Exploring of an open hammer die life with an expanding gutter using information technologies

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Abstract: Currently, open dies with a parallel bridge are widely used. The design of such stamps is carried out according to proven methods. However, the dimensions of the bridges obtained do not always provide a sufficiently high durability of the dies. The decrease in the durability of the dies caused by the overestimated resistance of the bridge is especially noticeable in the manufacture of simple forgings that do not have complex cavities filled by extrusion. Thus, industries need more durable tooling that can provide a large number of stamped parts, as well as save money on the development, design and manufacture of a new stamp. To this end, in this paper, an analysis of the application of an expanding burr groove in atool is considered. Practical experience of how the tooling is worn out with the number of stampings, the geometry of the tooling is measured, an analysis is carried out, and a mathematical model of the behavior of wear based on the experiment is presented. The same equation was obtained using Excel, which indicates that the mathematical model was obtained correctly. In addition, the paper considers the value of individual parameters of the tool geometry on the overall tool life.

1. Introduction
An important direction in the development of forging and stamping production is to increase the durability of technological equipment for stamping heat-resistant and stainless steels, titanium alloys and other hard-to-form alloys. The durability of open dies is small and amounts to 800-1000 pieces before the first restoration [1].

2. Relevance, scientific importance of the issue
The shape and dimensions of the flash gutter have a great influence on the durability of the open die. Being a pressure regulator in the die cavity, the flash gutter works under very difficult conditions: high normal and shear stresses, high surface temperature. All this leads to significant crushing and abrasion of the surface of the tooling [2].

3. Formulation of the problem
In the course of this work, it is necessary to obtain mathematical one-factor models that give an idea of the influence of the geometric parameters of the flash gutter on the overall wear of the die. A model obtained from the results of a practical experiment, as well as a model obtained using information technology (Excel) [3].
4. Theoretical part

One of the main parameters responsible for tool life is geometry. Consider the value of the geometric dimensions of the flash gutter on the durability of the stamp as a whole.

Flash refers to excess metal usually found at the periphery of the workpiece, which is subsequently trimmed in a separate die. It forms on the flaking surface, usually near the cavity of the stamp engraving. The flash design is critical as it plays two conflicting but important roles during stamping:

1) Acts as a limitation for external metal flow during the first phase of part formation. In this way, deep cavities as well as hard-to-reach and remote corners can be filled.

2) It removes excess metal from the cavity in the second phase after complete filling of the cavity in order to get rid of excess pressure.

Also, it acts as a cushion for hammer blows when shaping at high speeds.

Most finishing dies are designed with a burr groove in them, however, in practice, they are used only in the following cases:

- Fewer forming steps required
- A workpiece of complex shape with large multidirectional deformation should be obtained

Flash gutter thickness has always played an important role: as a lower value will require more energy to bring the forging to the desired size, while a higher value can cause insufficient die filling [4].

5. Practical importance, proposals and implementation results

2000 forgings were stamped in the experimental die.

To study the integral wear, 5 control forgings were selected within the manufactured batch.

To calculate the integral value of the die wear, the cross-sectional areas of the forgings were measured graphically.

![Figure 1. Cross-section of the control forging after the manufacture of 100 parts, sample No.1.](image1)

![Figure 2. Cross-section of the control forging after the manufacture of 500 parts, sample No.5.](image2)

![Figure 3. Cross-section of the control forging after the manufacture of 1100 parts, sample No.1`.](image3)

![Figure 4. Cross-section of the control forging after the manufacture of 1600 parts, sample No.6`.](image4)
The dependence is the equation of the straight line (1):

\[ y = ax + b. \]  \hspace{1cm} (1)

Thus, applying the least squares method, we get:

\[ S = \sum_{i=1}^{n} (ax_i + b - y_i)^2 \rightarrow \text{min} \]  \hspace{1cm} (2)

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where \( x_i, y_i \) - coordinates of experimental points; \( a, b \) - are unknown coefficients.

Let’s find the partial derivatives:

\[ \frac{\partial S}{\partial a} = 2 \sum_{i=1}^{n} (ax_i + b - y_i)x_i = 0; \]  \hspace{1cm} (4)

Table 1 shows measurements of the groove thickness:

**Table 1.** Measurement results for minimum burr thickness.

| Part No. | D, (mm) | \( \Delta D, \) (mm) | \( h_1, \) (mm) | \( h_2, \) (mm) | \( h_{cp}, \) (mm) | \( h_t, \) (mm) | \( S, \) (mm) | \( S \cdot h_t \) |
|---------|---------|---------------------|----------------|----------------|-----------------|---------------|-------------|----------------|
| 1       | 7.275   | 0.275               | 1.59           | 1.605          | 1.597           | 1.322         | 100         | 132.2         |
| 2       | 7.215   | 0.215               | 1.58           | 1.515          | 1.547           | 1.332         | 200         | 266.4         |
| 4       | 7.15    | 0.15                | 1.41           | 1.505          | 1.457           | 1.307         | 400         | 522.8         |
| 5       | 7.215   | 0.215               | 1.63           | 1.54           | 1.58            | 1.365         | 500         | 682.5         |
| 6       | 7.18    | 0.18                | 1.53           | 1.515          | 1.522           | 1.342         | 600         | 805.2         |
| 7       | 7.18    | 0.18                | 1.575          | 1.56           | 1.567           | 1.387         | 700         | 970.9         |
| 9       | 7.18    | 0.18                | 1.55           | 1.54           | 1.545           | 1.365         | 900         | 1228.5        |
| 10      | 7.29    | 0.29                | 1.595          | 1.55           | 1.572           | 1.282         | 1000        | 1282          |
| 1'      | 7.0     | 0                   | 1.39           | 1.405          | 1.397           | 1.397         | 1100        | 1536.7        |
| 2'      | 7.08    | 0.08                | 1.62           | 1.33           | 1.47            | 1.39          | 1200        | 1668          |
| 4'      | 7.21    | 0.21                | 1.53           | 1.54           | 1.535           | 1.325         | 1400        | 1855          |
| 6'      | 7.20    | 0.20                | 1.57           | 1.63           | 1.6             | 1.4           | 1600        | 2440          |
| 7'      | 7.10    | 0.10                | 1.64           | 1.54           | 1.59            | 1.49          | 1700        | 2533          |
| 9'      | 7.18    | 0.18                | 1.645          | 1.645          | 1.645           | 1.465         | 1900        | 2783.5        |
| 10'     | 7.16    | 0.16                | 1.68           | 1.605          | 1.642           | 1.482         | 2000        | 2964          |

Figure 5. Cross-section of the control forging after the manufacture of 2000 parts, sample No.10.”
\[
a \sum_{i=1}^{n} x_i^2 + b \sum_{i=1}^{n} x_i - \sum_{i=1}^{n} x_i y_i = 0; \quad (5)
\]
\[
\frac{\partial s}{\partial b} = 2(\sum (ax_i + b - y_i)) = 0; \quad (6)
\]
\[
a \sum_{i=1}^{n} x_i + nb - \sum_{i=1}^{n} y_i = 0; \quad (7)
\]
Can write a system of equations:

\[
\begin{cases}
a \sum_{i=1}^{n} x_i + nb - \sum_{i=1}^{n} y_i = 0 \\
\sum_{i=1}^{n} x_i^2 + b \sum_{i=1}^{n} x_i - \sum_{i=1}^{n} x_i y_i = 0
\end{cases} \quad (8)
\]

\[
b = \frac{\sum_{i=1}^{15} x_i y_i - a \sum_{i=1}^{15} y_i}{15}; \quad (9)
\]

\[
a = \frac{\left(\sum_{i=1}^{15} x_i y_i + \sum_{i=1}^{15} x_i y_i \right)^2}{\sum_{i=1}^{15} x_i^2}\left(\frac{\sum_{i=1}^{15} x_i}{15}\right)^2; \quad (10)
\]

When calculating the coefficients a and b, it is necessary to take into account that
\[
x_i = \varphi_i, \quad ay_i = h_i
\]
\[
(\sum_{i=1}^{15} x_i)^2 = 2340900000;
\]
\[
\sum_{i=1}^{15} x_i^2 = 20790000.
\]

We get:

\[
a = 7.84 \cdot 10^{-5};
\]
\[
b = 1,297.
\]

Accordingly, the results of the experiment can be described by the following straight line (11):

\[
h_i = 7.84 \cdot 10^{-2} \cdot S + 1,297 \quad (11)
\]

where \( h_i \) is the minimum thickness of the expanding bridge; \( S \) — is the number of stamped parts.

A similar study can be carried out using the Excel package, only for different types of approximation.

Let us consider the influence of the number of stamped products on the groove thickness with a quadratic dependence, shown in figure 6.

\[\text{Figure 6. Influence of the number of stamped products on the minimum groove thickness (quadratic dependence).}\]

\[
h_i = 0.0106S + 1,2922 \quad (12)
\]

\[
h_i = 10 \cdot 10^{-2} \cdot S_i + 1,2922
\]
As a result, a dependence in Excel is created, we got an equation close to the equation, obtained mathematically. They are identical. The Excel equation can be used with the score the degree of confidence which, the equality $R^2 = 0.5595$.

6. Conclusion
Flash land is not directly related to the tool life, since the coefficients for the minimum thickness of the expanding flash land, the number of stamped parts, and the diameter are equal to zero, and at heights they are insignificantly small.

The durability of the punch depends most of all on the deviations of the diameter of the workpiece during stamping, depends on the input and output thicknesses of the burr, as well as on the combined effect of durability and the thickness of the flash, i.e. tool life depends on the geometry of the flash gutter.

With an increase in the difference in diameter from the standard, the resistance will increase. With an increase in the thickness of the entrance flash gutter at the entrance and exit, the tool life decreases. The combined effect of durability and thickness increases die durability.

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