THE GEOMETRYSTABILITY OF THE MULTI RIFLED TUBES BY THE PRODUCTION

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Abstract

Trend in the area of boiler tubes in the energy sector specifically characteristics of the tube properties, not only from the perspective of material properties, but focuses mainly on the internal tube surface. For the inner surface is primary substance to lead heat transfer medium in the most efficient manner. In addition to reducing the effect of friction parameters are now the majority of customers and producers of tubes for Energy focuses on the shape of the inner surface, which ensures a better flow in addition to the media and more efficient transfer of heat energy. [1]

In this article we focus on optimizing the production of tube with multi-rifled inner surface from the perspective the stability of the geometric dimensions of tube produced and the impact of tool wear on the production cycle. For these analyses were used optical 3D scanning devices to ensure precise measurement of dimensions experimental drawn tubes with internal multi rifled surface. The experiment was performed at the production of Železiarne Podbrezová a.s.

Keywords: Energy sector, multi rifled inner surface, optical3D scan

1. INTRODUCTION

The production of cold-drawn precision seamless multi rifled tubes presents a high level of technology on an international scale. It is known that multi rifled tubes are implemented in production in well-known companies all around the world. Železiarne Podbrezová a.s.(later only as ŽP a.s.) is trying to create suitable conditions for production of multi rifled tubes and therefore increase its competitive ability. [1] In recent years, the positive effect of boiler-grade multi-rifled tubes in coal-firing power plants working at subcritical pressures has been highly praised among the power engineering community .[2] Generally, during the operation of a high-pressure boiler, tiny bubbles of water vapor tend to form on the inner tube surface in a membrane wall, thus inhibiting the heat transfer. [3]

In 2015, ŽP Research and Development Centre s.r.o. (later only as ŽPVVC s.r.o.) and ŽP a.s. prepared together a large scale factory experiment for the chosen type of multi rifled tubes, focusing on stability of dimensions of multi-rifled tubes by defined conditions of cold drawing. Stability of dimensions of multi rifled tubes was observed in several parts of the length of the tube - up to its final length 1909 metres. The experiment was conducted thanks to experience of ŽP employees and the use of precision optical 3D measurements of geometry at The Faculty of Materials Science and Technology in Trnava. From the theoretical point of view, the stability of geometry of multi rifled tubes was predicted by means of the theory of tool wear which is based on the statistical theory of reliability of mechanical systems. This experiment can be considered to be successful, given the presented results. However, stringent dimensional tolerances on inner rifling to ensure highest heat transfer possible make production of such tubes very challenging. [4, 5]

2. TECHNOLOGY OF PRODUCTION AND EXPERIMENTAL MATERIAL

In this part of the article, technology and experimental material used in the experiment are looked at in closer detail. In the experiment, the tubes 13CrMo4-5 steel grade with chemical composition in **Table 1** and mechanical properties - see **Table 2**. were used. Heat treatment at 680°C and chemical preparation were used before drawing according to standard procedure of chemical preparation at ŽP a.s.

Tensile strength testing is standardized by EN 10002-1:1995 and EN 10002-2:1995, which shows the shapes and dimensions of specimens, test conditions and yield determination. Uniaxial tensile strength testing consists in applying a tensile force on a specimen until fracture, in order to determine the mechanical properties characteristics. [6]

Table 1 Mechanical properties of 13CrMo4-5 steel grade according to EN 10216-2

Steel grade	Mechanical properties		
	$R_{p0,2}$	R_m	A_5
13CrMo4-5	min 290	440 - 590	min 22

Table 2 Chemical composition of 13CrMo4-5 steel grade according to EN 10216-2+A2

Steel grade	Chemical composition												
	C		Si	Mn		P	S	Cr		Ni	Mo		Cu
	min	max	max	min	max	max	max	min	max	max	min	max	max
13CrMo4-5	0.10	0.17	0.35	0.40	0.70	0.03	0.020	0.70	1.15	0.300	0.40	0.60	0.300

3. REQUIREMENTS AND A DIMENSIONAL SPECIFICATIONS

Dimensional specifications of multi rifled tubes are stated in **Table 3**. **Figure1** shows main dimensions that were measured.

Table 3 Dimensional specification of multi rifled tubes [1]

Mark	Items	Units	Value	Dimensional requirements of the tube
A	Outside diameter	mm	**28.6**	± 0.15
B	Major inside diameter	mm	**16.06**	± 0.15
D	Minimum wall thickness	mm	**5.7**	-0 / +20 %
E	Number of ribs		**4**	NA
F	Rib width (circumferential)	mm	**4.8**	± 0.6
S	Rib width (longitudinal)	mm	**8.3**	± 1.04
H	Rib height	mm	**0.7**	+/-0.15
K	Rib side angle	°	**54**	-10 ° / +15°
L	Rib radius (max)	mm	**-**	min 0,13 , max 0,60
L‘	Rib radius (min)	mm	**-**	min 0,13 , max 0,60
M	Rib pitch	mm	**21.85**	± 3.18
N	Lead	mm	**87.39**	± 12.7
P	Lead angle	°	**30**	Target
C	Minimal Inside Diameter	mm	**-**	-

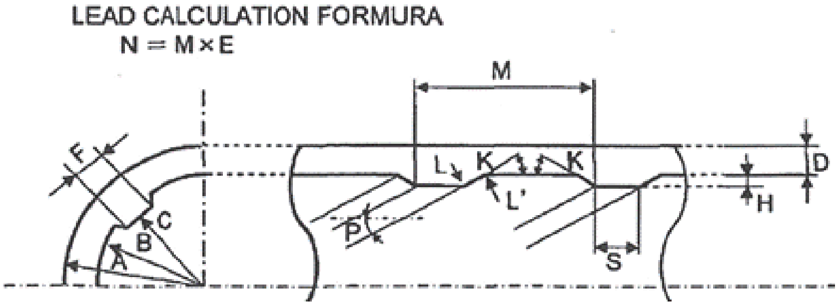

Figure 1 Measured dimensions [1]

4. OPTICAL 3D MEASUREMENT OF DIMENSIONAL REQUIREMENTS OF TUBES AND DISCUSSION

Optical 3D measurement was performed on GOM ATOS II TRIPLESCAN 5M, located at the Centre of Excellence 5-axis machining at the Faculty of Material Science in Trnava. The dimensional requirements were compared with dimensional specifications (see **Table 3**) provided by the customer. 30 examples of tubes for this experiment were cut. The Examples were cut from first tube, every 15th tube and last tube. The Six Examples from front of the Tube and six examples from end of the tube were selected for the dimension analysis. The ATOS optical 3 scanner is based on the principle of triangulation using stereo camera setup. This stereo camera setup and a projection unit are integrated in the ATOS sensor head. The sensor projects different fringe patterns onto the canned object´s surface. These patterns are recorded by the two CCD cameras (left and rights), forming a phase shift based upon sinusoidal intensity distributions on the CCD chips. The ATOS uses multiple phase shifts in a heterodyne principle to achieve highest sub-pixel accuracy. Based on the optical transformation equations, independent 3D coordinates are automatically calculated for each camera pixel. In the case of ATOS II TripleScan, a point cloud of up to 5 million surfaces points results for each measurement. The geometrical configuration of the ATOS sensor and lens distortion are calibrated using photogrammetric methods. [7]

Figure 2 Optical 3D scan of multi rifled tube

Figure 3 Optical 3D scan of multi rifled plug

In **Table 3** “Dimensional specification of multi rifled tubes” we can see values of parameters where we Met the specifications of parameter from the side of the final use product and from the side of the creation of multi rifled inner surface. The parameters are H - Rib height, P - Lead angle, F - Rib width (circumferential) (**Figure 5**), S - Rib width (longitudinal), K - Rib side angle. The **Figure 4** show a graphic view of the average value of the H dimension. We can see a tendency of decreasing the height of the rib by increasing the number of drawn meters of tubes. Dimension S - The width of the rib in the longitudinal direction is related to tool wear, which is caused by tribological effects (**Figure 6**). Dimension K - Rib side angle. Dimension K drops from 67 ° to 48.6 ° (**Figure 7**). This may be due to tool wear or plastic strain distortion. The dimension P - Lead angle is difficult to observe because during the drawing process, plastic deformation may occur, altering the value of "P" (**Figure 8**). [1]

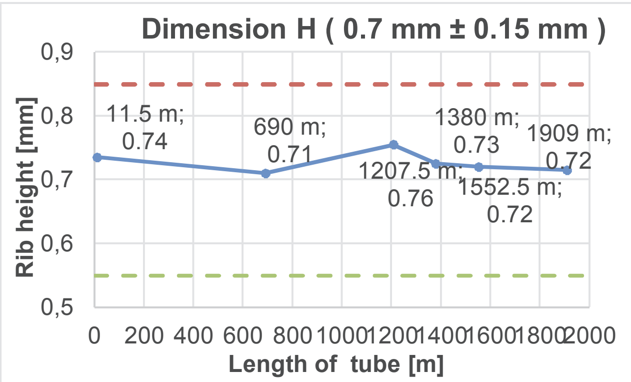

Figure 4 Rib height - Dimension "H" [1]

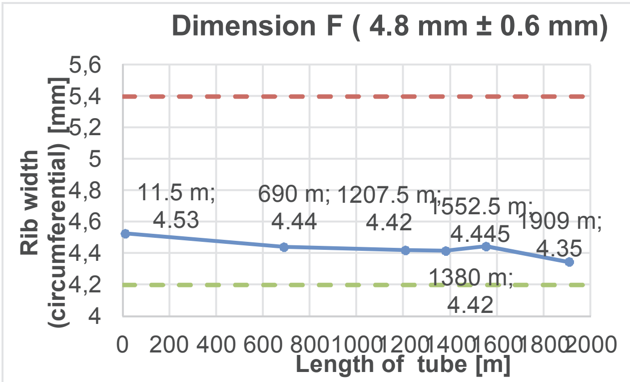

Figure 5 Rib width (circumferential)-Dimension"F"[1]

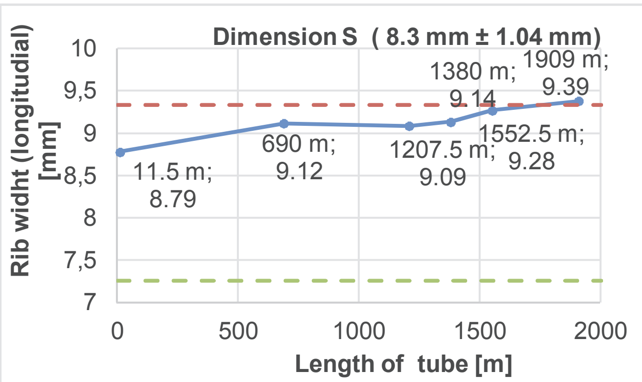

Figure 6 Rib width (longitudinal) - Dimension "S" [1]

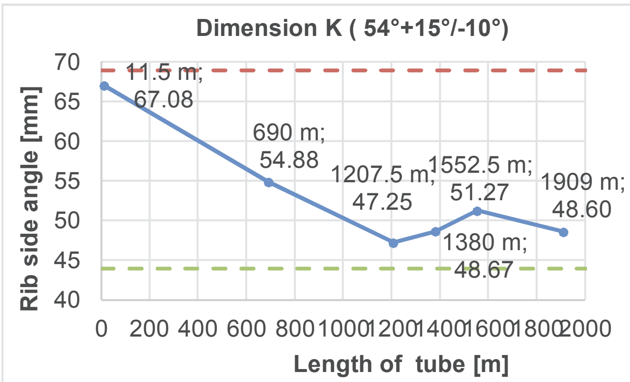

Figure 7 Rib side angle - Dimension "K" [1]

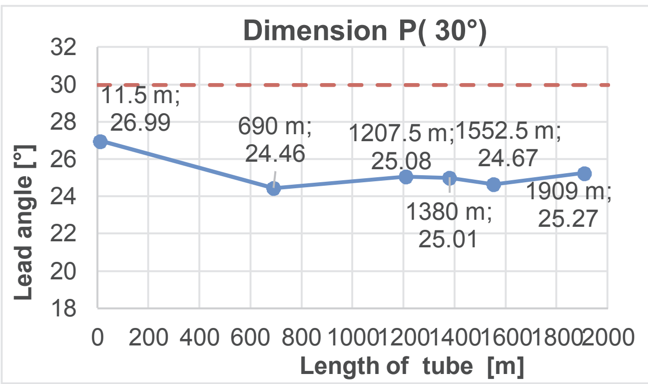

Figure 8 Lead angle - Dimension "P" [1]

5. MICROSTUCTURES AND MECHANICAL PROPERTIES OF STATES BEFORE MULTI RIFLED DRAWING

5.1. Microstructure of the tube with dimension Ø 36 x 8 mm (after heat treatment and before drawing)

The tube wich was drawing with dimension from Ø 48 x 9 mm on dimension Ø 36 x 8 mm was analysed in axial direction and directional direction. The microstructure was homogeneous and ferritic - pearlite with globular pearlite. Size of ferrite grain was 4.8 - 5 μm. Proportion of the perlite phase was approximately 30% (**Figure 9 a, b**) .[1]

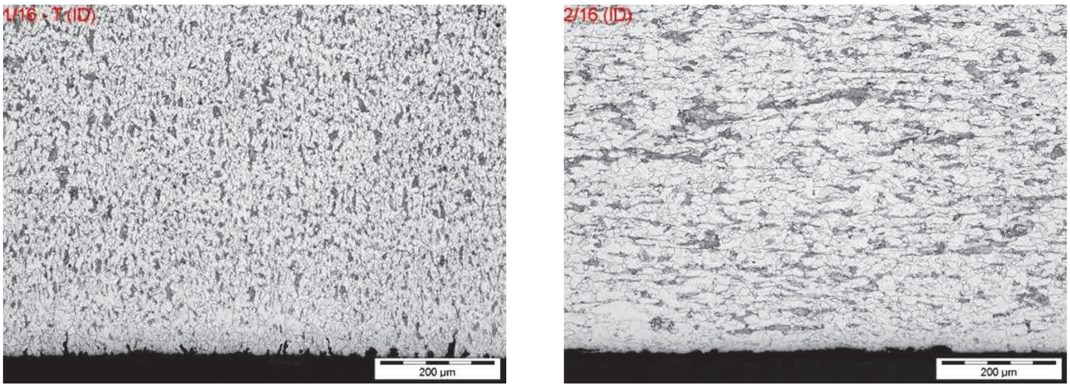

Figure 9 Inner surface of the tube in axial direction (left) and longitudinal direction (right). [1]

Table 2 shows the mechanical properties of 13CrMo4-5 steel grade according to EN10216-2+A2. Mechanical values were evaluated on a tube sample of Ø 36x8 mm (on pipes before the final pull - ribbing). In **Figure 10** we can see mechanical values of the tubes before drawing of multi rifled tubes. From all of states we choose 3 samples: RA, RB, RC - after heat treatment and before drawing, RR1, RR2, RR3 - after ribbing, RRF1, RRF2, RRF3 - after ribbing and after heat treatment. [1]

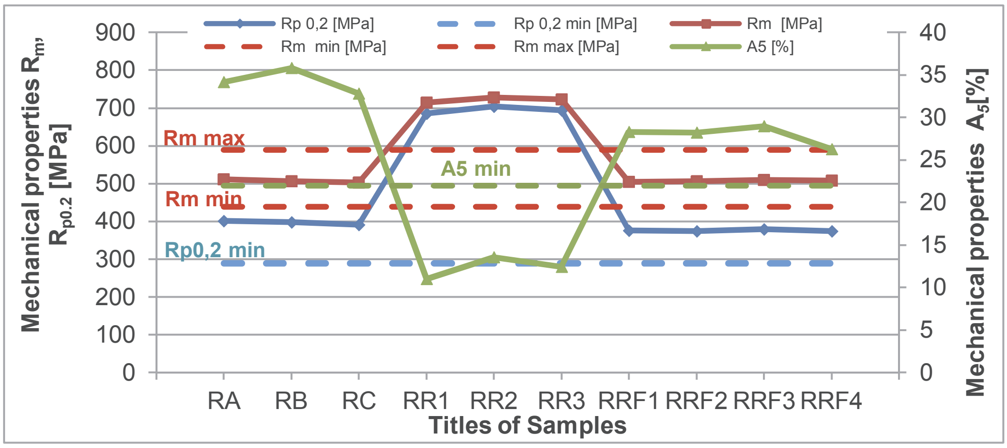

Figure 10 Mechanical values of the tubes with dimension Ø 36 x 8 mm

6. CONCLUSION

This experiment was realised to verify the possibility of drawing multi rifled tube in terms of the dimensional (geometric) stability of the specified dimension. We can state that the specified parameters that are essential from the point of view of the internal geometric stability of the given dimensions and from the point of view of the use of the product under optimum drawing conditions (positioning of the thorn and die, arrangement of the tribological pair - lubrication, drawing speed) are the geometry of the tube with the inter- Stable and meets the conditions defined in the full dimensional specification. It is very important that the following parameters are respected before the tube-shaped pulling technology and that the smallest surface cracks on the inner surface of the tube and the minimum eccentricity condition.

The microstructure of 13CrMo4-5 (**Figure 9**) shows homogenous ferit - pearlite with globular pearlite. This is the optimal microstructure in inner surface for drawing material. The surface was optimal for created multi rifled tube also with the mechanical properties before drawing after heat treatment (**Figure 10**).

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