

SIMULATION OF THE HEAT DISTRIBUTION BY THE FORWARD COLD FLOW FORMING

**Ibrahim Plančić, Malik Čabaravdić, Edin Begović
University of Zenica, Faculty of Mechanical Engineering, B&H**

**Sebastian Härtel
Technische Universität Chemnitz, Department Mechanical Engineering, Institute for
Machine Tools and Production Processes, Reichenhainer Straße 70, 09126 Chemnitz,
Germany**

**Stefan Kleditzsch
TOGO SCHERDEL GmbH, Am Federnwerk 1, 09496 Marienberg, Germany**

ABSTRACT

The process of forward cold flow forming is a specific procedure of material processing which is used for forming of different rotationally symmetric parts from cylindrical workpieces placed between the pin and roll in the military, aeronautical, nuclear and other industries. Under the pressure of the rolls (two or three rolls) material is brought to the state of plastic flow and extruded in the axial direction, what results in the reduction of the diameter and increase of the length of workpiece. The deformation of workpiece causes the increase of the heat during the processing. In this paper, the temperature analysis of tubular workpieces Al 99.5 during the processing by cold flow forming is shown. The numerical simulation of the process was carried out using simufact.forming GP 11.0 software. In the next step the results of numerical simulations were experimentally verified by measuring the temperature of heated workpieces during the forming with the help of contactless thermal imaging methods (Thermo-camera Fluke Thermography Series These 32).

Key words: process simulation, workpiece temperature, forward cold flow forming, Al 99,5 %

1. INTRODUCTION

Forward cold flow forming is a processing procedure for producing hollow cylindrical parts with constant or variable thickness of the wall using roller-shaped tools with the special pins (Fig. 1). The core of this procedure is to bring the material to the state of plastic flow and extrude it in the axial direction under the pressure of the rolls (two or three rolls), resulting in the reduction of the diameter and increasing of the length of workpiece. The deformation occurs in a narrow contact zone between the rolls and the material. Because the material is mostly processed in cold state, the effect of its strengthening takes place, causing the improvement of its mechanical properties. Because of the applied pressure during processing, a high concentration of energy arises, causing the heating of the material in the forming zone. The temperature in the deformation zone depends mostly on the type of the material, the forming speed/ velocity oder plastic strain rate and the achieved plastic strain. Results of the available experiments show that the temperature of workpiece in deformation zone by processing of steel is between 200 °C and 350 °C. To preserve the positive effects of the cold forming, the deformation zone must be intensively cooled. The cooling is performed using appropriate oil emulsion, which is through appropriate nozzles sprayed into the zone of deformation. Determination of the workpiece's temperature during the processing is a very important task. Its value can directly indicate the performance of the material strengthening and cooling efficiency during processing.

The results of the simulation of arised temperature in the deformation zone and their experimental verification by measuring the temperature during the forward cold flow forming of aluminum with purity of Al 99.5 (technically pure aluminum) are shown in this paper.

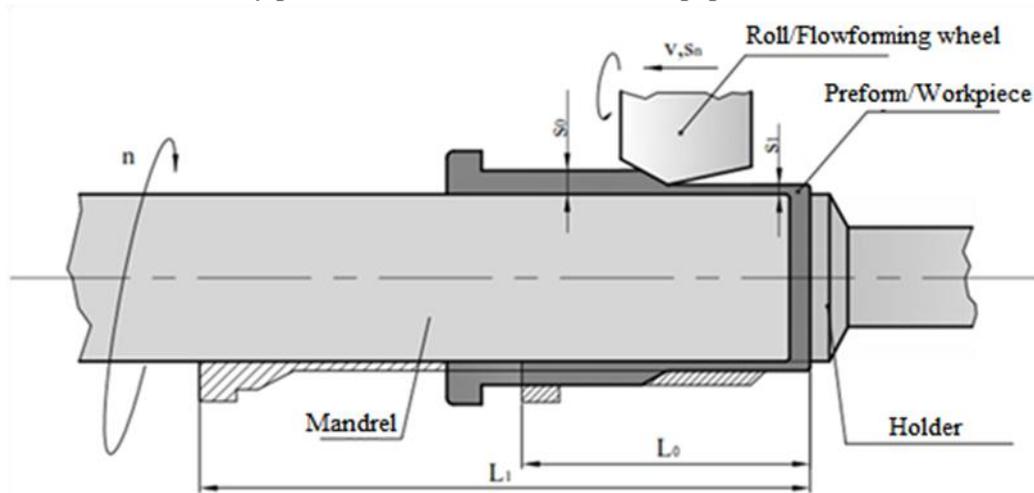


Figure 1. Schematic representation of the forward cold flow forming

2. EXPERIMENTAL WORK

In order to determine the temperature of the workpiece during the forward cold flow forming of technically pure aluminum, the processing of an Al 99,5 chamber has been accomplished in two stages. Dimensions of the workpiece before and after processing in these two stages are shown in the Fig. 2.

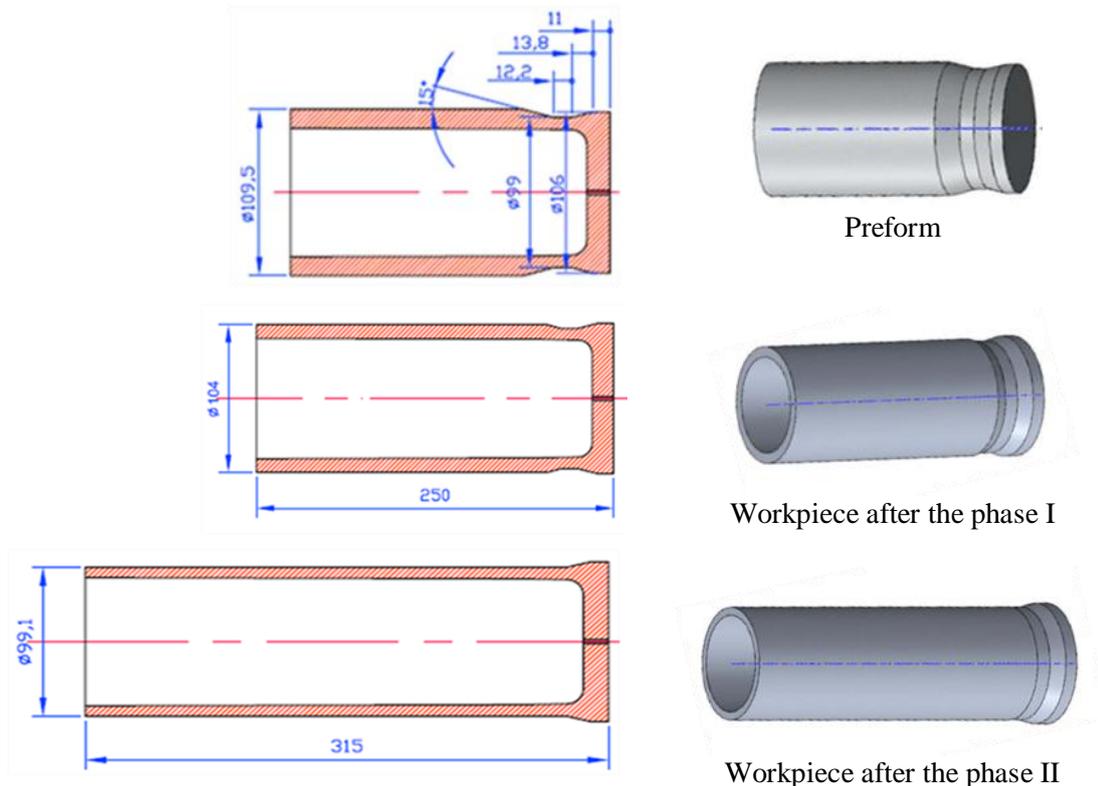


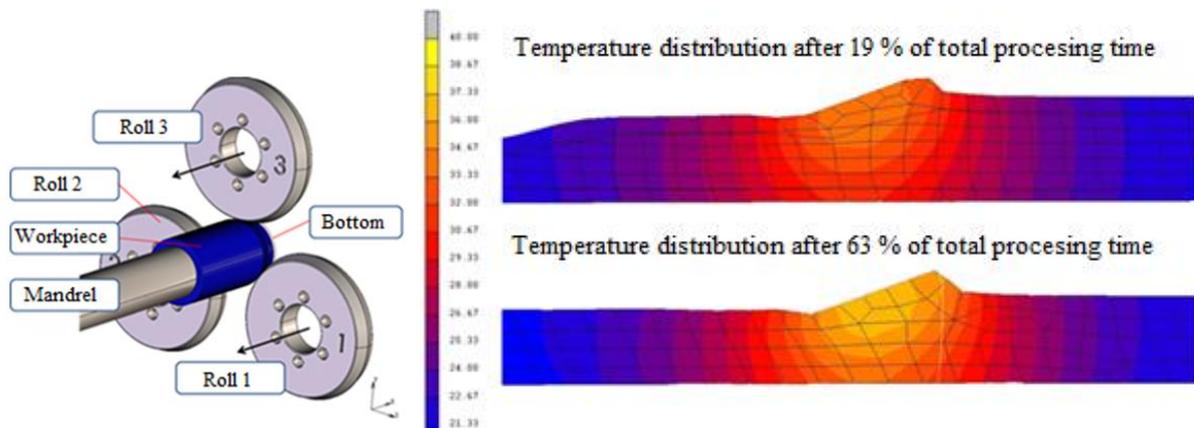
Figure 2. The workpiece in the different stages of processing [2]

Based on the design of experiment 12 workpieces were processed by forward cold flow forming in two stages. The actual overall plastic strain during the processing is in the range 51 to 58 %, while the partial degrees of deformation at certain stages ranging between $\phi_I=15\%$ to 35% i $\phi_{II}=16\%$ to 37% . The total percentage of drawn length in both stages ranges from 36 % to 50 % (from $L=74$ mm to 104

mm) and total logarithmic degree of deformation along the length ranges from $\varphi_{\min}=0,27$ to $\varphi_{\max}=0,59$. The results of simulations and measurements of temperature are presented below.

2.1. Simulation of the temperature for workpieces of Al 99,5 by forward cold forming

For FEM process simulation is used Simufact.forming GP 11.0 software from Simufact Engineering GmbH (Germany) with $\Delta s = 2,75$ mm, $n = 190$ °/min and $s = 80$ mm/min. The simulation was carried out at the Professorship Virtual Production Engineering (Virtuelle Fertigungstechnik) of the TU Chemnitz, Germany. CAD model and temperature distribution in the deformation zone for two characteristic moments of processing (19% and 63% of total processing time) is shown in Fig. 3.



Slika 3. CAD model and temperature distribution in deformation zone obtained from FEM process simulation

The result shows that the temperature is changed according to the duration of the processing (smallest value at the beginning of the process, increases with the duration of the contact between rolls and the workpiece). It is also shown that the maximum temperature during the forward cold flow forming with intensive cooling does not exceed 40 °C in the second half of the contact length.

2.2. Verification of the simulation results by the experimental measuring of the temperature

Measuring of the temperature of cylindrical workpieces during forward cold flow forming was performed with non-contact method using thermo-camera Fluke Thermography Series These 32 (USA). The measuring data were systematized for each sample using SmartView software 3.1. The example of obtained data for characteristic positions during processing and maximum temperatures (in the contact zone between tool and workpiece) for one workpiece is shown in Fig. 4. The same investigations were carried out for all other workpieces during first and second stage of forward cold flow forming.



Slika 4. Characteristic positions (start, middle and end of the workpiece) for the determination of the temperature by processing of one sample from Al 99,5(Nr. 8) in the first processing stage [1]

The measured values of maximum temperature for each sample during first and second stage of processing are shown in Fig. 5, as well as the comparison of model and experimental results.

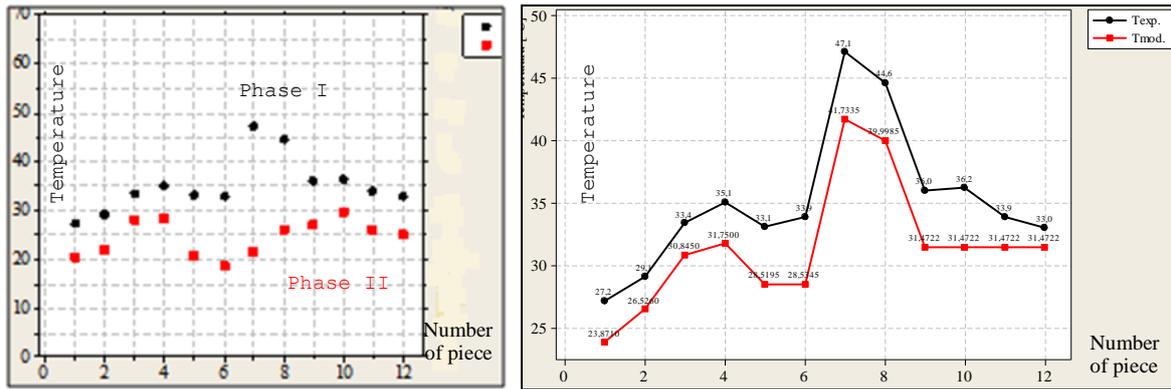


Figure 5. Max. temperatures during processing in I and II stage of forward cold forming (left) and comparison between model and experimental values (right)

It can be seen that the maximum temperatures during the first stage are higher for all workpieces than the temperatures in the second stage of processing. Maximum values of the temperature are achieved for maximum degree of reduction by processing, i.e. for maximum in-feed of rolls (3,5 mm) and maximum axial speed (100 mm/°). This is also confirmed by the mathematical model of the temperature [1] in dependence of input parameter n, s, Δs (a). This model is obtained using design of experiment (DoE) and regression analysis:

$$T(n,s,a) = Y = 7,37 + 0,088 \cdot n + 0,0276 \cdot s - 0,677 \cdot a - 0,0004375 \cdot n \cdot s - 0,0176 \cdot n \cdot a + 0,104 \cdot s \cdot a \dots\dots\dots (1)$$

where is:

T-temperature [°C]; n-rotation speed [°/min]; s-axial speed [mm/°]; a(Δs)-in-feed [mm].

The difference between model and experimental values of temperatures is from 5 % to 15 % (1,5 to 5°C), Fig. 5 (right).

3. CONCLUSION

The comparison of the results of simulation and the measuring of the temperature during the processing in two stages of forward cold flow forming shows that the heating of workpieces have insignificant influence to the strengthening effects of material. The experiment has shown that the temperatures that occur by processing, are in the range between 20°C and 50°C. For input parameters Δs=2,75 mm, n=190 °/min and s=80 mm/min are obtained temperatures from 34°C to 37°C using the FEM process simulation. Experimental values for this case vary between 33°C and 36°C.

4. REFERENCES

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