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NUMERICAL ANALYSIS OF THE FORMING PROCESS OF HEAD TOOTHING IN ROLLING EXTRUSION ON A SHAFT FROM ALUMINUM ALLOY 7075

ANALIZA NUMERYCZNA KSZTAŁTOWANIA UZĘBIENIA CZOŁOWEGO W PROCESIE PRZEPYCHANIA OBROTOWEGO NA WALKU ZE STOPU ALUMINIUM 7075

W opracowaniu przedstawiono metodę kształtowania uzębienia czołowych z wykorzystaniem technologii przepychania obrotowego. W obliczeniach numerycznych wykorzystano modele numeryczne narzędzi o specjalnie zaprojektowanym do tego celu kształcie. Przedstawione wyniki obliczeń numerycznych obejmują kinematykę płynięcia metalu, rozkłady naprężeń oraz odkształceń. Ustalone w symulacjach parametry technologiczne kształtowania uzębienia czołowego umożliwiają prognozowanie zmian kształtu wyrobu w planowanym do przeprowadzenia eksperymencie.

Keywords: Rolling extrusion, FEM, numerical modelling, head tothing

This paper presents the forming method of head tothing with the application of rolling extrusion technology. Tools numerical models were used in numerical calculations. The presented numerical results concern metals flow kinematics, distributions of stresses and strains. Determined in the process technological parameters of head tothing forming allow foreseeing real material flow in the experiment planned for conducting.

1. Introduction

Shafts with head tothing are applied in technique on a large scale mainly in coupling devices. The manufacturers of these products constantly search for new solutions guaranteeing faster work and reliability at the lowest cost per piece. In order to meet these requirements, it is necessary to look for new solutions, both at the designing stage and during manufacturing. Comparison between different technologies of this kind of part manufacturing (machining, casting, powder metallurgy and metal forming) shows advantages of the last one [1,3-6]. Among them, the most interesting solutions concern manufacturing with allowances as low as possible.

This paper presents the analysis results of the new forming process of products with head tothing by means of the rolling extrusion technology. The authors concentrated on the possible to obtain teeth outline and dimensional deviations, which is of great importance in economical analyses of manufactured finished products.

2. Rolling extrusion process

A new proposal within the scope of parts with head tothing forming is the rolling extrusion technology [1,2]. In this process material is formed by means of three rotating rolls. The workpiece is provided by means of a pusher moving the billet in a working space between these tools - rolls. The rolling extrusion process course depends on different shapes of profiled rolls and its rotary velocities correlated with pusher displacement. A schematic diagram of this process is shown in Figure 1, in which the expected movements of particular tools and the cylindrical billet are marked.

The implementation of the rolling extrusion technology is not connected, in the assumption, with limiting of the product length and allows for any setting of the forming cycle, within the scope of matching of rolls rotational movement and the linear movement of pusher displacing the formed material. This solution connects in itself advantages of the cross wedge rolling by means of three working tools [3-5] with additional possibilities guaranteed by the application of the pusher inserting the billet into the workspace. In that way, the length of the product obtained in this method is limited by a stroke of the pusher and rigidity of the rotating billet, which can undergo buckling.

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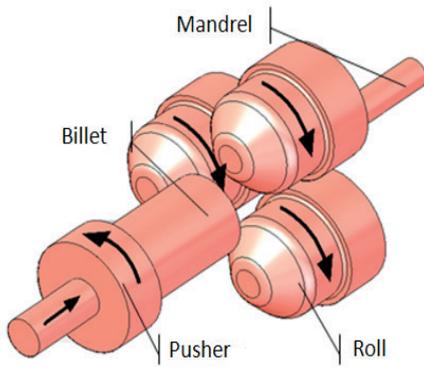


Fig. 1. Schema of the rolling extrusion process [1]

In this process also can be applied rear bumper or mandrel which extend the scope of application of this technology. Using these additional tools, it is possible to limit axial material flow which permits to obtain flanges, hubs etc

Thinking about head toothing by rolling extrusion method, the authors focused on calculations of lightweight part from aluminium alloy 7075. This material can be applied in modern coupling elements where the total weight of mechanism plays an important role in designing and operating.

3. Numerical analysis

Numerical calculations of the rolling extrusion process of head toothing, realized with the application of software Deform3D, according to the schema given in Figure 2, were discussed. In order to achieve the result the most similar to the real one, it was decided that the process would take place in conditions of heat exchange with the air. Material model of aluminium7075 was taken form software library. The temperature of the billet was 460°C and the forming rolls (modelled as rigid bodies) it was assumed 150°C. The heat exchange coefficient between tools and the billet was assumed equal 5000 W/m²K and between the billet and the air it was 200 W/m²K. Constant friction model with friction factor $m = 1$ was taken into account during calculations due to risk of slipping presence [7]. For rotational metal forming processes it is a normal value, but for another application cases (forging, extrusion etc.) normally friction factor values about 0.72 are applied [8].

Working rolls sets have the external diameter 225 mm Tools rotary velocity was constant and set on 60 rot/min. The only element that underwent deformation was the billet – full and hollow with the external diameter 70 mm, other elements, such as rolls, were considered as rigid elements which did not undergo deformation. For the calculations needs, it was necessary to design special shape of teeth on tools [9]. This patented solution is presented in the Figure 3.

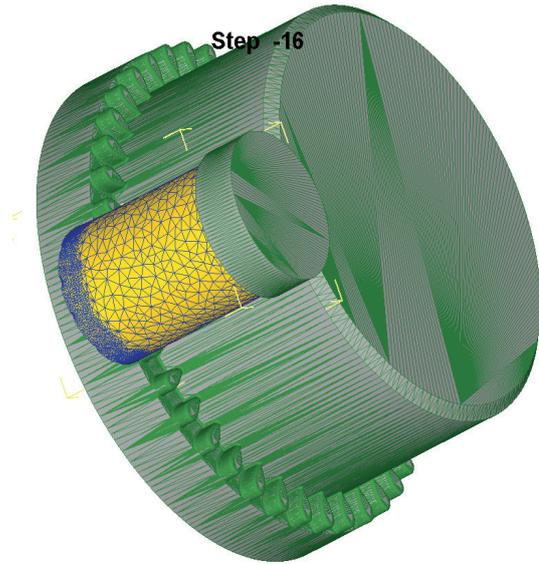


Fig. 2. The worked out for the calculations needs numerical model of rolling extrusion process with visible mesh with local refinement in the zone of formed teeth (two rest rolls invisible)

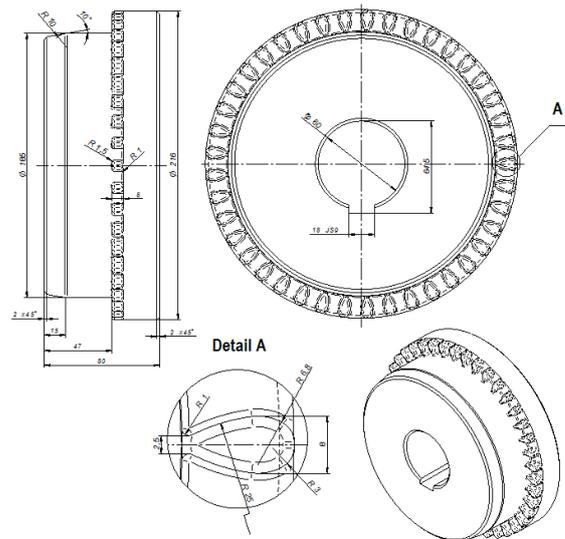


Fig. 3. Designed shape of tools for head toothing forming by means of rolling extrusion process [9]

Figure 4 presents the forming process with distributions of effective stress with process advancement given in percents. The maximum values of effective stress during this process reach the values about 100 MPa at the area of contact tools – workpiece. After teeth forming stresses values decrease till the end of the rolling.

In the Figure 5 the distribution of effective strain in this process is shown. The highest values of effective strain are observed in the area of teeth forming. The core of the formed part stays without strain, yet, it gives part rigidity. In the same cases of forming from tube shaped billets material flowed also into the billet axis, which disturbed final shape of obtained parts. Finally, all calculation cases were realized using full billets.

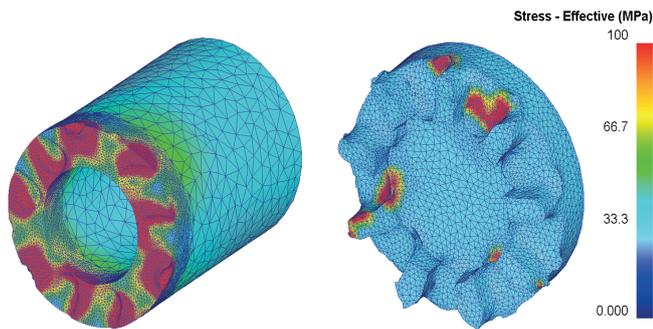


Figure 4. The shape progression of workpiece during head tothing forming with the marked distributions of effective stresses with process advancement (10% left side and 100% right side)

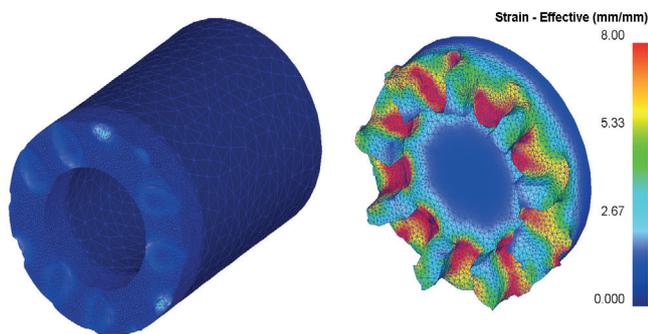


Fig. 5. The shape progression of workpiece during CWR process with the marked distributions of effective strain with process advancement (10% left side and 100% right side)

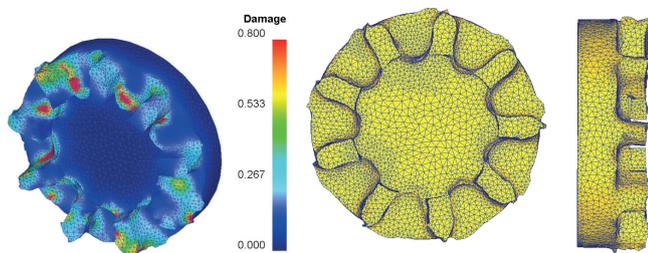


Fig. 6. Distribution of Cockcroft- Latham damage criterion (left side) and final shape of calculated head tothing (right side)

The distribution of Cockcroft- Latham damage criterion in the proposed case is shown in Figure 6. The maximal values of this fracture risk criterion reached values about 0.8 at the bottom of teeth. This informs about elevated risk of internal cracks presence at these areas, but it could be provoked by taken into calculation constant friction model with $m = 1.0$. Normally verified in these cases state of tensile stress [10] also can be useful, but limiting value of friction factor is also connected with higher values of shear stress on the surface of formed teeth. Thinking about application of this method it would be better to apply bigger rounding at these areas of tools, which corresponds with needed to obtain final parts shapes. For better visibility in the same

Figure 6 the final shape of obtained in calculation part with head tothing is presented.

4. Summary

The conducted numerical calculations show the possibility of forming of head tothing on billets from aluminium alloy 7075 by means of rolling extrusion technology. On the basis of the obtained numerical results, it was planned to make experiments in the rolling extrusion aggregate, allowing for practical realization of the rolling extrusion process by means of designed rolls.

The further works on determining the dependency between the process parameters and the achieved dimensional deviations of the formed products should lead to obtain products of shape close to the final outline.

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REFERENCES

- [1] J. Bartnicki, The theoretical and experimental research of rolling extrusion process, Lublin 2009.
- [2] J. Bartnicki, FEM analysis of hollow hub forming in rolling extrusion process, *Metalurgija* **53**, 641 (2014).
- [3] Z. Pater, Cross – Wedge Rolling, Lublin 2009.
- [4] A. Danno, T. Tanaka, Characteristics of billet deformation in 3-roll wedge rolling of axisymmetric stepped shafts, Kyoto (1984),
- [5] R. Glaß, F. Hahn, M. Kolbe, L. W. Meyer, Process of partial bulk metal forming – aspects of technology and FEM simulation, *Journal of Materials Processing Technology* **80-81**, 174 (1998).
- [6] J. Tomczak, Z. Pater, T. Bulzak, Designing of screw impressions in the helical rolling of balls, *Archives of Civil and Mechanical Engineering* **14**, 104 (2014).
- [7] Z. Pater, A. Gontarz, W.S. Weroński, The chosen aspects of theory and technology of cross – wedge rolling, Lublin 2001.
- [8] A. Gontarz, A. Dziubińska, Ł. Okoń, Determination of friction coefficient at elevated temperatures for some Al, Mg and Ti alloys. *Archives of Metallurgy and Materials* **56**, 379 (2011).
- [9] J. Bartnicki, J. Tomczak, The tool for rolling extrusion of head tothing P.397944, 2012.
- [10] A. Stefanik, H. Dyja, P. Szota, S. Mróz, Determination of the Critical Value of Normalized Cocroft – Latham Criterion during Multi Slight Rolling Based on Tensile Test, *Archives of Metallurgy and Materials* **56**, 543 (2011).

