EFFECT OF FRICTION ON THE PUNCH FORCE DURING COMBINATION EXTRUSION OF ENAW-1050A ALUMINIUM ALLOY

THOMAS Piotr

Department of Applied Computer Science and Armament Engineering,
Faculty of Mechatronics and Machine Design, Kielce University of Technology, Kielce, Poland, EU
thomas@tu.kielce.pl

Abstract

The experimental results of the combination extrusion process for ENAW-1050A aluminium alloy are presented. Depending on the punch and die sizes used, the tests were performed for three different values of relative strain in backward direction, ε_2, and a constant strain in forward direction, ε_1. The test aimed at determining the effect of friction on maximum values of punch forces. Non-lubricated and lubricated (zinc stearate) extrusion processes were used.

Keywords: Combination extrusion, aluminium

1. INTRODUCTION

Combination extrusion is the process which combines forward extrusion and backward extrusion in one operation. As a result of this combination, not only the time of forming is reduced but also the costs of production are lower due to the elimination of one tool from the production process. Among the available literature, the works [1÷5] are the most extensive reports on forward and backward extrusion. None of them, however, deals with the issues of combination extrusion. Papers [6÷16] contain practical rules and guidelines for technological process design of selected elements applicable under industrial conditions. Publications [17÷20] report the results of computer simulations and experimental study of material flow and punch force values in the combination extrusion process with a flat-cone punch. Given the above, it is considered appropriate to undertake the experimental study of the effect of friction on the values of combination extrusion punch forces.

2. PURPOSE AND SCOPE OF STUDY

This experimental study aims at determining the influence of friction on the values of punch forces for different degrees of backward strain ε_2 at a constant forward strain ε_1 during the process of lubricated and non-lubricated combination extrusion. It was assumed that in the combination extrusion process, shown schematically in **Figure 1**, the material being extruded moves freely both in the forward and in the backward axial directions.

The tests were performed on pre-softened aluminium discs A1 99.5 (ENAW-1050A) with dimensions $d_o \times h_o$ = 24.95×16mm. Mechanical properties of the test material are summarized in **Table 1**. These properties were determined from the static tensile tests performed to PN-EN 10002-1+AC1.

Table 1 Aluminium A1 99.5% (ENAW-1050A) properties.

Material	$R_{0.2}$	R_m	A	$A_{11.3}$	Z
A1 99.5%	24MPa	82MPa	46%	34%	86%

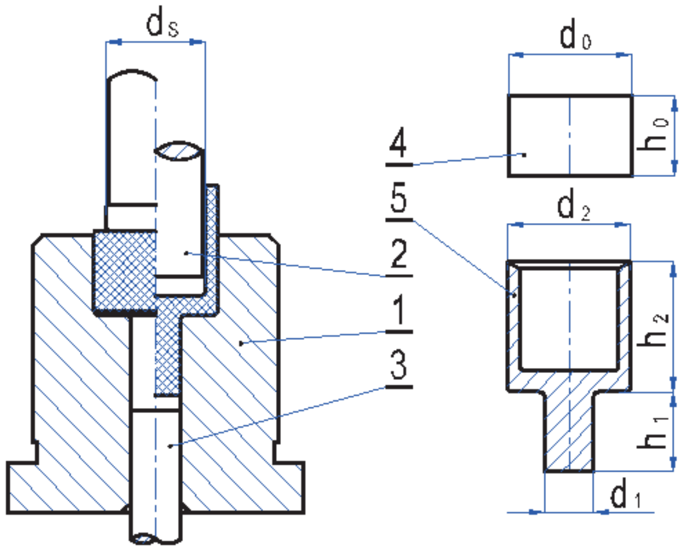

Figure 1 Schematic diagram of combined extrusion with a flat-face punch: 1 - die insert; 2 - flat-face punch; 3 - counterpunch; 4 - slug; 5 - part.

During non-lubricated combination extrusion, the friction coefficient is μ = 0.29 and μ = 0.1 when lubricated extrusion is used. These values were determined in the ring upsetting test (Burgdorf method). Various dimensions of the workpiece with a shape as in **Figure 1** were obtained:

- For the upper part of the component extruded in the backward direction, the outer diameter was d_2 = 25.2mm with inner diameters of d_s=15, 17, 19mm,
- For the lower part of the extruded component, d_1=10mm=const.

The following degrees of deformation were obtained with the assumed material dimensions:

- for backward extrusion, respectively

$$\varepsilon_2 = \frac{d_S^2}{d_0^2} = 0.36; 0.46; 0.58 \tag{1}$$

- for forward extrusion

$$\varepsilon_1 = \frac{d_0^2 - d_1^2}{d_0^2} = 0.84 \tag{2}$$

It was assumed that the maximum height of the cylindrical part of the component was 14mm due to the design of the extrusion die limiting free movement of the material in the forward direction because of the ejector in the tool.

The tests were performed on the ZD100 testing machine with a maximum pressure of 1MN in which a die for combination extrusion was mounted. The changes in punch force values were recorded by two inductive displacement sensors, analog-digital converter LC011-1612 installed in the computer. Data visualization was performed with the POM16 program in the form of graphs of punch force as a function of punch displacement.

3. STUDY RESULTS AND THEIR ANALYSIS

The tests yielded the curves of punch forces as a function of punch displacement during the combination extrusion process. **Figures 2** and **3** show changes in the punch force for three different degrees of backward strain ε_2 at the constant value of forward strain ε_1 = 0.84.

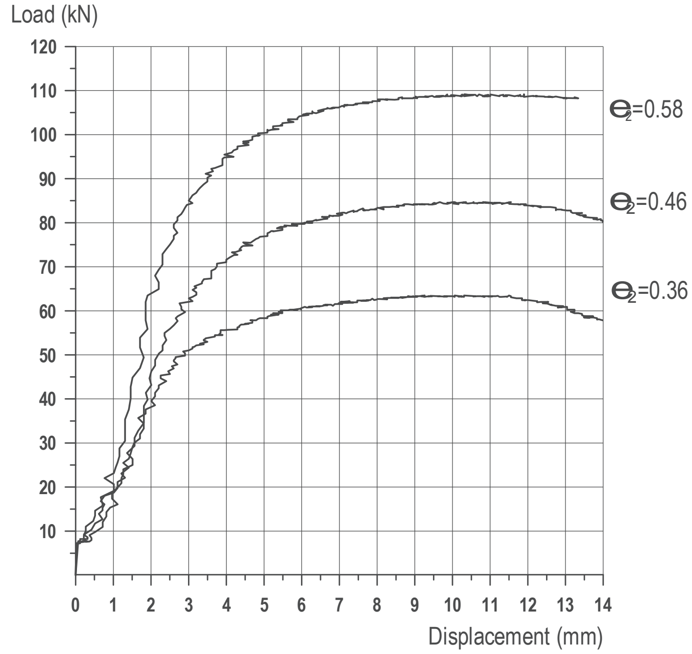

Figure 2 Punch force changes as a function of displacement during combined extrusion for different values of relative backward strain ε_2 and constant forward strain ε_1=0.84 (μ = 0.29)

The punch force changes plotted in **Figure 2** refer to extrusion processes where no lubricant was used (μ = 0.29). The curves depicted in **Figure 3** were plotted for the material lubricated with zinc stearate (μ = 0.1).

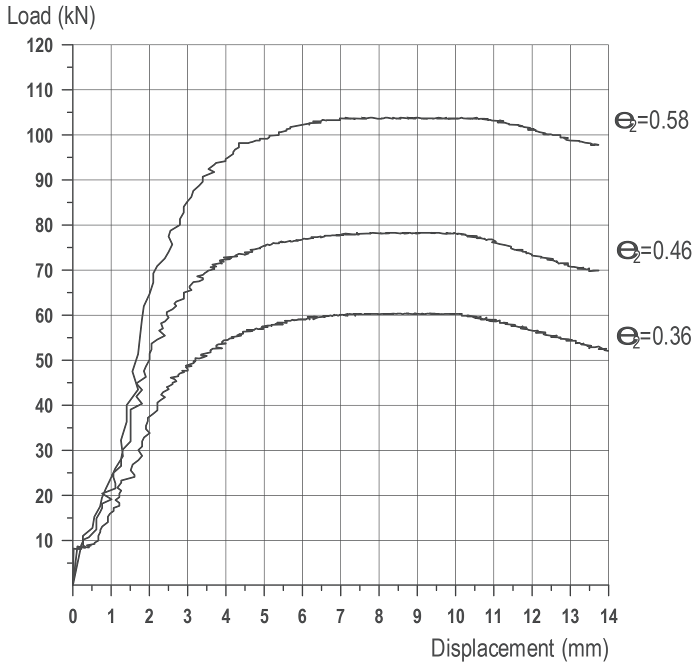

Figure 3 Punch force changes as a function of displacement during combined extrusion for different values of relative backward strain ε_2 and constant forward strain ε_1=0.84 (μ = 0.1)

From the figures above it follows that increased values of strain ε_2 lead to increased punch force values. The force increases quickly with increasing punch displacement in the initial phase of the process to decrease gradually after reaching the maximum value. Reduced friction coefficient caused the maximum force values to decrease for the same relative strains ε_2. The punch force values remained the same.

It has to be noted that for the maximum backward strain ε_2=0.58, the extrusion process proceeds at a smaller value of punch displacement relative to the other strains, ε_2=0.46; 0.36. The combination extrusion process involves a free movement of the material in the axial backward and forward direction. Exceeding the value of 14mm in the forward direction is limited by the front face of the counterpunch. This limitation causes the material to move only in the backward direction and the punch force is doubled.

4. SUMMARY

The following conclusions can be drawn on the basis of the test results: increased degree of backward strain ε_2 contributes to an increase in extrusion force values; the tests with lubrication showed a reduction in extrusion force values, in particular for the maximum degrees of the backward strain ε_2.

It should be stressed that the experimental results presented here showed the advantage of combination extrusion over forward and backward extrusion processes used separately. The forming of tubular-cylindrical parts using the combination extrusion eliminated the need to use two technological operations. The cylindrical part of the component is manufactured in forward extrusion, while the tubular part of the component is made in backward extrusion. This system reduces labour intensity and cost of the tools and by substantially decreasing the forming forces, improves the durability of the tooling.

REFERENCES

[1] DOM F. J. Meltspun aluminium successful in racing pistons. Aluminum, 1994, vol. 70, no 9/10, pp. 575-578.

[2] KRAWIEC, A. CHYŁA, P. CHYŁA, P. BEDNAREK, S. ŁUKASZEK-SOŁEK, A. Numerical analysis of the influence of lubrication conditions on the filling pattern in a complex process of extruding particular high-melting materials. AGH University of Science and Technology Press, Metallurgy and Foundry Engineering, 2012, vol. 38, no. 1, pp. 13-24.

[3] MIŁEK, T. Determine parameters hydromechanical bulge forming of axisymmetric components made from copper tubes. 23rd international conference on metallurgy and materials. Ostrava: Tanger, 2014, pp. 285-290.

[4] MIŁEK, T. Experimental research on hydromechanical bulge forming of pipe connections. Steel Research International 79, Special Edition, 2008, vol. 1, pp. 280-287.

[5] MIŁEK, T., KOWALIK, B., KULINSKI, B. Evaluation of the possibility of performing cold backward extrusion of axisymmetrical thin-walled aluminum die stampings with square section. Archives Of Metallurgy And Materials, 2015, vol. 60, issue 4, pp. 3043-3049.

[6] BANASZEK, G. MICHALCZYK, J. The concept development and numerical method of plastic forming sleeves abort variable longitudinal section. Publisher SIGMA-NOT Hutnik, Wiadomości Hutnicze 2014, vol. 81, no. 5, pp. 300-303.

[7] FOYDL, A, PFEIFFER, I, KAMMLER, M. Manufacturing of Steel-reinforce Aluminum Products by Combining Hot Extrusion and Closed-Die Forging. Key Engineering Materials, 2012, pp. 504-506.

[8] JANG, D. H., OK, J. H., LEE, G. M. The forming characteristics of AA 2024 aluminum alloy in radial extrusion process combined with backward extrusion. Materials Science Forum, 2006, vol. 519-521. pp 955-960.

[9] MICHALCZYK, J. BANASZEK, G. The research of influence selection parameters on process of production pipes the method of single operation two-sided complex extrusion. Publisher SIGMA-NOT Hutnik, Wiadomości Hutnicze 2011, vol. 78, no. 1, pp. 81-84.

[10] MICHALCZYK, J. Development and preliminary numerical study of the new single-operation process of two-sided complex extrusion of deep bottomed sleeves. Publisher SIGMA-NOT Hutnik, Wiadomości Hutnicze 2010, vol. 77, no. 5, pp. 217-219.

[11] MICHALCZYK, J. Study and analisys of new non discards process of extrusion of pipes. Publisher SIGMA-NOT Hutnik, Rudy i Metale Nieżelazne 2011, R. 56, no. 11, pp. 680-684.

[12] MICHALCZYK, J. The analysis of influence of shape die block on the flow of metal and force parameters in the joint process extrusion and cup-ironing of deep sleeves. Publisher SIGMA-NOT Hutnik, Wiadomości Hutnicze 2013, vol. 80, no. 1, pp. 70-73.

[13] MICHALCZYK, J. The Conception and numerical modelling of single-operation process of production of axi-symmetric tube blank with complex shape. Publisher SIGMA-NOT Hutnik, Wiadomości Hutnicze 2012, vol. 79, no. 5, pp. 345-348.

[14] MICHALCZYK, J. The influence of factors temperature and velocity on the of energy and force parameters a two-sided complex process the extrusion of deep-bottomed sleeves. Publisher SIGMA-NOT Hutnik, Wiadomości Hutnicze 2011, vol. 78, no. 3, pp. 243-247.

[15] MICHALCZYK, J. The theoretical and experimental analysis process double-said pipes extrusion in some aspects in competitive method production. Publisher SIGMA-NOT Hutnik, Wiadomości Hutnicze 2011, vol. 78, no. 5, pp. 396-399.

[16] MICHALCZYK, J.The experimental research and the verification of numeric calculations two-sided complex extrusion process of bottom deep sleeves. Publisher SIGMA-NOT Hutnik, Wiadomości Hutnicze 2010, vol. 77, no. 8, pp. 422-425.

[17] THOMAS P. Computer simulation of combination extrusion of ENAW1050A aluminum. 4th International Conference Recent Trends in Structural Materials, Materials Science and Engineering 179, 2017, pp.1-6.

[18] THOMAS P. Experimental investigation of combined extrusion of aluminum products for different shapes of die inserts. 10th European Conference of Young Researchers and Scientists, Transcom 2013, Žilina, pp. 199-202.

[19] THOMAS P. Experimental Studies of Combined Extrusion of Parts Made of ENAW-1050 Alloy. In Metal 2015, 24th International Conference On Metallurgy And Materials, Ostrava: Tanger, 2015, pp. 440-444.

[20] THOMAS P. CHAŁUPCZAK J. Research and analysis of stress force in combined extrusion for different shapes of die stampings. Rudy i Metale Nieżelazne, 2008, R-53, no. 11, pp. 726-730.