Simulation of Weld Elbows Hot Forming Process

J. Zajac, P. Beraxa, P. Michalík, F. Botko, and M. Pollák

***Abstract*—Presented article is focused on mathematical simulation of forming process of weld elbows for the purpose of production process improvement. Necessity of simulation and subsequent experimental verification of results is based on problems during the manufacturing process of weld elbows. Simulations were made using Deform 3D and final shapes of arcs were subsequently analyzed. Simulation in software is realized using finite elements method. The simulations were held under ideal conditions and with ideal shape of spike end tool. Models of semi products were based on requirements from the industry. Subsequently will be performed experimental verification of obtained data by manufacturing of test samples using unimproved tool. Goal of analyses is to achieve shape of the spike end tool with no further necessity of adjustment for obtaining correct final product.**

***Index Terms*—Forming process, material, simulation, spike end tool, weld pipe elbow.**

I. Introduction

Mathematical simulations are currently very effective way to predict shape and properties of final products, which simplify and cheapen construction and preparation of production process. Presented article is aimed on mathematical simulation of production weld pipe arc 76,1 × 2,9 mm. Necessity of simulation and subsequent experimental verification of results is based on problems during the manufacturing process of weld elbows. Spike end tool is special designed tool to form elbows, but in manufacturing process are often requirements on changes of tools shape from the reason of additional correction of the product shape. Described process must be repeated always after tool lifetime, where individual processes represent time demands what affect downtimes of productions, what directly influence economical profits. Following significant factor is disruption of the surface layer of the spike end tool made of lost wax casting technology as a result of grinding process after tool modification in production what result in reduction tools lifetime.

II. Preparation of Simulation

Simulation was realized by using software Deform 3D. Aim of simulation was to obtain ideal dimensions of weld pipe elbow manufactured with ideal condition settings. Results obtained from simulation will be used as “bouncing ramp” for subsequent analyses and experimental verification, which are intended to achieve and prescribe shape and dimensions of spike end tool, which do not need additional manual operations. Weld pipe elbows are made of steel according to EN S 235 JRH (STN 11 353). Material S235 is non-alloy quality structural steel intended for manufacturing of seamless pipes. Steel grade is generally suitable to welding. Chemical composition and mechanical properties are shown in tables below (Table I-III). Properties of material EN S 235 JRH were used in simulation process to acquire precise results [1]-[3].

TABLE I: Chemical Composition of Steel S 235 JRH

Chemical composition [%]				
C	Mn	P	S	N
max 0.2	max 1.4	max 0.04	max 0.04	max 0.009

TABLE II: Mechanical Properties of S 235 JRH

Mechanical properties			
Rm (MPa)	Re (MPa)	KV (J)	A (%)
360-510	min. 235	27	min. 26

TABLE III: Elastic Properties of Steel S 235 JRH

	Young´s module of elasticity [MPa]	Poisson´s ratio
S 235 JRH	210000	0,3

Spike end tool (Fig. 1) is made of steel according to ISO STN 17 322 (Cr-Ni-W-Mo steel). Depend on fact, that in simulation was tool considers as an ideal rigid solid and for simplifying the process of simulation was ignored heat transfer, although the chemical and mechanical properties do not significantly affect the simulation processes [4], [5].

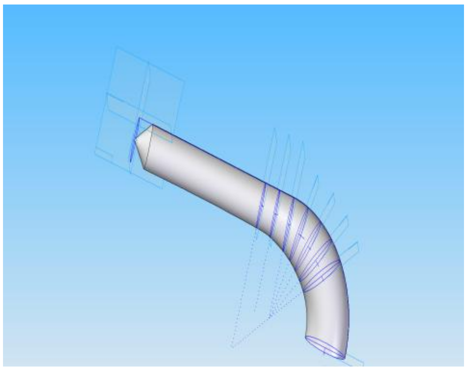

Fig. 1. 3D model of tool.

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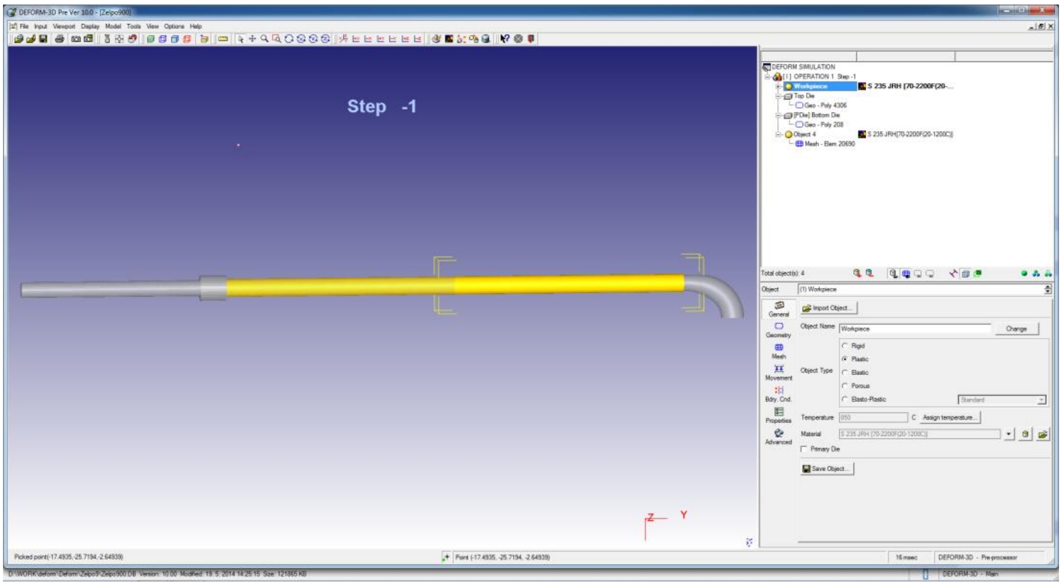

Fig. 2. Imported models of semi product and tool in environment of software Deform 3D.

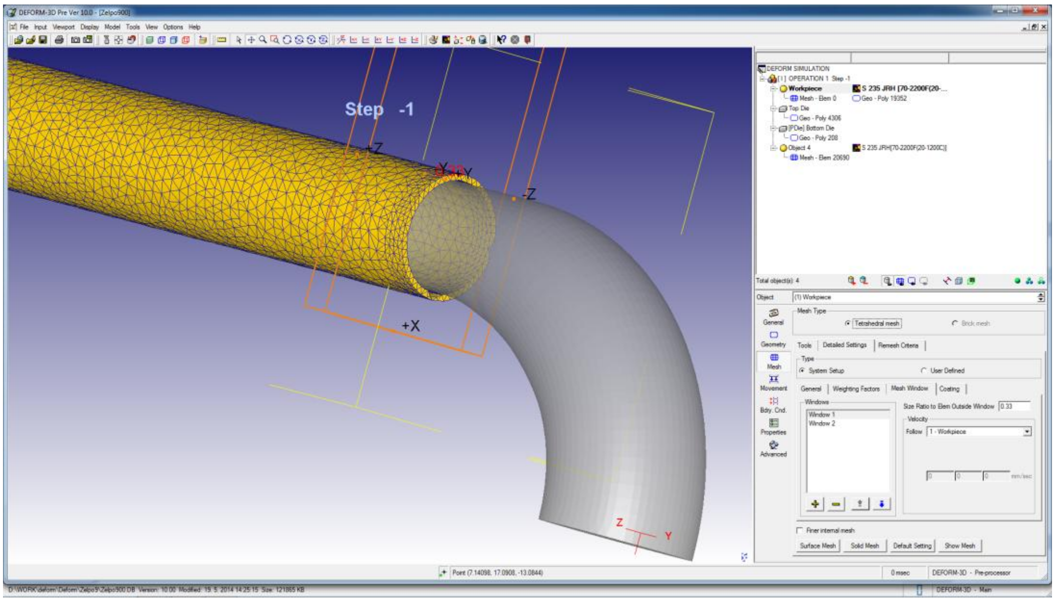

Fig. 3. Compressed mesh of FEM (Mesh Window).

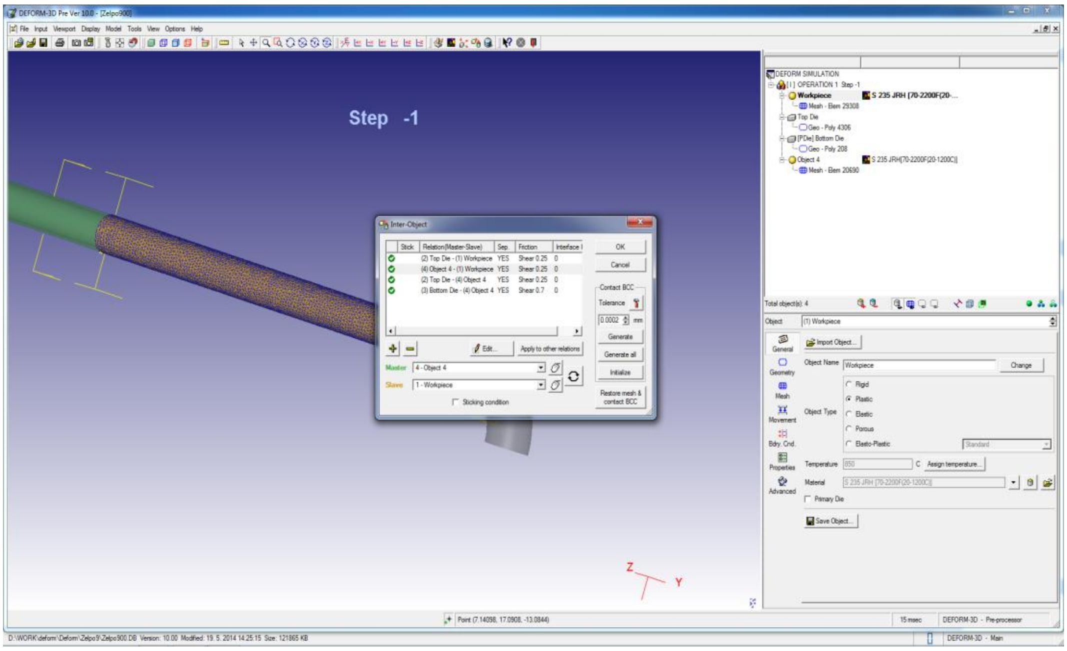

Fig. 4. Define of friction parameters.

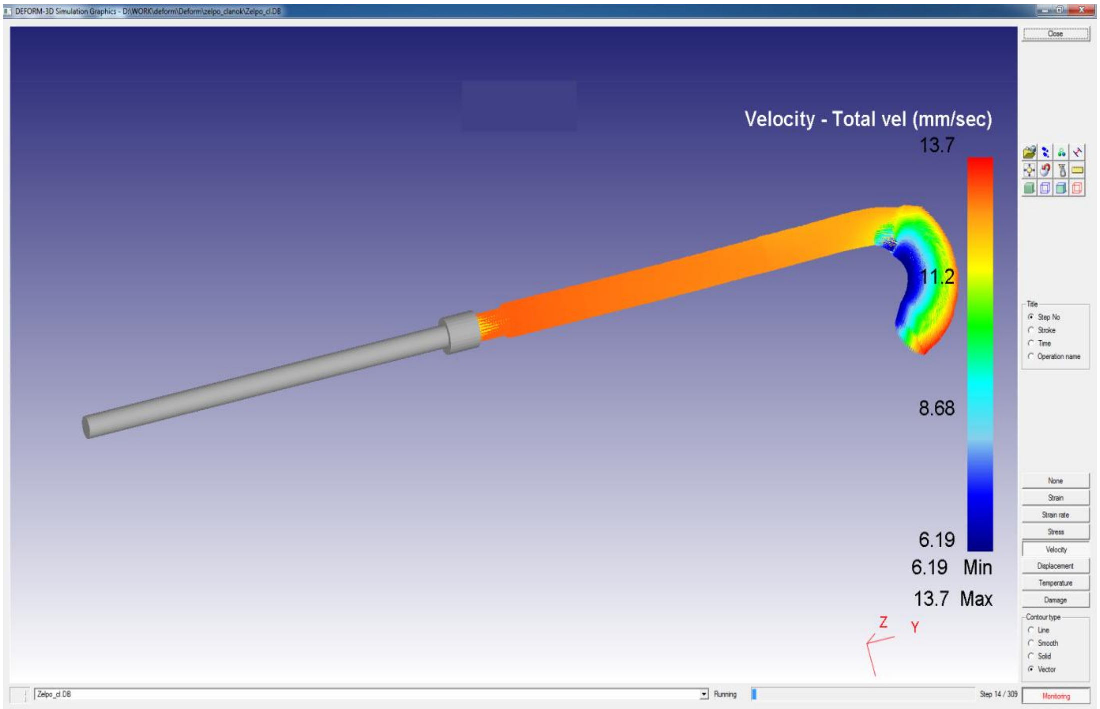

Fig. 5. Simulation process.

Models of semi products were based on requirements from the industry and were realized in environment of the software Deform 3D (Fig. 2).

III. Conditions of the Simulation

Simulation in software Deform 3D is realized using finite elements method. Deform provide possibility to set number elements, where for simulation part was set 200 000 finite elements for tool. For ends of pipes was created compressed mesh of finite element in ratio 1:0,33 (Mesh Window) (Fig. 3) to improve contact conditions. This preset allows creating smaller finite elements on regions of the workpieces which are in contact for elimination of distortion in simulation process.

Simulation could be adversely affected by biggest compression ratio. Workpiece was defined as plastic material. Deformation preset was set as "Active in FEM + meshing". [6]-[8] Boundary conditions define contact between workpieces to provide permanent contact during simulation process (preset COMFORM COUPLING in Deform 3D). Symmetry planes were not set by the reality from the reason of subsequent research should point on eccentricity of pipes (dimension and shape). Temperature for hot forming is in documentation prescribes on 850 ℃.

Simulation process was considered with using constant temperature without possibility of heat transfer, what reduce time of simulation. Temperature of spike end tool was set on 780 ℃, velocity of pushed plate was set according to manufacture requirement. Interaction between objects were set by values selected from library in Deform 3D for warm forming on values 0,25 (Fig. 4) for friction between workpieces and tool, which is for simulation purposes represent one unit with guide rod using method of comfort coupling. [7]-[9].

IV. Simulation

Simulation was realized overall in 1000 steps with step 1 mm. Process of simulation can be observed in real time with monitoring actual values of velocity, temperature, deformation, strain etc (Fig. 5) [10].

Finish simulation provide to obtain data and values, which can be evaluate using post processor. In the fact of aim to geometry parameters of final product the model was extracted in STereoLithography format (*.stl), what provide possibility to reverse convert model into solid model in CAD software and subsequently measure and verify required/prescribed dimensions and geometrical parameters (Fig. 6).

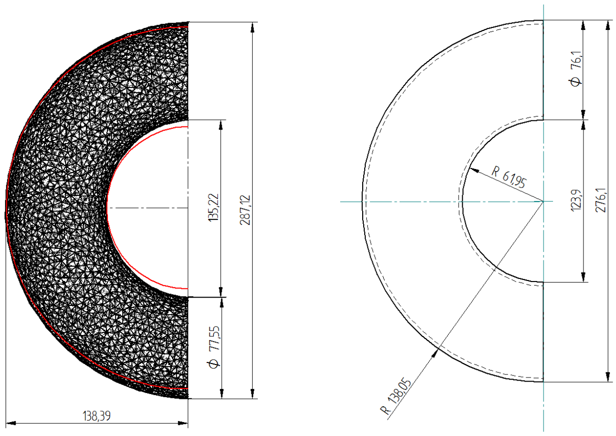

Fig. 6. Comparison of dimension.

V. Conclusion and Results

Following figure (Fig. 6) shows difference between ideal shapes of weld pipe elbow (Fig. 6. right) and simulation obtained shapes (Fig. 6 left). Most significant differences between ideal and simulated weld pipe elbow are, final diameter of pipe, where ideal dimension is 76,1 mm but dimension obtained from simulation is 77,55 mm (nominal difference is 1,45 mm, thus 1,9 %). Overall prescribed width of ideal product is 276,1 mm but simulated dimension is 287,12 mm what is 11,02 mm difference compared to ideal value (2,761 %). Inner pitch of weld pipe elbow is according to documentation 123,9 mm but simulated dimension is 135,22, difference is 11,32 mm (9,1 %). Overall shape of simulated product is opened in comparison with ideal shape, what is represented by red lines in figure below (Fig. 6).

Subsequently will be performed experimental verification of obtained data by manufacturing of test samples using unimproved tool. Preliminary results shows that current shape and dimensions of tool do not ensure correct parameters of final product (weld pipe elbow). Change of dimensions and shape of the tool appears necessary, especially on calibration section.

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