

PAPER • OPEN ACCESS

## Innovative manufacturing techniques of the profiled drawing tool

To cite this article: S V Parshin 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **560** 012082

View the [article online](#) for updates and enhancements.

**ECS**

The Electrochemical Society

THE KOREAN ELECTROCHEMICAL SOCIETY

**The best technical content in electrochemistry and solid state science and technology!**

**Available until November 9, 2020.**

**PRIME™**  
PACIFIC RIM MEETING  
ON ELECTROCHEMICAL  
AND SOLID STATE SCIENCE

**2020**

**REGISTER TO ACCESS CONTENT FOR FREE! ▶**

# Innovative manufacturing techniques of the profiled drawing tool

**S V Parshin**

Institute of New Materials and Technologies, Ural Federal University named after the first President of Russia B.N. Yeltsin, 19, Mira St., Yekaterinburg, 620000, Russia

E-mail: Netskater@mail.ru

**Abstract.** In this article, the new technique of fast production of the tool of irregular shape for profiling of variable thickness wall tubes is described. The specific technological sequence is given, recommendations about computer modeling are made, and the explaining illustration for one of characteristic cases of chosen tube type profiling is given. There is an introduction defining relevance of the solved problem, and recommendations about its solution are made.

## 1. Introduction

Complication of designs of the equipment in the atomic, heat-technical, transport fields of the industry results in need of application of products with a sophisticated profile of cross section. Tubes with the variable thickness of a wall (TPTS) belong to such products. According to the name, such tubes have the differing external and internal forms in cross section. Application of such tubes can be caused by certain constructive reasons or technological need.

Can be referred to the problems limiting widespread introduction of such products in mass application. It is mainly an insufficient study of process and need of design and production of the tool for tubes profiling.

## 2. Materials and methods

The main use of such type of tubes is construction, metallurgy, oil and gas industry, aerospace, nuclear engineering, production of heat exchangers, high-frequency equipment. For this reason, the range of materials used is very wide and includes carbon and corrosion-resistant steel, titanium and copper alloys.

Among the main methods of obtaining such tubes, drawing in a profile die, pressing in a profile die, rolling with a roller tool, etc. can be mentioned.

## 3. The study of subject

Production of tubes with such profile is possible at the expense of the selected technology of deformation of a smooth tube in profile die. At the same time, production of profile tubes of a specific standard size is rather small so in this connection the cost of production of the specialized tool (dies and mandrels) makes the significant impact to product cost. In addition, it is necessary to mention that production of the hard-alloy tool of irregular shape is impossible or it is rather expensive that results in need of production of such dies from tool steel. However, even in this case production of the drawing channel of the required accuracy in preparation (a profile hole) makes an extremely difficult task demanding considerable consumption of time and a significant tool wear.



The need to quickly determine the size of the workpiece and the tool profile, which take into account the actual metal flow, lead to the need to create an automated system for selecting the dimensions of the blank tube for the design of profiles of simple form, and the design of calibration profiles of complex curved shape.

To build an automated system, the methods of computer geometry are used, the use of which allows you to build specified shapes, determine their size and area, etc.

The automated system contains three modules. The first module allows you to determine the parameters of the blank tube in general, sets their value for single-pass drawing of tubes with a cross section in the form of regular polygons, and compares the data with values according to standards. The second module is designed to determine the dimensions of the cross-section of the blank tube with a two-pass drawing; it defines a geometric parameters of the intermediate transition based on the construction of streamlines and equipotentials for tubes containing regular polygons in section. The third module is designed to calculate the required number of transitions of curvilinear profiles with the determination of the sizes of all intermediate transitions.

The resulting dimensions of the blank tube, as a rule, differ from those available in actual standards for round tubes.

The experience of calculations using the choice of the diameter of the blank tube and the thickness of its wall according to standards showed that sometimes there is an increase in the total drawing for single pass drawing more than acceptable. Therefore, in this case, one pre-transfer of the drawing on a stationary cylindrical mandrel is required to obtain tube sizes equal to those originally calculated, or to obtain these dimensions directly at the tube plant.

Further, if necessary, we carry out the calculation for multi-pass drawing. There can be many transitions from the size and configuration of the blank tube to the parameters of the finished tube. The actual will be the one in which the metal moves along current lines orthogonal to the initial and final profiles, and the contour of the working tool corresponds to equipotentials, orthogonal to the current lines. The position of the equipotentials on the current lines is determined by the required value of the elongation.

To determine the configuration and size of the TPTS intermediate profile, a computer-aided method for constructing current lines and equipotentials has been developed. Based on the proposed automated system, calculations are performed; some results are given for two-pass drawing.

If the finished profile tube cannot be obtained in one pass - then it is necessary to determine the calibration of the instrument on the intermediate dimensions of the second and subsequent passes.

The construction of the cross-sectional profile of the working tool was performed based on the position that the movement of metal particles during plastic deformation conforms the law of least resistance, which is implemented by constructing streamlines (metal movement trajectories) orthogonal to the profile of the blank and the profile of the finished tube. In addition, closed curves should be constructed dividing the streamlines into parts that are orthogonal to them and which have been called equipotentials.

To determine the position of the metal streamlines, the equipotentials and the profile of the instrument, a method for their computer construction has been developed, which briefly looks as follows.

We build the outer and inner (hole) contours of the finished tube, which are taken as equipotential. Further, these curves (for blank and finished profile) are described in the Kompas 3D program by cubic Bezier splines, which look like this:

$$\beta(\tau) = (1 - \tau)^3 P_0 + 3\tau(1 - \tau)^2 P_1 + \tau^3 P_3, \tau \in [0.1] \quad (1)$$

It is known that a spline is a curve that has the smallest curvature and passes through given points, i.e. it is a line of the smallest length. Bezier curves are edited so that at the intersection of profiles the tangents to them are parallel to the auxiliary perpendiculars. Within the boundaries of the plots, we construct Bezier curves (streamlines) through the corresponding points of the initial profile. In turn, the resulting set of curves - streamlines is divided into parts, defined as follows. We find, given by the

deformations  $\mu_1, \mu_2 \dots \mu_n$  of the cross-sectional area at the transitions  $F_1, F_2 \dots F_n$ . Next, look for

$$\alpha_1 = \sqrt{F_0} - \sqrt{F_1}; \alpha_2 = \sqrt{F_1} - \sqrt{F_2}; \dots; \alpha_n = \sqrt{F_{n-1}} - \sqrt{F_n}; \quad (2)$$

In accordance with the found, mark up the segments on the streamline and on the points obtained in the Kompas-3D program, we construct orthogonal curves to these lines, called equipotentials. Two adjacent equipotentials determine the profiles of the input and output sections. If necessary, the condensation of the streamlines is possible.

#### 4. Determination of the longitudinal profile of the tool.

The above cross-sections in the form of equipotentials and the distance between them, measured along the normals (lines of current), allow us to determine the length of the working part of the working main tool. However, it is necessary to determine the side surface of the tool. For this purpose, we will use ruled surfaces defined by equipotentials.

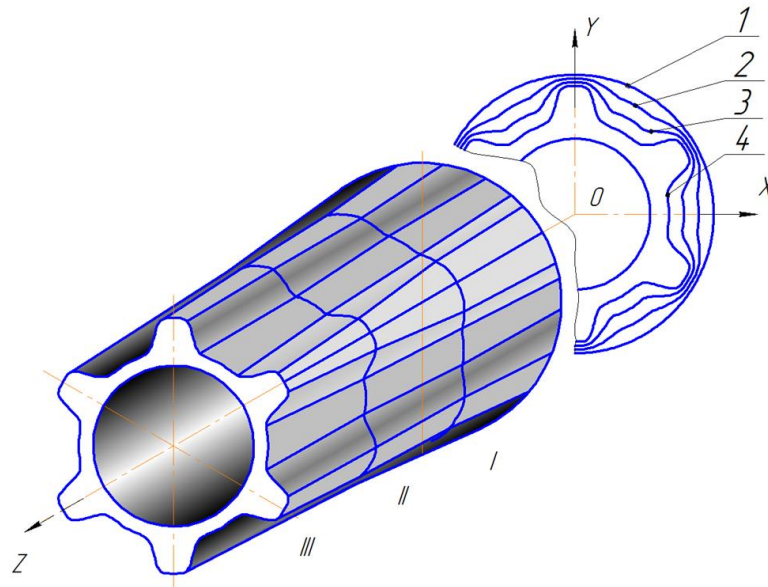
For regular polygons, we build regular conoids with generators in the form of straight lines. The condition of parallelism is set by the requirement of a uniform intersection of the generator in all its positions with the curved guide and the guide segments of a regular polygon under one-pass deformation. For profiles that are curvilinear in cross section, we build regular cylindroids whose parallelism condition requires the uniform distribution of the points of intersection of the generator in all its positions with curvilinear guides defined by two adjacent equipotentials.

The axial distance between adjacent equipotentials can be found if the angle of inclination of the lateral surface forming is known. This angle is found from the condition of the minimum dragging force.

The mathematical model of the process contains the following equations written in a spatial orthogonal coordinate system: equilibria, physical and geometric equations, we set the boundary conditions: at the front end of the tube in the form of displacements, and on the contact surfaces in the form of tangential stresses defined by Zibel's law.

The practical technology containing the following sequence is offered:

1. Modelling of die internal channel in CAD software and with use of analytic or finite element model [1-12] calculations for the centre of deformation and its iterative adaptation taking in account the accuracy of the received tubes. Adaptation is carried out based on creation of current lines and equipotentials and also conoids and cylindroid in longitudinal section depending on type of a profile (figure 1).
2. Processing of solid model with reduction of her dimensions by the size of an allowance for further processing [13-18]
3. Transfer of model for preparation for the 3D-print
4. The print on the 3D-printer with a sufficient accuracy. [19-21] Data from open sources are that that the print by the photopolymer (high-detailed acrylic plastic) on the Stratasys Objet Eden 3D-printer, provides the print accuracy (layer thickness) to 16 microns and is carried out by layer-by-layer putting liquid polymeric material, and each layer is cured by an ultraviolet ray. The greatest possible size of model is declared 340 x 340 x 200 mm.
5. Metallization of the received detail, for example, by chemical or metal dusting [22-24]. Final thickness of the put layer corresponds to thickness of the allowances established earlier.
6. Use of the received detail as an electrode for electrochemical or other erosive processing.
7. Die finishing processing by sand cleaning, and the subsequent polishing.



**Figure 1.** A deformation center model current tube when drawing a curvilinear profile in three transitions: 1 – external contour of preparation; 2,3 – isopotential of the first and second pass; 3 – contour of a ready tube. I, II and III – die calibration the first, second and third pass.

Advantages of this technology consist in rather high speed of receiving the ready tool (that does possible production at the time of the order of part of tubes), high precision of geometry and purity of a surface, possibility of die production directly from the thermoprocessed blank.

## 5. Conclusion

Use of such technology allows to carry out production of the tool for profiling of tubes in several passes by application of die or mandrel sets with consistently narrowed output section. Besides, becomes possible to manufacture the tool with a curvilinear form in longitudinal section at the expense of what it is possible to receive the most uniform distribution of pressure of metal to die working surfaces. It, in turn, reduces wear of the tool and allows to bring tool steel die wear rate closer to that for hard-alloy.

## Acknowledgments

The reported study was funded by the state budget themes “Theoretical foundations for the development of new processes and machines for improving the competitiveness of manufactured products”, “Developing the theoretical foundations of technologies and equipment for producing new types of metal products”.

## References

- [1] Moaveni S 2008 *Finite Element Analysis. Theory and Application with ANSYS*. (Mankato: Pearson Prentice-Hall, Inc.)
- [2] Sawamiphakdi K, Lahoti G D and Kropp P K 1991 Simulation of a tube drawing process by the finite element method *J. Mater. Process. Technol.* **27** 179-190
- [3] Karnezis P and Farrugia D C J 1998 Study of tube drawing by finite-element modelling *J. Mater. Process. Technol.* 690-691
- [4] Moon Y H, Lee D H, Van Tyne C J 2005 Optimal distribution of drawing strains in the two-pass tube drawing process *Proc. Inst. Mech. Eng., Part B: J. Eng. Manuf.* **219** 595-602
- [5] Palengat M, Chagnon G, Millet C and Favier D. 2007 Tube drawing process modelling by a finite element analysis *Materials processing and design: modeling. Simul. Appl.* 705-710
- [6] Kuboki T, Nishida K, Sakaki T and Murata M 2007 Effect of plug on levelling of residual stress

- in tube drawing *J. Mater. Process. Technol.* **204** 162-168
- [7] Neves F O 2005 Numerical and experimental analysis of tube drawing with fixed plug *J. Braz. Soc. Mech. Sci. Eng.* **XXVII**(4) 426-431
- [8] Okui T, Kuroda K and Akiyama M. 2005 Suppression of bending phenomenon of steel tube in diameter reduction by cold press *Proc. Int. Mech. Eng. Part B: J. Eng. Manuf.* **220** 627-635
- [9] Bihanta R, Guillot M, Fafard M, D'amours G and Rahem A 2010 *Numerical studies on the production of variable thickness aluminium tubes for transportation purposes* (Detroit, Michigan, USA)
- [10] Guillot M, Fafard M, Girard S, Rahem A and D'Amours G 2010 *Experimental exploration of the aluminum tube drawing process for producing variable wall thickness components used in light structural applications* (Detroit, Michigan, USA) 10M-0129
- [11] Béland J F 2009 *Optimization of Cold Tube Drawing of Aluminium 6063-T4 with Finite Element Method*. (M.Sc. Thesis, Laval University, Quebec, Canada)
- [12] Lange K, Pöhlandt K, Raghupathi P S, Saniter J D, Sauer W, Schey J A, Weinmann K J and Widera G E O 1985 *Handbook of Metal Forming* (McGraw-Hill) 13-22
- [13] Avitzur B 1983 *Handbook of metal-Forming Process* Ed. John Wiley & Sons. (N. York, Cap. 9: Tubing and Tubular products)
- [14] Brethenoux G 1996 Cold forming processes: some examples of predictions and design optimization using numerical simulations *J. of Mat. Proc. Tech.* **60(1-4)** 555-562
- [15] Karnezis P E and Farrugia D C J 1998 Study of cold tube drawing by finite-element modeling *J. Mat. Proc. Tech.* **80-81** 690-694
- [16] Joun M S and Hwang S M 1993 Pass Schedule Optimal-Design In Multipass Extrusion And Drawing By Finite-Element Method *Int. J. Mach. Tools & Manufacture* **33(5)** 713-724
- [17] Pospiech J 1998 Description of a Mathematical Model of Deformability for the Process of Drawing Tubes on a Fixed mandrel *J. of Mat. Eng. and Performance* **21** 71-78
- [18] Gebhardt A 2003 *Rapid Prototyping* (Hanser Verlag: Munich, DE)
- [19] Wannarumon S and Bohez E L J 2004 *Rapid Prototyping and Tooling Technology in Jewelry CAD 1*
- [20] Sun H B and Kawata S 2006 Two-Photon Photopolymerization and 3D Lithographic Microfabrication *Adv. Polym. Sci.* 170
- [21] Krivec S, Matsko N, Satzinger V, Pucher N, Galler N, Koch T, Schmidt V, Grogger W, Liska R and Lichtenegger H 2010 Silica-Based, Organically Modified Host Material for Waveguide Structuring by Two-Photon-Induced Photopolymerization *Adv. Funct. Mater.* 20
- [22] Krulik G A and Othmer K 1983 *Electroless plating. Encyclopedia of Chemical technology* (John Wiley & Sons, New York) vol. 9, 206-218
- [23] Teixeira L and Santini M 2005 Surface conditioning of ABS for metallization without the use chromium baths *Journal of Materials Processing Technology* **170** 37-40
- [24] Mandich N V and Krulik G A 1993 On the mechanisms of plating on plastics *Plating and Surface finishing* 80(12) 68-73