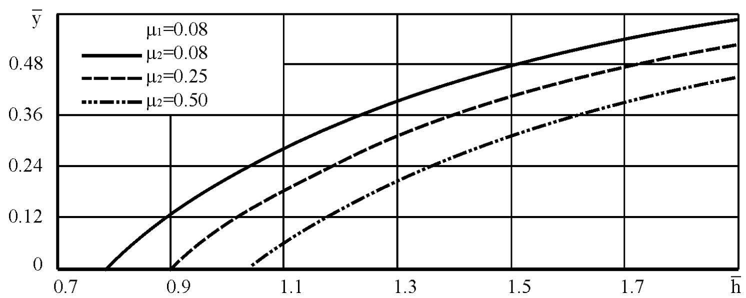


Figure 7. Dependence of relative value of dimple on the relative height of flange

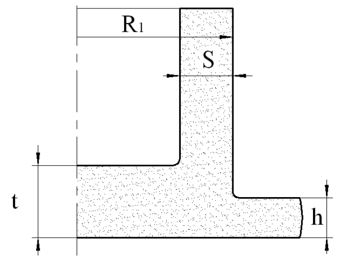


Figure 8. Scheme of a cup obtained by combined extrusion

Analysis of geometric parameters of the details obtained by the combined extrusion with dimple may do the following conclusions. An increase height of flange leads to increase of the thickness of the wall of cup (when will be formation of dimple). That explained by that when big thickness of the wall the flow of metal intensively on the back direction. Because of this is the formation of dimple.

According to obtained data constructed the graphic dependence relative thickness of wall relative height of flange and relative thickness of bottom of cup (**Figure 9**). This picture shows areas in which there are geometric parameters of details obtained by combined extrusion process without dimple.

Made experimental research of combined radial-back extrusion. Received details of the various sizes. Internal size of dies were the following R_1 = 18 mm и R_1 = 14 mm. Received details with the dimples (**Figure 10**).

Experimental data are on the **Figure 9**. The second and the third details obtained without the dimples and the theoretical data is confirming it.

Conclusions

Cold extrusion processes are promising in the manufacture of hollow parts such as bushings and cups with flanges.

In radial, direct and combined radial-back extrusion may appear the defect such as the dimple. Dimple reduced accuracy of manufactured parts.

By the theoretical methods of analysis (power balance and finite element methods) of radial, direct and radial-back extrusion processes, the problems on the determination of geometric parameters of extruded parts without dimples have been solved.

It was found out that the friction in radial and direct extrusion processes positively influences the critical size of extruded parts wherein dimples being to occur.

Graphic dependence for determination of geometric parameters of parts extruded without dimple have been constructed.

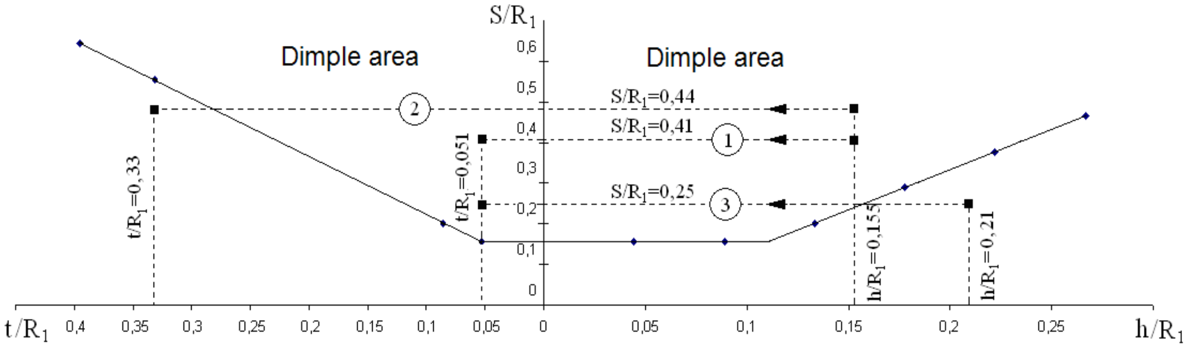


Figure 9. Graphic dependence for the determination of details size without dimples

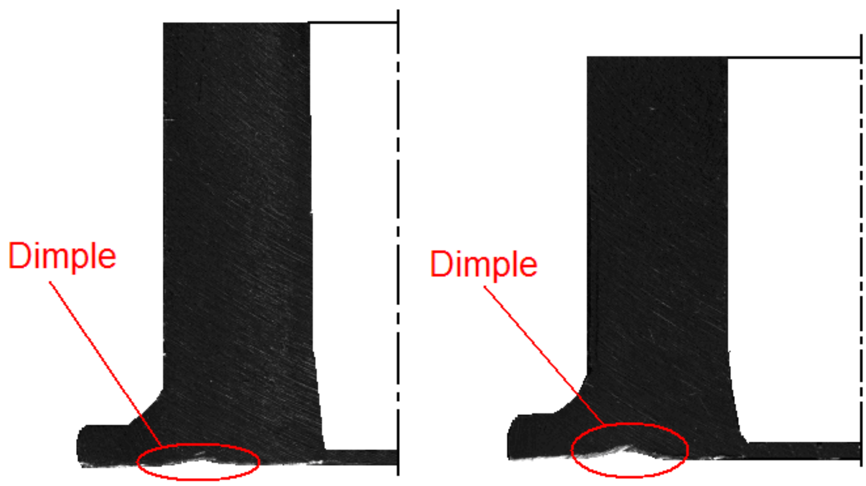


Figure 10. Details obtained by the radial-back extrusion

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Прогнозирование формоизменения в процессе прессования

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Выполнен теоретический анализ образования утяжины в процессах прямого, радиального и радиально-обратного выдавливания. На основе теоретических исследований процессов радиального, прямого и радиально-обратного выдавливания решена проблема определения геометрических параметров выдавливаемых без утяжин деталей. Определены параметры, влияющие на дефектообразование в процессах радиального, прямого и комбинированного выдавливания. Построены графические зависимости для определения геометрических параметров выдавливаемых деталей без образования утяжин.