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STUDY OF AN ENERGY-SAVING DIE FOR RADIAL REDUCTION**Oleg Gaidamak**, Candidate of Technical Sciences, Associate Professor
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Reducing the power of forging and pressing equipment is an important task of modern metal forming technologies. The article is devoted to the development and research of dies capable of significantly (tens or more times) reducing the power of the used forging and pressing equipment due to the use of energy-saving dies that can significantly increase the deforming force. A stamp capable of significantly increasing the deforming force is called energy-saving. The article shows that using different types of levers, it becomes possible to significantly increase the useful force of stamping tools acting on a deformable workpiece. Thus, it becomes possible to use relatively low-power pressing equipment to achieve significant forces of the working tool. Based on the given mathematical dependences of the geometric and power characteristics of the energy-saving stamp, a computer program was developed in MS Excel and modeling was carried out, with the help of which it was studied how the deforming force R changes depending on the change in the angle of inclination of the punches β and the corresponding graph was plotted at a predetermined constant pushing force $F = 1$ N. After analyzing the resulting graph, it can be argued that a tenfold increase in the deforming force R compared to the pushing force F , which is created by the pressing equipment, is observed at an angle of $\beta = 5.35$ degrees, fifty times at an angle of 1.1 degrees. At angles approaching 0 degrees, the increase in the deforming force can reach significant values and is limited only by the strength of the energy-saving stamp itself. Calculation formulas are given that allow calculating the main dimensions of the punches and the working stroke of the forging and pressing equipment for a given working stroke of the punches and a given increase in the deforming force. Possible areas of application of the energy-saving stamp are shown.

Key words: radial reduction, energy-saving die, increase in deformation force.

F. 17. Fig. 6. Ref. 6.

1. Introduction

One of the important tasks of modern metal forming technologies is to reduce the deformation forces and the power of pressing equipment. It is possible to solve this problem in different ways. One of them is the creation of dies capable of significantly (tens of times or more) increasing the useful force that can be developed by a deforming tool installed on a standard press, compared to the force of the press itself. This can be achieved by developing energy-saving dies, which will increase the standard press force many times over.

2. Analysis of last researches and publications

There are various types of radial crimping machines that provide radial deformation of the part [1-3]. These machines do not solve the problem of reducing the deformation forces and the power of the press equipment used.

Even the ancient Greek thinker Archimedes (287 BC - 212 BC) suggested using levers to increase human capabilities when moving heavy loads. Humanity still uses these levers to this day. Using different types of levers, it becomes possible to significantly increase the useful force of stamping tools acting on a deformable workpiece. Thus, it becomes possible to use relatively low-power pressing equipment to achieve significant forces of the working tool.

3. The aim of the study

Study of an energy-saving die for radial reduction in order to create an engineering methodology for calculating the main dimensions die and working stroke of the press.

4. Presenting main material

Consider the proposed design of an energy-saving stamp for making a square on the tail part of a part, for example, a reamer. The energy-saving stamp (Fig. 1) consists of the following parts. Four punches 4



arranged in pairs one opposite the second and fixed in the guides 7 with the help of axes 5 cottered with cotter pins 6. The guides of the punches 7 are fixed between themselves by the upper plate 3 and the lower plate 8. The pusher 1 (in the projection "top view", the pusher 1 is not shown) moves along the guide 2. The ejector 10 moves along the guide 9. The deformable part 11 is located in the hole of the ejector 10.

Energy - saving die works as follows. The workpiece 11 is inserted into the hole of the ejector 10, which is inserted into the guide 9. The punches 4 take their original position, shown by dotted lines B. The press slider (not shown in the figure) presses the pusher 1, which in turn presses the punches 4. The punches turn around axes 5 move down, compressing the workpiece in the radial direction and deforming it, forming a round, square profile of the tail part of the reamer workpiece.

The final position of the punches is shown by the main solid lines B. In order to remove the formed workpiece 11, the ejector 10 raises the punches 4 to the initial position B and then is removed from the guide 9 together with the workpiece 11.

We investigate the power characteristics of this design. To this end, we will develop a design scheme for an energy- saving stamp (Fig. 2) [1].

Let's find out what will be the reaction R , which creates a deforming force and acts on the workpiece, depending on the pushing force F and the change in angle β , in the process of deformation. To solve this problem, we compose the equilibrium equations, these are the equations of the projections of forces on the coordinate axes and the sum of the moments about the point O.

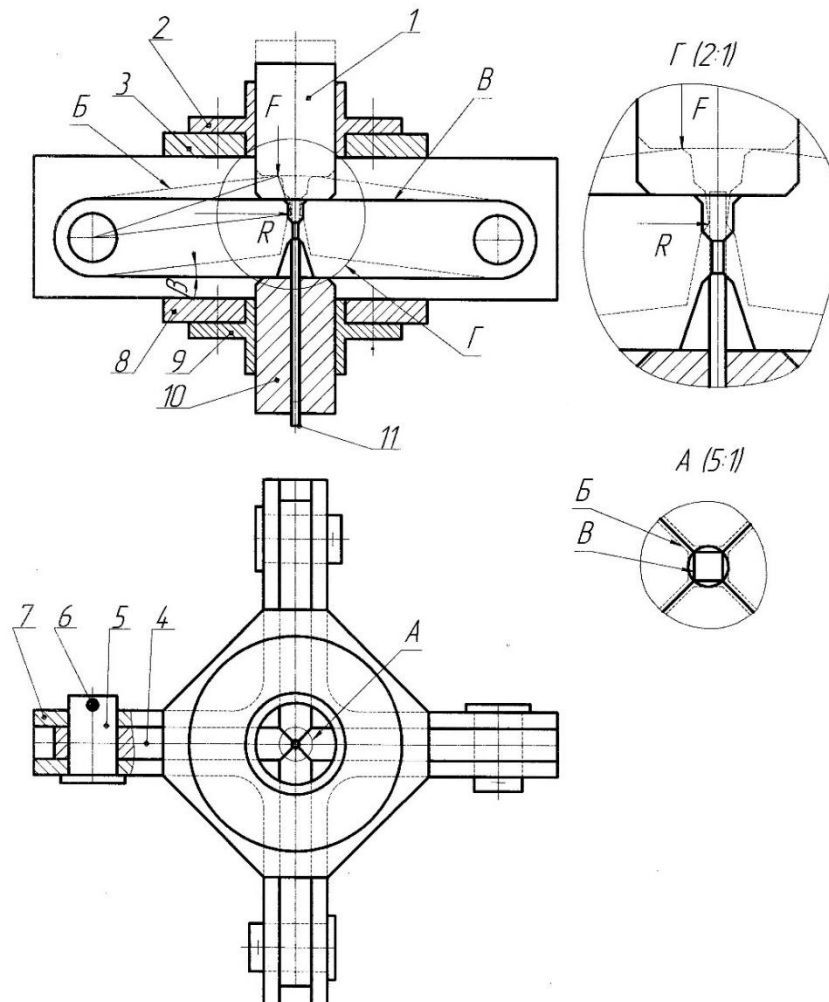


Fig. 1. Structural scheme of an energy-saving die:
1 – pusher, 2 – pusher guide, 3 – top plate, 4 – punches, 5 – axle, 6 – cotter pin, 7 – punch guide,
8 – bottom plate, 9 – ejector guide, 10 – ejector, 11 – blank.

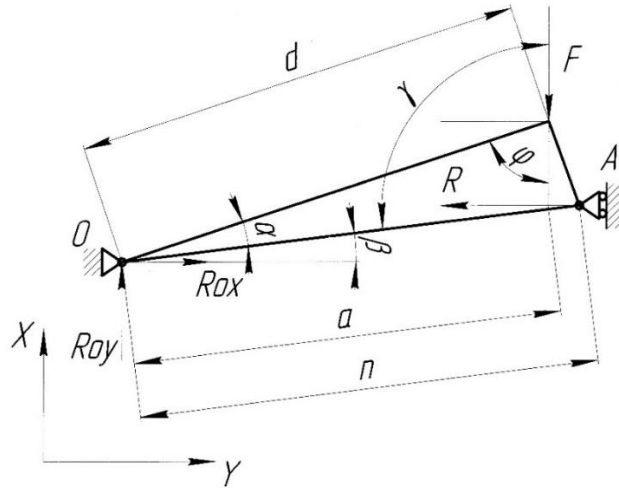


Fig. 2. Calculation scheme of the stamp

$$\sum F_x = 0, \quad R_{ox} - R = 0, \quad (1)$$

$$\sum F_y = 0, \quad R_{oy} - F = 0, \quad (2)$$

$$\sum M_o = 0, \quad R \cdot n \cdot \sin \beta - F \cdot a \cdot \cos \beta = 0. \quad (3)$$

From the sine theorem we write the equations:

$$d / \sin \gamma = a / \sin \varphi. \quad (4)$$

From equation (4) we find:

$$a = (d \cdot \sin \varphi) / \sin \gamma. \quad (5)$$

From the design scheme, we determine the value of the angles

$$\varphi = 90 - \alpha - \beta, \quad (6)$$

$$\gamma = 90 + \beta. \quad (7)$$

We substitute equations (6), (7) into equation (5):

$$a = [d \cdot \sin(90 - \alpha - \beta)] / \sin(90 + \beta). \quad (8)$$

From equation (3) we find:

$$R = (F \cdot a \cdot \cos \beta) / (n \cdot \sin \beta). \quad (9)$$

From equation (2) we find:

$$R_{oy} = F. \quad (10)$$

From equation (1) we find:

$$R_{ox} = R. \quad (11)$$

Total support reaction at point O:

$$R_o = \sqrt{R_{ox}^2 + R_{oy}^2}. \quad (12)$$

The angle α is assigned from design considerations according to the dimensions of the punch. The angle β changes from a certain value of the deformable workpiece selected by the dimensions and the dimensions of the punch to zero degrees. Usually $7^\circ > \beta > 0^\circ$.

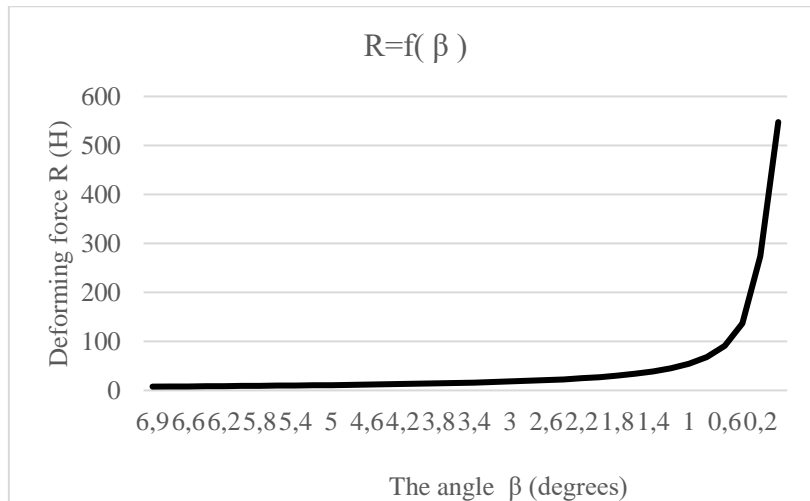


Fig. 3. Dependence of the deforming force R on the angle β at a constant value of the pushing force $F = 1 \text{ N}$

According to the given mathematical dependencies, a computer program was developed in MS Excel and simulation was carried out, with the help of which it was studied how the deforming force R changes depending on the angle change β and the corresponding graph was plotted (Fig. 3) at a predetermined constant pushing force $F = 1 \text{ N}$.

After analyzing the resulting graph, it can be argued that a tenfold increase in the deforming force R compared to the pushing force F , which is created by the pressing equipment, is observed at an angle of $\beta = 5.35$ degrees, fifty times at an angle of 1.1 degrees. At angles approaching 0 degrees, the increase in the deforming force can reach significant values and is limited only by the strength of the energy-saving stamp itself. The given results were obtained for the studied stamp with dimensions $n = 250 \text{ mm}$, $d = 243,77$, $\alpha = 11.3^\circ$ (Fig. 2). In this case, for the studied workpiece with a diameter, 10 mm the deformation value for the formation of the square part of the reamer is $1,46 \text{ mm}$. To achieve this value of deformation, the punches in the initial position have a slope $\beta = 7^\circ$, while the calculated increase in the deforming force is 7.6 times, and with a decrease in the angle, the β increase in the deforming force increases sharply. Especially at corners $\beta < 1^\circ$ effort increases by 50 or more times. However, the value of deformation of the workpiece for the studied dimensions of the stamp for small angles will be small. So the magnitude of the deformation when turning the punches from $\beta = 1^\circ$ to $\beta = 0^\circ$ is $0,04 \text{ mm}$. If we want to increase the stroke of the punches for given angles, it is necessary to increase the dimensions of the punches, their radius of rotation relative to the axes of rotation, respectively.

To determine the size n of punches, we use the calculation scheme shown in (Fig. 4).

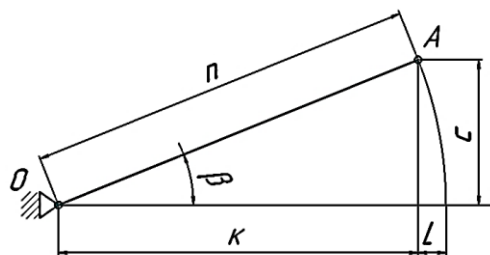


Fig. 4. Calculation scheme for determining the dimensions of punches.

Usually, when designing stamping equipment, the initial values are the required stroke of the deforming tool (punches), which is indicated in (Fig. 4) as L and the required deformation force R_0 . The size n will be sought for the angle of inclination of the punch β corresponding to the required increase in the deformation force. For example, for an angle $\beta = 5.35$ degrees which corresponds to a 10 -fold increase in the initial deformation force. At the same time, it is necessary to ensure the required displacement of the punch by the value L . The size n , which will provide this required displacement, will be sought from the following considerations.



$$\cos\beta = \frac{\kappa}{n}, \quad (13)$$

$$\kappa = n \cdot \cos\beta, \quad (14)$$

$$L = n - \kappa = n - n \cdot \cos\beta = n \cdot (1 - \cos\beta), \quad (15)$$

$$n = \frac{L}{1 - \cos\beta} \quad (16)$$

The value of the working stroke of the pusher C of the press on which the energy-saving stamp is installed is determined by the formula (17)

$$C = n \cdot \sin\beta \quad (17)$$

For example, if we need to create a deforming force of 10 t. But there is a press with a working force of 1 t, while the stroke L should be 5 mm. Let us find the size n of the punch of the energy-saving stamp according to the formula (16), it will be

$$n = \frac{5}{1 - \cos 5,35} = 1147,76 \text{ mm}$$

At the same time, we determine the stroke of the pusher C press

$$C = 1147,76 \cdot \sin 5,35 = 107,01 \text{ mm}$$

With an increase in the degree of deformation, the resistance to deformation of the workpiece increases significantly compared to the initial stage of deformation, while the design of the stamp automatically provides an increase in the deforming force of the working tools (punches), which favorably affects the conditions of the workpiece forming and the force deformation mode.



Fig. 5 Indicative parts list



Fig. 6. An energy-saving die for radial reduction

Thus, it can be argued that the use of energy-saving dies in industry will significantly reduce the power of press equipment to achieve the same results. In addition, according to [3, 4, 5], radial compression creates a favorable stress-strain state and contributes to the deformation of the workpiece without destruction. The scope of application of an energy-saving die can be most effective for minting production (minting coins, etc.), where parts with a small depth of deformation are deformed with high resistance to deformation, as well as other tasks in which a large force is required with relatively small deformation. The number of punches in an energy-saving die can be different, depending on the task. An indicative list of parts in the manufacture of which the energy-saving stamp shown in Fig. 5. The general view of the energy-saving stamp is shown in Fig. 6.

6. Conclusions

A class of dies has been proposed that can be called energy-saving, which means dies that are able to increase the deformation force by tens or more times in comparison with the force of the press equipment on which they are installed. By developing mathematical dependencies and computer research of the loads that the punches of an energy-saving stamp can develop, the effectiveness of the proposed design is clearly shown. Possible areas of application of an energy-saving stamp in industry are shown, examples of calculations of the main dimensions are given.

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ДОСЛІДЖЕННЯ ЕНЕРГООЩАДНОГО ШТАМПА ДЛЯ РАДІАЛЬНОГО ОБТИСНЕННЯ

Зменшення енергосилових характеристик ковальсько-пресового обладнання є важливою проблемою технологій обробки металів тиском. Стаття присвячена дослідженню штампів здатних суттєво (в десятки і більше разів) зменшити потужність існуючого ковальсько-пресового обладнання на підприємствах за рахунок використання енергозберігаючих штампів, що дозволяють суттєво збільшити деформуючу силу порівняно з силою обладнання на якому встановлено цей штамп. Штамп здатний суттєво збільшити зусилля, що деформує, названий енергозберігаючим. Показано, що застосовуючи важіль у вигляді деформуючого пуансона стає можливим суттєво збільшити корисну силу штампових інструментів, що діє на заготовку, яка деформується. Таким чином, стає можливим застосовувати відносно малопотужне ковальсько-пресове обладнання для досягнення зусиль робочого інструменту, що істотно перевищує зусилля, яке створюється пресовим обладнанням. За розробленими математичними формулами геометричних і силових характеристик енергоощадного штампів проведено комп'ютерне моделювання в MS Excel, за допомогою якого показано як змінюється сила деформування R в залежності від зміни кута нахилу пуансонів і отримано відповідний графік при заданому зусиллі, що постійно створює штовхач преса яке в розрахунках задане як $F = 1N$. Провівши аналіз отриманого графіка можна побачити, що десятикратне підвищення деформуючої сили R порівняно з силою штовхача ковальсько-пресового обладнання F , спостерігається при куті нахилу пуансона 5,35 градуса, а п'ятидесятикратне при куті нахилу пуансона 1,1 градуса. При кутах, які близькі до 0 градусів, збільшення деформуючого зусилля може досягати великих величин і може бути обмежене лише міцністю деталей енергоощадного штампів. Наведено розрахункові формули, які дозволяють розрахувати головні розміри пуансонів та робочого ходу ковальсько-пресового обладнання при заданому робочому ході пуансонів та заданому збільшенні зусилля, що деформує заготовку. Показано можливі сфери застосування енергоощадного штампів.

Ключові слова: радіальне обтиснення, енергоощадний штамп, підвищення сили деформування.

Ф. 17. Рис. 6. Літ. 6.

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