Combined drawing with extrusion of square box parts from a square billet

Yu V Bessmertnaya, S N Larin
Tula State University, 92, Lenina ave., Tula, 300012, Russia
E-mail: mpf-tula@mail.ru

Abstract. The effectiveness of the technology of making square box parts can be ensured with the help of new technologies of deformation. This article considers a method combining drawing and extrusion of square box parts from a square billet, which allows achieving high economic indicators. The paper presents a study of the material flow and recommends a variant of the die design, which makes it possible to maximize the material utilization factor and rationalize the stamping technology.

1. Introduction
New technological processes for making square box parts can be used at various enterprises of the machine-building complex, including the enterprises of automotive industry where it is used for the manufacture of fuel tanks.

Fuel tank is the housing that holds fuel when the engine is running. There is a wide variety of them. Fig. 1 shows a general view of the fuel tank.

![Figure 1. General view of the fuel tank](image)

The main requirement for fuel tanks is a high tightness of the container, which prevents the leakage of fuel (or its vapors) into the environment. This ensures safe operation and economy of fuel consumption in general.

The assembly of the half-shells of the fuel tank is carried out first by resistance spot welding, and then by resistance seam roller welding along the perimeter of the fuel tank.

The technical task is to increase the service life, reduce labor intensity and improve the quality of the car's fuel tank due to the absence or reduction of welding seams.

2. Materials and methods
The technology of manufacturing square metal shells is based on the forming of sheet circle billets [1-3]. As a result of cutting the sheet material (sheets, strips, rolls) to make circle billets, metal waste...
occurs, reaching 30% or more (fig. 2).

![Figure 2. Cutting the material](image)

Therefore, instead of using a circle workpiece, we suggest changing the shape of square billets to obtain low-waste or waste-free cutting of sheet material. However, when such blanks are reshaped, significant crowning occurs on the open end section of the shell and the metal waste increases when this section of the shell is cut along the height (fig. 3).

![Figure 3. General view of a square shell with crowned open end section](image)

In this case, when forming a workpiece, the kinematics of the flow of the billet’s material becomes more complicated, the stresses in the material increase, which makes it difficult to intensify the operations of forming a square or multifaceted billet without destruction. The resulting shells have a shallow cavity with a significant waste of material for trimming [4-11].

The proposed method differs from the known methods and devices because during the forming, the operations of extruding the corner sections of a square billet to the shape of a circle are combined and at the same time drawing is carried out to get a shell without crowns at the open end [12].

Theoretical studies were carried out using the QForm2D / 3D software package [13].

In this paper, the material flow was investigated during the drawing of a square billet with a thickness of 1.5 mm according to the scheme shown in fig. 4. The gap between the punch and the die is equal to the material thickness. Billet was made of steel 08kp. A hydraulic press with a nominal force of 50 MN and a speed of 50 mm/s was chosen as the equipment. When drawing, a 1.5 mm thick die with a conical input part and a square cavity [1-3] and with slots for slide blocks is used. These slide blocks move diagonally relative to the working cavity of the die at different speeds V, while acting on the corners of the square billet with a force P. Slide blocks push out the corner sections of the square billet. Friction coefficient $\mu = 0.15$. 


Figure 4. Process diagram: a) general view; b) a die with slide blocks

The study of the speed change at 6 points (fig. 5) were carried out in the diagonal directions (points P0, P1, P2) and in the middle of the side (points P3, P4, P5).

Figure 5. Layout of the traced points

3. Results and Discussion

Fig. 6-9 show the graphical dependences of the change in the speed of the radial movement of the traced points, depending on the drawing time at various speeds of the slide blocks.
Figure 6. The speed of the radial movement of the traced points depending on the drawing time at the slide block’s speed of 20 mm/s.

Figure 7. The speed of the radial movement of the traced points depending on the drawing time at the slide block’s speed of 25 mm/s.

Figure 8. The speed of the radial movement of the traced points depending on the drawing time at the slide block’s speed of 35 mm/s.
Analyzing these graphs, we can conclude that the nature of the movement of the studied points is different. Points P0 and P1, which are located, respectively, at the edges of the corner section and the middle of the side of the square blank (Fig. 5) are of the greatest interest. P0 is located in the area that does not deform during the drawing without the extrusion of the corner sections using slide blocks.

When using the method of combined drawing and extrusion of square box parts from a square billet, it can be seen that the speed of point P0 increases rapidly, and the greater the speed of movement of the slide blocks, the more significant its growth. It should be noted that there is a slowdown in the movement of point P3. In the last stages of drawing, the speeds are leveled and reach the speed of the punch.

Table 1 shows the stages of forming a square billet at the moment of equal speeds of points P0 and P3. You can clearly see how the process of extruding the corner sections of a square billet is carried out. With an increase in the speed of the slide blocks, the resulting billet has the edge close in shape to a circle.

Table 1. Stages of forming a square billet at the moment of equal speeds of points P0 and P3

| Speed, m/s | 20  | 25  | 35  | 40  |
|------------|-----|-----|-----|-----|
| Time, s    | 0.283 | 0.383 | 0.625 | 0.825 |
| Blank type | ![Image] | ![Image] | ![Image] | ![Image] |

In table 2, we can observe a general view of a square box part obtained at various speeds of the slide blocks.
Table 2. General view of a square box part obtained at various speeds of slide blocks

| Speed of Slide Block (Vn) | Crown Height (hk) |
|--------------------------|-------------------|
| 20 mm/s                  | 22.5 mm           |
| 25 mm/s                  | 19.3 mm           |
| 35 mm/s                  | 9.6 mm            |
| 40 mm/s                  | 3.4 mm            |

Vn – speed of the slide block
hk – crown height.

From the analysis of table 2, it can be seen that with an increase in the speed of the slide blocks, crowning decreases to a greater extent.

Conclusion
During the extrusion of the corner sections, tensile stresses are reduced, which prevents the destruction of the billet’s material at the transition of the bottom to the wall and creates conditions for intensifying the forming process and reducing the number of drawing operations. The technologies developed on the basis of the proposed method for producing shells from square sheet billets allow saving up to 30% of sheet material and reducing the production cost by 25% or more.

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