Production Engineering of Parts by Cold Stamping

A Gerasimova1,a*, B Belelyubskii1,b

1National University of Science and Technology "MISIS", street the Lenin prospect, 4, Moscow, 119049, Russia

E-mail: aallochka@rambler.ru, bnis_mgymi@mail.ru

Abstract. In the scientific article presents the results of the finite element modeling of cold extrusion of carbon steel, the stress-strain state of massive dies at high cyclic stresses characteristic of the cold extrusion of steel are presented. The possibility of significant amplification of dies in their working area by creating a variable external pressure from the rims of a special design is shown. Dies banding with variable external pressure, proportional to the internal pressure in the die, is aimed at increasing the technical resource of the tool.

1. Introduction

One of the main tasks of modern engineering technology is to improve the accuracy and quality of blanks. This task is most fully realized when using processes based on a cold plastic deformation. Among the most progressive processes based on the cold plastic deformation is a cold massive forming [1-5].

The cold massive forming is one of the most productive methods for production parts from steel, non-ferrous metals and their alloys with high ductility. This method is widely used in machine building, instrument engineering and other branches of the metal-mechanic industry [6-10].

The use of this technology makes it possible to produce parts of particularly complex shapes that cannot be obtained using other processing methods. Metal molding without destroying its integrity allows increasing the utilization rate of the material up to 95 % even for parts of complex configuration.

Such processing is carried out in several operations, providing a gradual and consistent change in the shape: from the initial shape of the blanks to the desired shape of the part. In the process of metalworking, the material is hardened and its plasticity decreases. In order to increase plasticity and reduce the resistance to subsequent deformations, inter-operative annealing is used [11-15].

High deformation stress leads to an increase in the number of punching, reduce in the durability of die tooling, requires the use of process lubricants and increased power equipment, which leads to tangible initial investments in this method of metal processing by pressure. The cost recovery is offset by greater productivity and the possibility of automation [16-19].

One of the main factors limiting the use of cold forming processes is the destruction of a tool from high cyclic stresses in a tooling. The process of destruction in metals as a phenomenon of accumulation and development of defects has been investigated by a number of authors, for example, in [6], but today, to evaluate the performance of a tool, Mises energy criterion is often used. The magnitude of the stress intensity is compared with the allowable stresses in the metal during its axial testing. To determine the rational variant of the technological process of manufacturing parts by cold
extrusion, today it is possible to effectively carry out computer simulation [20-22]. Below are presented the results of a simulation of one of the cold extrusion options for a typical part. For the calculation in the QForm software package, the following process data were taken:

1. Geometric contours of the blanks and tools were imported from CAD.
2. The workpiece is a plastic medium, the tools are an elastic medium.
3. Equipment - hydraulic press, the speed of movement of the tools is constant.
4. The initial temperature of the workpiece and tool - 20 °C.
5. Coefficient of friction $\mu = 0.15$.
6. The axisymmetric problem was modeled.
7. The parameters of the hardening curve, mechanical and temperature properties of steel 20X.

Solid-state modeling of a tool kit with a blank of steel was realized. For the axisymmetric scheme of plastic deformation, the right half of the section of rotation bodies is drawn.

As a result of the carried out finite element modeling of cold extrusion processes, the fields of elastic deformations, displacements and equivalent stresses in high-loaded parts of the tooling are determined. For fixing the instrument, the boundary conditions are assumed: die with rim (in the study they are united by one body) rests on the bottom end (refer with: Fig. 1).

![Figure 1](image1.jpg)

**Figure 1.** Grid of finite elements and effective stress in the die

The calculated values of equivalent stresses in the die for such a high degree of cold deformation during extrusion of a bar can exceed 5-7 thousand MPa, which is several times higher than the allowable values for tool steels, and even hard alloys used for relatively small products withstand no more than 2500 -3000 MPa. Simulations obtained fields of displacement of the die body and other parameters (refer with: Fig. 2). The supporting lower surface of the die in this virtual experiment is fixed with the possibility of sliding in the radial direction. The simulation has shown that under such stress the die will collapsed during the first processing cycles.

![Figure 2](image2.jpg)

**Figure 2.** Elastic displacements of matrix points under load, QForm-2d.

The usual ways to reduce the loads in the cavity of the matrix are to increase the thickness of its wall (refer with: Fig. 3) and pressing one or more bands.
Figure 3. The stress field in the die for increasing thickness of its wall.

From the figure above it follows that with an increase in the wall of the matrix from 40 to 80 mm the stresses in it decrease to 5700 MPa, but they also significantly exceed the allowable values. The use of presstressed structures partially solves the problem of the strength of a highly loaded tool, however, with a wide amplitude of cyclic deformations, fatigue failure of the tool occurs on the internal surface of the die.

The authors of this work also investigated the design of die with a bandage of an “arched” or “cap” structure (refer with: Fig. 4). The rim (bandage) rests only on the outer annular surface on a rigid base, therefore, under the influence of the deformation force, the bandage can elastically change its shape, since its middle part of the die has the ability to go down under load.

Figure 4. Diagram of a bottom tool of “arched” structure and a field of vertically elastic displacements of the die.

With the increase of the axial force from the press on the material in the cavity of the die in it increase the pressure and tensile stress. In proportion to the action of this force, the middle part of the instrument is elastically lowered. This leads to the appearance of radial compressive stresses between the outer and inner layers of the bandage. The magnitude of these stresses is proportional to the axial displacement, i.e. axial load, as well as the magnitude of the working stresses in the cavity of the die (refer with: Fig. 5).

Figure 5. Equivalent stresses in a bottom tool under load.
Thus, the variable internal operating voltages can be partially balanced additionally by the outer part of the rim. Such banding allows to reduce tensile tangential stresses in the working cavity of the matrix when critical stresses occur, as well as to reduce high compressive tangential stresses in the die from the bandage when relieving the force and internal pressure in the cavity.

This method of strengthening the matrix during cold extrusion can be attributed to one of the methods of "proportional banding" of working cavity. Reducing the amplitude of the cycle of stresses and deformations in the working cavity of the dies and in general of high-pressure vessels is the way to increase their resource.

2. Conclusions
1. The scheme of cold extrusion of a steel product with the use of rims of the arched structure and installation of fastenings on the annular bearing surface of the external contour of the bandage is investigated.

2. The proposed design of the tool has the properties of proportional bandaging, creates useful variable compressive stresses. The expected effect of the use of such a snap is to increase the technical resource of the tool and develop the capabilities of the process of cold extrusion of metals.

3. References
[1] Semenov E I 2007 Forging and forming: 4-volume Guidance Mashinostroenie (Moscow)
[2] Navrotsky G A 1973 Cold forging, Guidance Mashinostroenie (Moscow)
[3] Ragulin A V, Anyukhin A S, Filippov Yu K 2009 Principles of stamps design for volumetric pressing News of MSTU 1 151-156
[4] Gorbutyuk S M, Gerasimova A A, Radyuk A G 2015 Using the Coating for the Diffusion Layer Obtaining on the Walls of the Mold (CM) Metallurgical and mining industry 7(9) 1085-1088
[5] Gerasimova A A, Radyuk A G, Titlyanov A E 2015 Creation of a diffusional aluminum layer on the narrow walls of continuous-casting molds Steel in Translation 45(3) 185-187 DOI: 10.3103/S0967091215030079
[6] Kolmogorov V L 1997 Plasticity and destruction Metallurgy (Moscow)
[7] Nikolaev E A 2010 Fundamentals of fracture mechanics Public Perm State Technical University (Perm)
[8] Fomin A A, Gusev V G 2013 Safe machining of blanks with nonuniform properties Russian Engineering Research 33 602-606 DOI: 10.3103/S1068798X13100043
[9] Gerasimova A A, Radyuk A G, Titlyanov A E 2016 Wear-Resistant Aluminum and Chromonickel Coatings at the Narrow Mold Walls in Continuous-Casting Machines Steel in Translation 46(7) 458 - 462
[10] Zarapin A Yu, Chichenev N A 1999 Designing lines for the production of composite materials based on the object-oriented approach Heavy Engineering 6 16-20
[11] Romanovsky V P 1979 Guidance of cold forming Mechanical Engineering (Leningrad)
[12] Lavrinenko Yu A 2014 Volumetric forming on machines: Study guide Publishing House of MSTU N.E. Bauman (Moscow)
[13] Gluschenkov V A 2012 Hardening of metals in metal forming Publishing House of Samara State Aerospace University (Samara)
[14] Keropyan A M, Gerasimova A A 2017 Connection of the temperature in contact area of the wheel-rail system with the railway slope of industrial railway transport Izvestiya Vysshikh Uchebnykh Zavedenij. Chernaya Metallurgiya 60(5) 355-363 DOI: 10.17073/0368-0797-2017-5-355-363
[15] Miropolsky Yu A 2017 Cold forging on automatic machines Mashinostroenie (Moscow)
[16] Gorbutyuk S M, Morozova I G, Naumova M G 2017 Reindustrialization principles in the heat treatment of die steels Steel in Translation 47(5) 308-312
[17] Gorbutyuk S, Kondratenko V, Sedykh L 2018 Tool stability analysis for deep hole drilling MATEC Web of Conferences 224 DOI: 10.1051/matecconf/201822401035
[18] Karelin I N, Sedykh V D, Sedykh L V 2013 Modernization of a sharply bending elbow in a steel pipeline Chemical and Petroleum Engineering 49(5-6) 351-354
[19] Kobelev O A, Tsepin M A, Skripalenko M M, Popov V A 2009 Features of technological layout of manufacture of unique mono-block large-dimension plates Advanced Materials Research 59 71-75 DOI: 10.4028/3-908454-01-8.71
[20] Novoselov Y, Bratan S, Bogutski V, Gutsalenko Y 2013 Calculation of surface roughness parameters for external cylindrical grinding Journal Fia-bility & Durability Supplement 1 5-15
[21] Fomin A A 2013 Vibrational motion of a complex mill under the action of the cutting force Russian Engineering Research 33(1) 57-60 DOI: 10.3103/S1068798X13010036
[22] Bratan S, Roshchupkin S, Revenko D 2017 Probabilistic approach for modeling electroerosion removal of grinding wheel bond Procedia Engineering 206 1426–1431