ZÁPADOČESKÁ UNIVERZITA V PLZNI | FAKULTA STROJNÍ

OPTIMIZATION OF TECHNOLOGICAL PARAMETERS OF FLOW FORMING PROCESS

Jiří Malina
West Bohemia University
Univerzitni 8, 306 14 Pilsen
Czech Republic

ABSTRACT
The extreme price escalations of raw materials, energies and human labor lead to a progressive tendency to find new and more effective methods. One of this progressive method is the spin extrusion. An alternative use of the experimental spin extrusion machine [1, 2] is for flow forming. The aim of this work was in the first step to try to apply the flow forming on the forming of a thin walled semi product and verify the relevancy of this method. The second step was to try to find suitable technological parameters for the hollow shaft.

KEYWORDS
Flow forming, hollow shaft, mechanical properties, micro-hardness, annealing

INTRODUCTION

Flow forming [3, 4, 5] uses three rollers for the reduction to final diameters. These three rollers are not driving and their rotation is attained through the friction between the wrought rotating semi-product and the shaping rollers **Figure 1**.

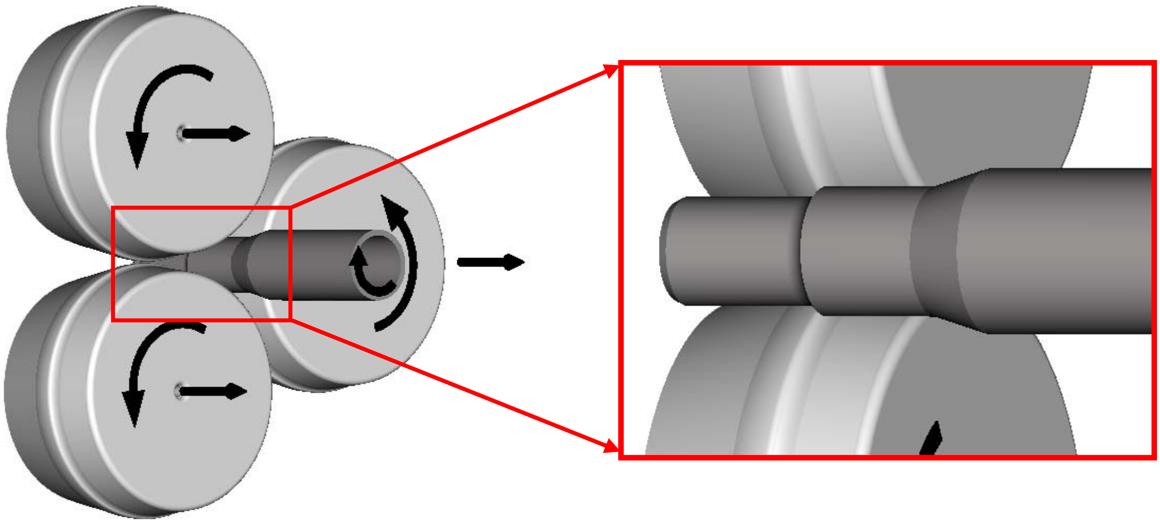

Figure 1: Schematic illustration of profile rolling

The optional parameters for this forming technique are, apart from material, the size of reduction and speed of feed. During the experiment, the influence of the forming parameters on the quality of the final product was obtained.

THE INITIAL SEMI-PRODUCT

A semi product made of hot rolled thin-walled 16MnCrS5 steel tube was used with an initial diameter of 60 mm and wall thickness of 6 mm **Table 1**.

Element	C	Si	Mn	Cr	S	P
%	0,16	0,4	1,2	1	0,03	0,03

Table 1: Chemical composition of 16MnCrS5 steel

The 16MnCrS5 steel is low alloyed manganese-chromic steel with good hardening capacity for cementation. It is primarily used for medium stressed motor vehicle components.

The initial ferrite pearlite microstructure had an average grain size of about 10±5 μm **Figure 2**, without significant decarburization in the surface layer **Figure 3.**

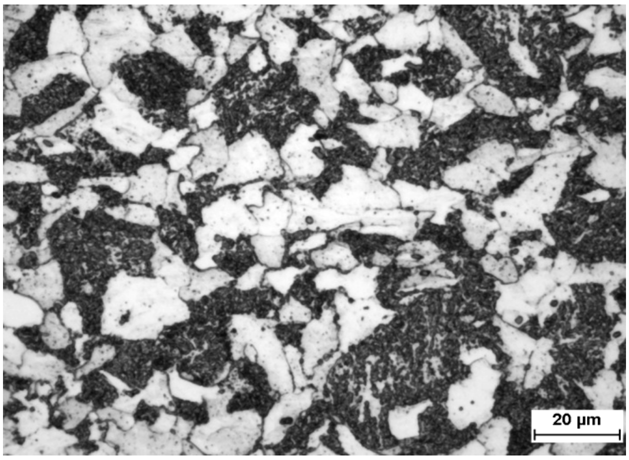

Figure 2 The ferrite and pearlite structure in the middle of the wall of initial semi-product in the cross section cut

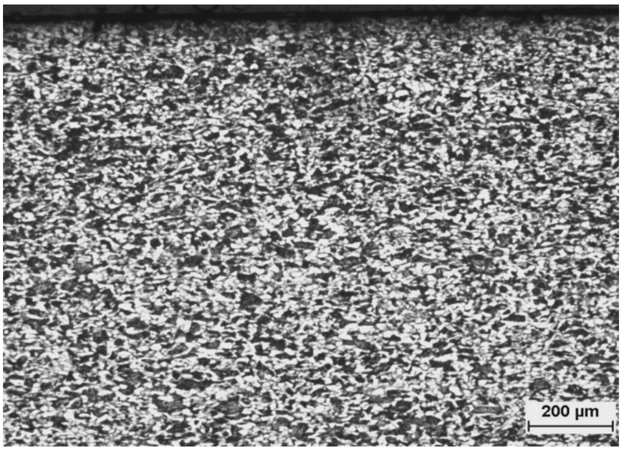

Figure 3 Initial structure in the surface layer in the axial cut

EXPERIMENT

Firstly the initial formability of the material without heat treatment was tested. The material had the following mechanical properties **Table 2.**

HV 0,2	R_m [MPa]	R_{p02} [MPa]	A_{5mm} [%]
238	687	680	23

Table 2: The micro-hardness and mechanical properties of the initial material

The material in this state was found to be unsuitable for this forming technology. It was impossible to use the material in this state for production and it was necessary to use soft annealing.

The initial material was soft annealed at 700°C for 30 to 180 min **Figure 4.**

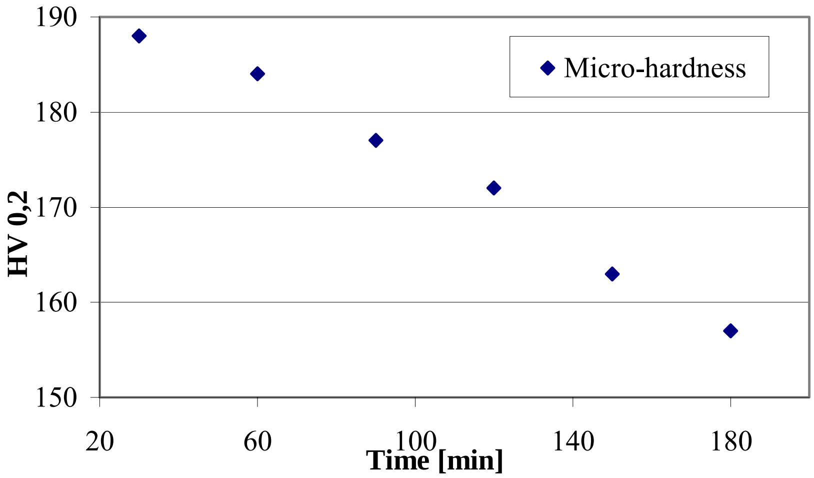

Figure 4: The relation between micro-hardness HV 0,2 and annealing time

On the basis of the resulting relationship between micro-hardness and annealing time and the metallographic analysis, the initial material was annealed at 700°C for time 60 and 180 min.

The annealing time of 60 minutes was chosen, because after this time the lamellar pearlite can transform to globular, leading to increased formability of the material.

The annealing time of 180 min provided the possibility of comparing the forming process on the material with inferior mechanical properties **Table 3** with globular pearlite structure.
Mechanical properties were measured on the micro tensile specimens **Figure 5.**

Annealing time [min]	HV 0,2	R_m [MPa]	R_{p02} [MPa]	A_{5mm} [%]
60	184	582	375	41
180	157	476	312	44

Table 3: The micro-hardness and mechanical properties of the initial material, after soft annealing

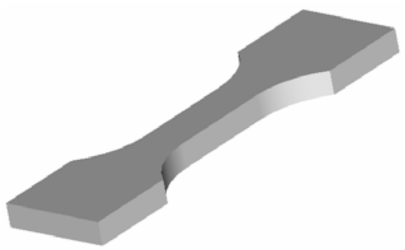

Figure 5: The shape of the test specimen with length 5 mm and the cross section 2x1,2 mm

While forming to the required size, the feed speed was varied and its influence on the surface quality was observed. In this case the surface of the material was not turned before forming. The feed speed was 1, 2 and 3 mm/rev **Figure 6**.
On the basis of the surface analysis, a feed speed of 2 mm/rev was chosen as the optimal speed. This feed led to the most balanced surface quality.

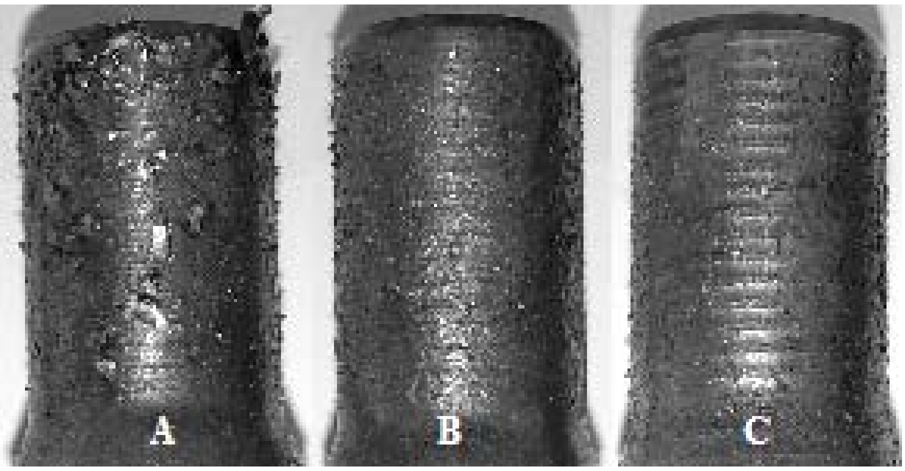

Figure 6: The influence of the feed speed on the surface quality A) Feed speed 1 mm/rev B) 2 mm/rev C) 3 mm/rev

Both variants of the heat treated materials were reduced to the same dimensions **Figure 7.** The size of reduction and speed of feed (2 mm/rev) were also the same.

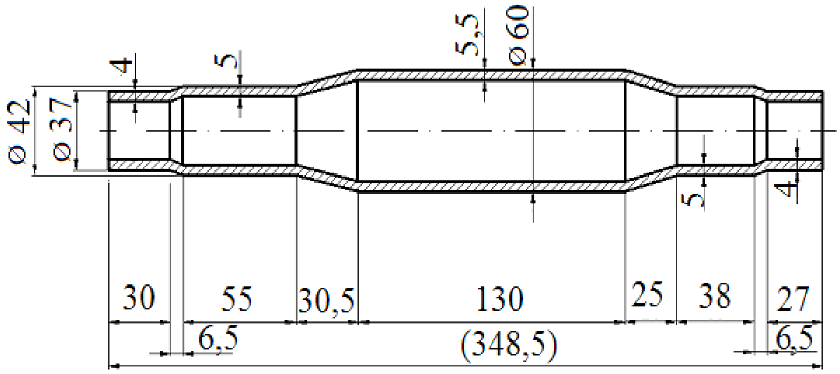

Figure 7: The dimensions of the product

The forming process was successful like on the first material variant annelid for 60 min, too on the second variant annelid for 180 min. The materials and technological properties shown to be useful for the reach required goal, which was production of the hollow shaft **Figure 8.**

Figure 8. The final shape of the product

The final product was cut into sections. The structure, micro hardness and mechanical properties were found for the smallest and middle diameters, which were where the material was reduced. The results of the microstructure analysis proved the structure refinement in the surface layer, in both materials variants **Figure 9** and **Figure 10**.

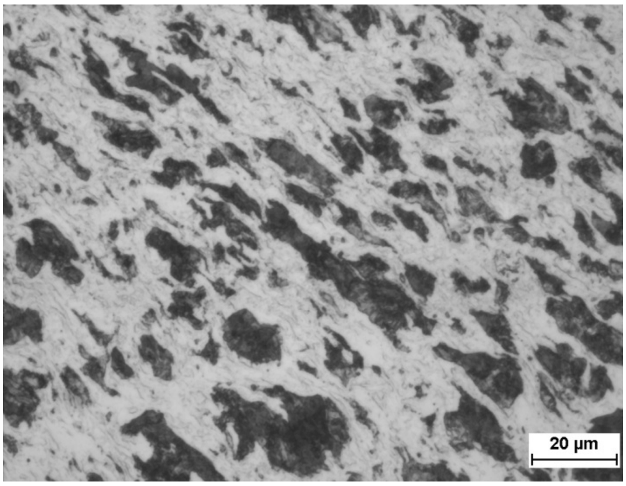

Figure 9: The structure in the surface layer after reduction on Ø 37 mm (annealed 60min at 700°C)

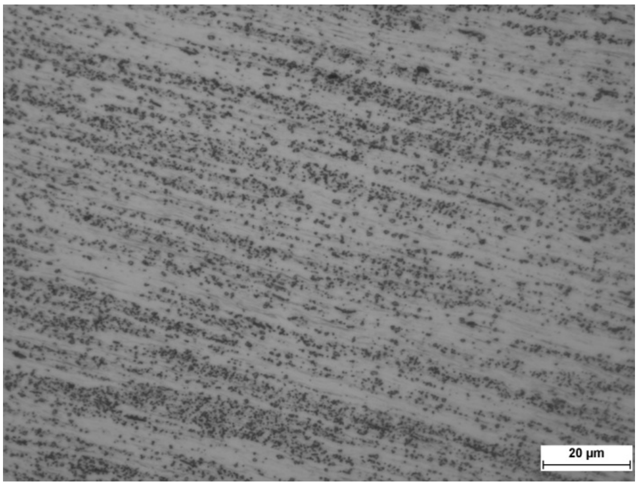

Figure 10: The structure in the surface layer after reduction on Ø 37 mm (annealed 180min at 700°C)

The mechanical properties were relatively similar for the smallest diameter Ø 37 mm and the middle diameter Ø 42 mm, but there were big differences between materials **Table 4.**

Diameter	Annealing time [min]	HV 0.2	R_m [MPa]	R_{p02} [MPa]	A_{5mm} [%]
Ø 37	60	248	750	736	27
	180	230	647	645	26
Ø 42	60	245	739	716	27
	180	221	624	622	26

Table 4: The micro-hardness and the mechanical properties in relation to size of reduction and annealing time

CONCLUSION

The results of the experiment verified that an experimental machine developed primarily for spin extrusion is suitable for the flow forming process, and that it is possible to produce a viable product with this technology. This product has many potential uses in the construction area. It can, because of the minimal amount of scrap created during production, contribute to the reduction of material costs.

On the material annealed at 700°C/60 min an increase of ultimate strength by about 29% and yield strength by about 96% was obtained. For the forming material annealed at 700°C/180 min, a 36% increase of R_m and 106 % of R_{p02} was achieved. All with residual ductility A_{5mm} higher than 25 %.

In the future, the fatigue properties of the whole semi-product will be tested.

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