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THEORETICAL AND EXPERIMENTAL ANALYSIS OF ROLL BENDING OF HALF RING OF GAS TURBINE

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Abstract

The article presents an analysis of forming half reinforcement ring housing the gas turbine. The ring is made of INCONEL alloy 617 material, which is based on nickel-chromium-cobalt-molybdenum alloy characterized by high strength and resistance to oxidation at high temperatures as 1100-1200°C. Square bar of dimensions 50x50 roll bending at half ring with a diameter of 1500 mm, an intermediate product is prepared for machining. The forming process is divided into two operation. The first operation is to pre-bending the rod. The second operation is to roll bending to the radius determined by the deflection. The article presents the map of reduced stress of HMH for two operations, obtained from the numerical simulation based on the finite element method. It also presents the load on the tools during the entire process. Physical tests were carried out on the device for roll bending steel profiles DURMA PBH 125. The article sets out the minimum allowances technology needed to complete half of the ring. A comparison of deviations, outside diameter of the ring, was resulting from the spring back in the study of physical and numerical simulations. We also compared the flatness deviation of the ring resulting in the research. The results of theoretical research have confirmed good agreement with physical examinations. The research provided an opportunity to develop technologies forming of half ring on the above machine of bending steel profiles.

Keywords: *roll bending, gas turbine component, INCONEL alloy 617, MES, Bar Bending Machine*

1. Introduction

Production of electricity generators powered by gas turbines firing natural gas in the European Union at an average of 22.8%. The largest producers of electricity using gas turbines are Italy (6^{th} place in the world), United Kingdom (14), Spain (16), Germany (18) and the Netherlands (21) [1].

The gas turbine converts the kinetic energy of the exhaust gas flowing into mechanical energy turbine rotor. The main components of the gas turbine are gas combustion chamber, gas turbine, rotodynamic compressor. This paper presents a method of forming half of the ring component of the gas turbine. Half of the ring is a component Silo housing a gas turbine combustor. Formed rod is half the flange designed sequentially used to machine cutting. The design of the combustion chamber must meet the criteria of ensuring the stability of combustion, resistance to high temperature, vibration, high mechanical loads. Therefore, special materials must be used, which meet the above criteria. Such an alloy is Inconel alloy 617. This alloy is composed of nickel-cobalt-chromium molybdenum-based shows high strength and resistance to oxidation at high temperatures (Tab. 1) [2].

*Tab. 1. Chemical composition (%) alloy elements, according to VdTÜV WBL.485 * – lack of VdTÜV WBL.485*

	Ni	Cr	Fe	C	Mn	Si	Co	Cu*	Mo	Ti	Al	P	S	B*
min	Rest	20.0		0.05			10.0		8.0	0.20	0.60			
max		23.0	2.0	0.10	0.70	0.70	13.0	0.50	10.0	0.50	1.50	0.012	0.008	0.006

Manufacturers of components for gas turbines make high demands on the tolerance of the products:

– outer diameter of the geometric deviation with a value of +/-1mm,
– flatness deviation of +/-1mm.

Another problem is the effect spring back material after unloading rolls, which are a consequence of geometrical deviations, and the product, does not meet the established tolerance. Producers also need the least technological allowances, for economic reasons and the possibility of obtaining dimensional materials from steel mills. It is difficult deformable material; narrow tolerances cause great difficulties performed the component using plastic forming.

Therefore, the aim of this article is investigate above problems using the Finite Element Method.

2. Numerical analysis

The process of forming a ring made of Inconel alloy 617 material was simulated in the commercial DEFORM-3D is based on Finite Element Method.

Model geometric tools and batch material is designed in the UNIGRAPHIC NX6 and then exported as a file with the extension *. stl to the program DEFORM-3D. The tested model is half of the ring with an outer diameter Ø 1500 mm, 50x50 mm cross section.

Charging material needed to obtain half of the ring is a rod with a length of 2277.7 mm, which counted technological oversize the rod at the ends of 380 mm. Geometric model of the test material was shortened to the length of 1200 mm. The geometry of the tool has also been simplified, i.e. removed unnecessary rounding and outer holes. Simplification does not affect the process of rolling rod in a circular shape and, consequently, increase quality and shorten the simulation performed (Fig. 1).

Assumed rotational speed tools at 4 rpm, the geometric parameters of the position of the tools relate three roll bender designed for steel profiles DURMA type PBH 125, which were carried out physical examinations (Fig. 2). In this machine, each of the rollers is powered; the lower rollers rotate in the same direction, while the top roll in the opposite. Roll the top does not move, while the lower rollers move along the radius determined by the eyepiece of the roll bender [3].

Ring processed, at room temperature (cold forming). The rod moved in accordance with the rotating roller, as a result of friction between the tool and the bent material. While the bending of the ring tools were not lubricated.

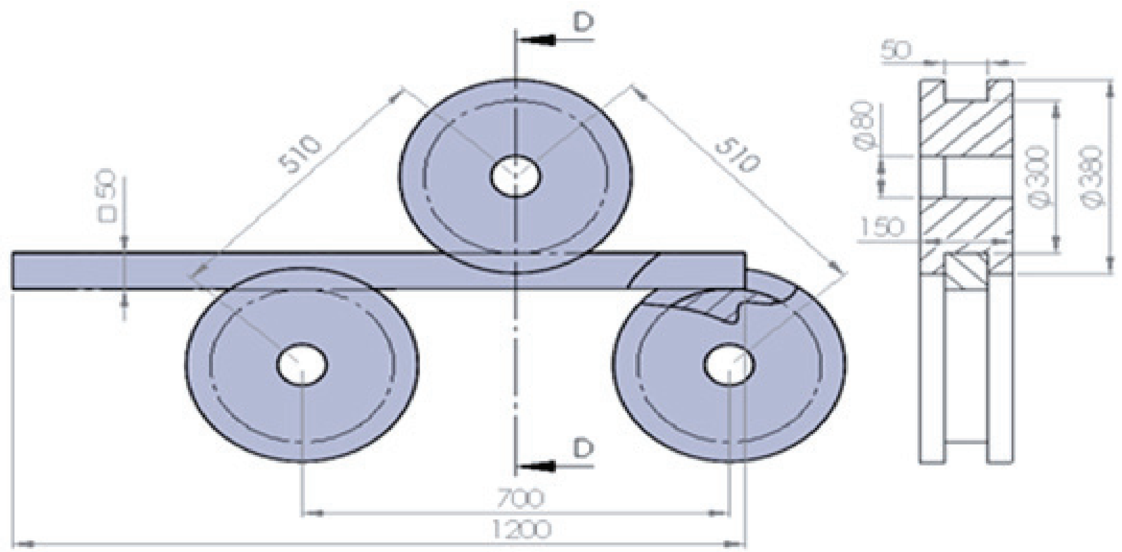

Fig. 1. Geometrical model tools and batch material relating to the first operation

Fig. 2. Material formed placed in the working rolls during physical testing

The process of forming a ring with a diameter of 1500 mm was divided into two operations:

1. The first operation shows the initial bending of the ring. The rod is placed in the blanks of rollers, and located, so that the end of the rod in contact with one of the lower rollers. This roll bending forces the rod deflection equal to 10 mm.
2. The second operation is a roll-bending bar, where the tools are in set of the first operations and also perform a rotary movement around its own axis. This operation ends when of the whole range rolling of.

The above-mentioned operation is repeated until it reaches the middle of the ring predetermined outer diameter of 1500 mm.

The test model in the form of a square rod discretized using the finite element in an amount of tetragonal type 82 612.0 and 19 307.0 nodes.

Formed rod made of Inconel Alloy 617, which is defined by the following parameters, as a result of the material obtained with the hot-rolling (Tab. 2) [4]:

Tab. 2. Typical Room-Temperature Mechanical Properties for 20°C

No.	Description	Value	Unit
1	0.2% Yield strength	318	MPa
2	Tensile strength	769	MPa
3	Elongation	56	%
4	Hardness BHN	181	
5	Thermal conductivity	13.4	W/kg*K
6	Modulus of elasticity	212	GPa
7	Density	8.36	Mg/m3
8	Melting range	1332-1380	°C
9	Poisson's ratio at 20°C	0.30	

The following is a chart of the uniaxial tensile test the sample made of alloy 617, at room temperature as well as at temperatures of 650-1000°C. Increased mechanical properties of the alloy were tested at intervals of 50°C (Fig. 3) [5].

The numerical simulation also used the model of forming tools as rigid solids. The program DEFORM-3D automatically defined contact pairs of type "node is a surface" between the ring and tools. Tolerances penetration node to a specified surfaces as a pair of contact was set at 0.29. For each pair of set contact friction coefficient is 0.2. The temperature of the batch material, as well as tools set at the level 180ºC.

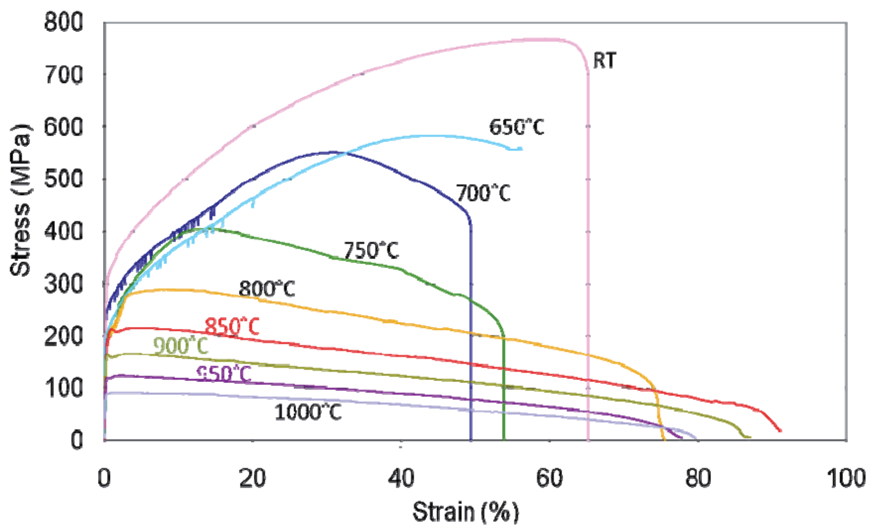

Fig. 3. Tensile stress-strain curves for Alloy 617 [3]

3. Results of numerical analysis

In the first place shows the results of a numerical simulation regarding the operation No. 1. As expected after the initial bending deflection value equal to 10 mm, lost stability and deform permanently.

Numerical simulations confirm the results of physical research, for which the stress of HMH take the values above the yield stress equal to 450 MPa (Fig. 4). Below the histogram by means of which we are able to estimate quantitatively, the distribution of nodes with the corresponding values of the average stress. It also allows for an initial verification of the results, where we see that 450 MPa is 0%, and the correct results start from the border 417 MPa, at 0.4% of nodes (Fig. 4b). Deflection will give adequate radius the formed band of the next operation. The result of numerical simulation is also load distribution on the tool during the bending operation end of the rod. It can be seen that at a deflection of the rod equal to 2.95 mm are the maximum pressure on the roll takes 30 Mg (Fig. 5). This is a result of loss of stability of the material and the transition from elastic to plastic state.

The other hand the pressure on the lower roller is 25 Mg and 13 Mg, which was formed in a reaction derived from the force.

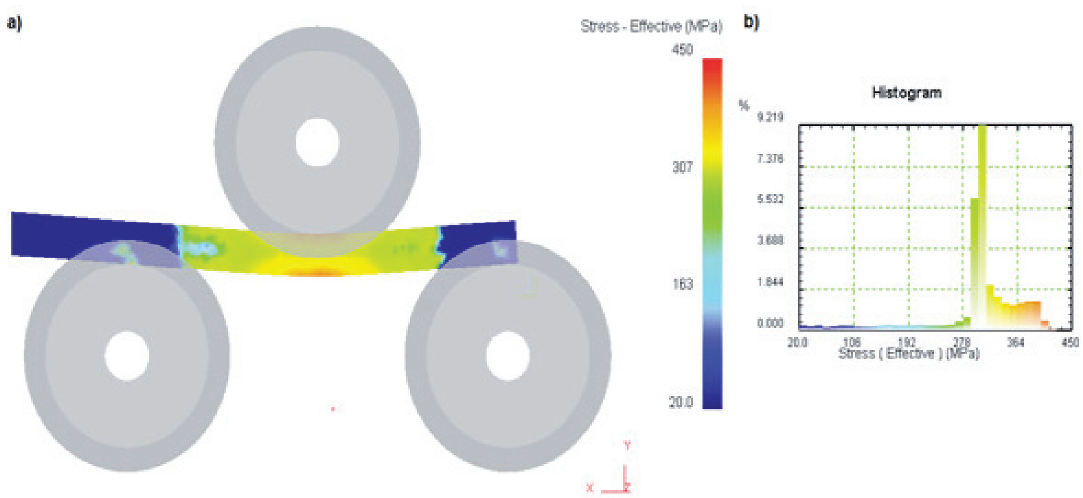

Fig. 4. The average stress of HMH for deflection equal to 10 mm, b) histogram – the percentage distribution of nodes with the corresponding values of stress

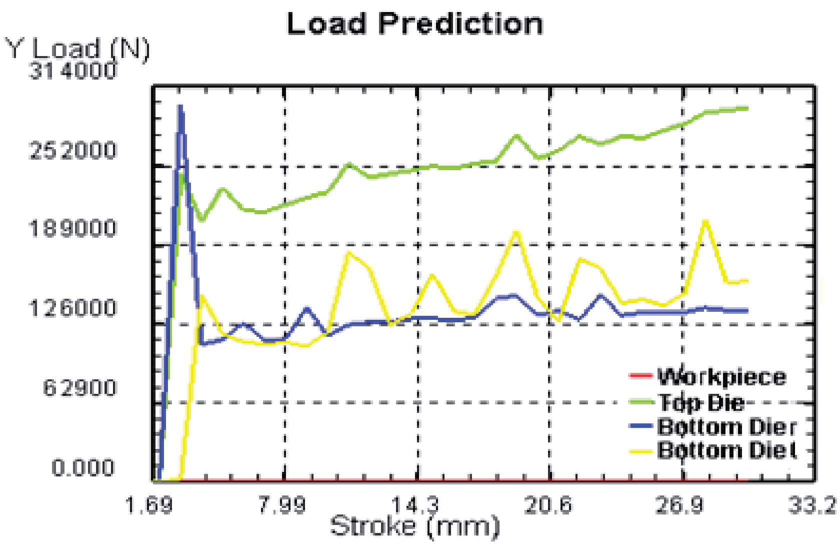

Fig. 5. Graph of the forces acting on the tool during the forming of the rod

The second operation applies to rolling ring with a given curvature, which is the result of the first operation. As you can see, reduced stress of HMH exceeds the yield strength and takes the value of 650 MPa. The analysis can also be noted, the occurrence of high stresses in the front part of the ring piece, which are caused by the expansion rod, which is limited blank of tools (Fig. 6).

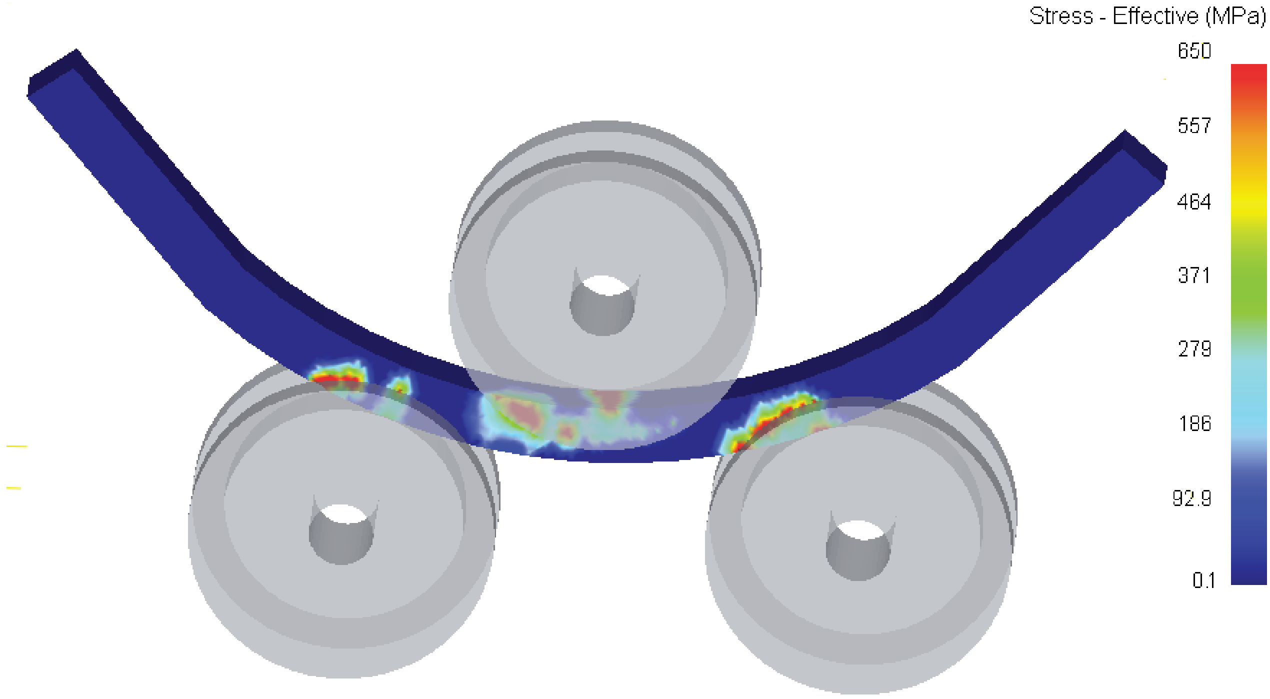

Fig. 6. The stress reduced of HMH the forming of the ring – the second operation

4. Conclusion

Physical tests made during the roll bending rod in a circular shape, have shown that you can reduce the allowances technology adopted in the planning process. According to research, physical technological allowance should have a length of 300 mm from each side of the rod, as well as the result of a numerical value 346 mm (Fig. 7). The results of numerical simulations confirm compliance with the physical tests for the convergence error is 15%.

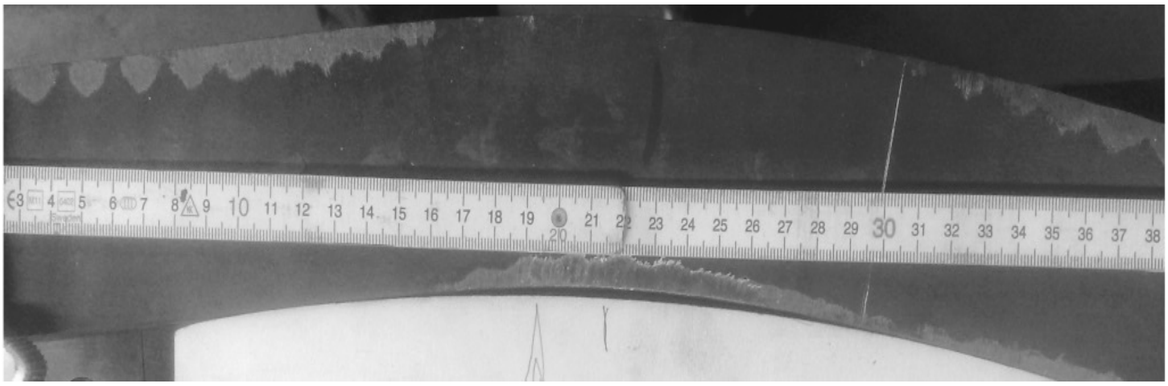

Fig. 7. Length technological allowance to cut obtained after the physical tests

Half of the ring is made of rod shows a lack of flatness deviation in the length of the working after processing forming. Flatness deviation occurs however, the ends of the technological allowance of 2.3 mm (Fig. 8), for the numerical simulations, flatness deviation take the value of 3.1 mm.

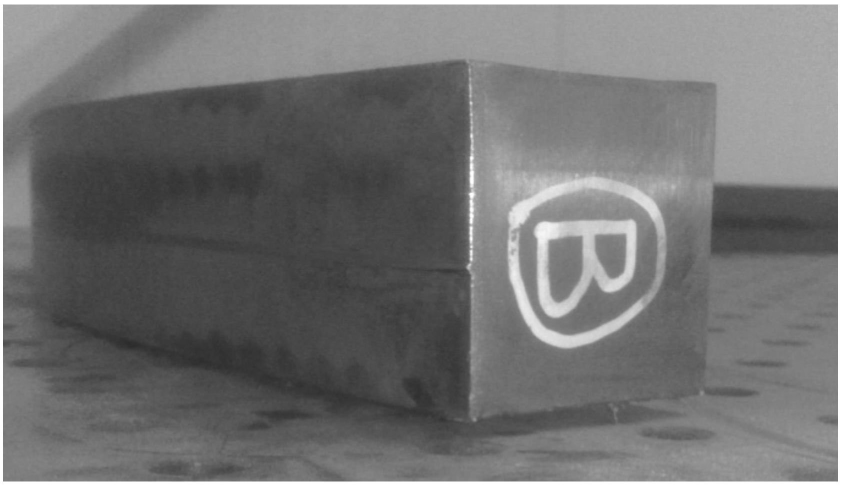

Fig. 8 Deviation the end of allowance technological

Another problem is the occurrence of spring back ring after unloading tools. The results of numerical simulations indicate that increasing the inner diameter of the ring caused by the residual stresses at the level of 15 mm. The confirmation of the results obtained are physical examinations, where the suspended amounted to 18 mm.

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