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MODELING AND VERIFICATION OF THE CLADDING TUBE BEND

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ABSTRACT

This paper deal with modeling of the bend of cladding tube and following realisation of a modeled bend. FEM modeling gave possibility for modeling many combination of the bending parameters and than pick the best combination of a bending parameters. Results, like shear stresses and deformations, obtained from model are listed. Best combination of working parameters was used for the manufacture of a bend. The bended tube was subjected to analysis. The results shown that there are no imperfections like cracks or layers delamination. Results of investigation by SEM including measurement of chemical distribution around interface of cladding tube are shown. For investigation and modeling FEM Software PMD® (Package for Machine Design), SEM microscope Jeol JSM 7600F, optical microscope Nikon Eclipse MA 200 were used.

KEYWORDS: FEM model, Bending, Cladding tube, SEM, Light microscopy

INTRODUCTION

Technology of production of clad tubes was mastered by many other manufacturers and a gradual decline in prices of clad tubes makes them an alternative to the use of homogeneous tubes of high-quality metal, or to use overlay. Using clad tubes is subject by mastering the technological operations necessary for producing the normal technical equipment. While the welding is practically mastered opposed to assess the impact of large deformations, which are mainly bends. Especially the large diameter and thickness is not mastering bending economically unacceptable. Using FEM modeling of bends allows verification required for bending or bending parameters determining the border, where there will not be major changes in the properties compared with the supplied tube. The paper describes the various steps to verify the manufacturability of quality bending of clad pipes

MATERIALS AND METHODS

Experimental material

Production

Outer Part is made from nickel alloy Sandvik Sanicro 38 ((1.0405)). Chemical composition is shown in Table 2. Inner part of tube is made from steel type Sandvik 4L7 (EN equivalent is P265GH (1.0405)). Chemical composition is shown in Table 3.

Production of cladding tube is pointed at Fig. 1

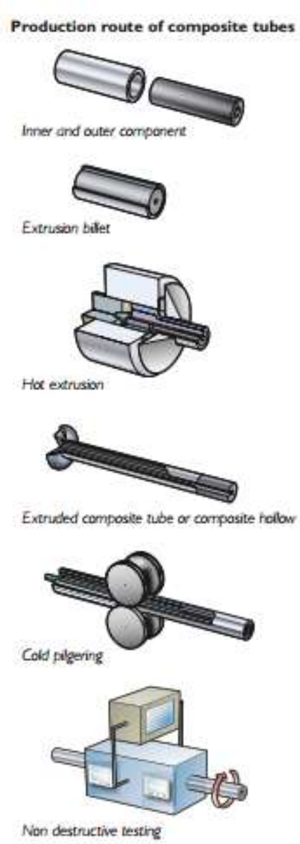

Fig. 1 Production of cladding tubes [1]

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Table 1. Tube specification [2]

SANICRO 38/4L7 OD 76,2 x 6,58	
Outer diameter	76,2 mm
Wall thickness	6,58 mm
Sanicro 38 thickness	1,86 mm +0,6/-0,4
Minimal thickness of Sandvick 4L7	4,72 mm
Bend angle	90°C
Bend radius	200 mm

Outer layer

Table 2. Chemical composition of Sanicro 38 %wt. [2]

Sanicro 38	
C	≤0,03
Si	≤0,5
Mn	0,8
Cr	20
Ni	38,5
Mo	2,6
Cu	1,7
Ti	0,8

Inner layer

Table 3. Chemical composition of Sandvik 4L7 %wt. [2]

Sandvik 4L7	
C	≤0,2
Si	0,3
Mn	0,7
P	≤0,025
S	≤,020
Cr	-
Ni	-
Mo	-
Others	-

FEM modeling

Firstly was into FEM model set inputs like, mechanical properties and yield strength as function of temperature for both materials. From this data the approximation of areas of plastification was established.

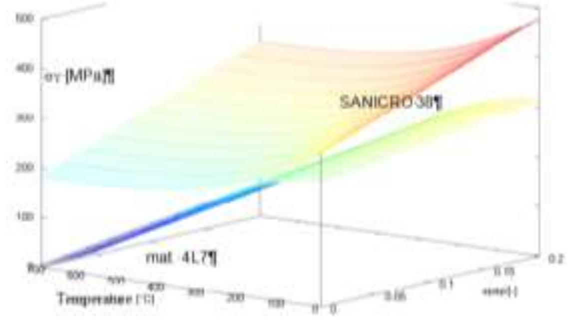

Fig. 2 Approximation of areas of plastification [3]

Next step was numerical simulation of bending, with focus on deformation and shear stresses. Results of simulations with satisfaction results are shown below.

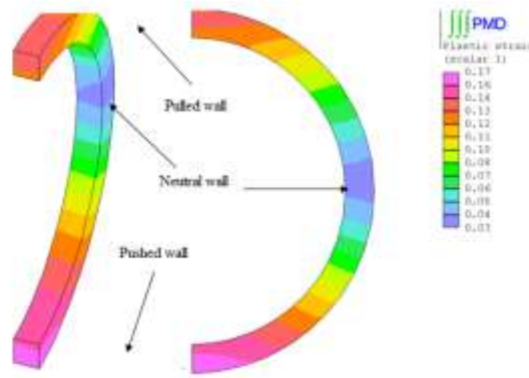

Fig. 3 Scheme of deformations across the tube [3]

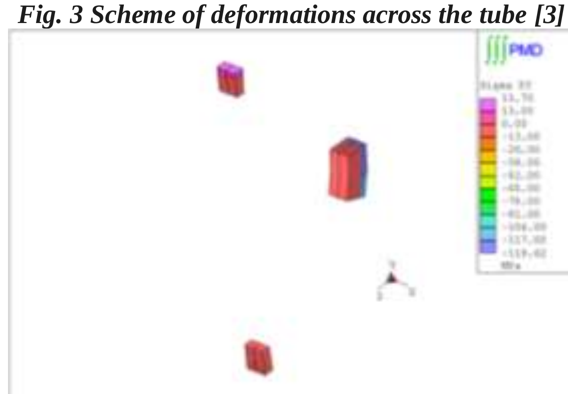

Fig. 3 Shear stresses in the XY plane [3]

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Fig. 4 Shear stresses in the XY plane [3]

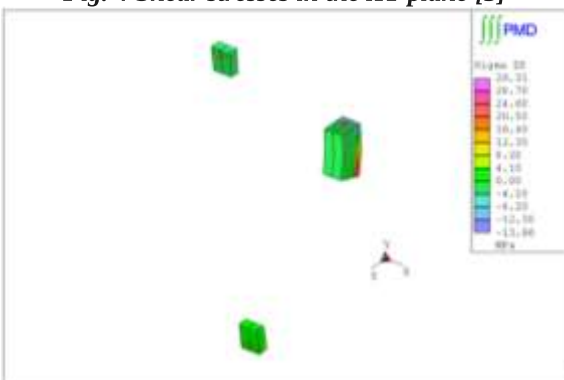

Fig. 5 Shear stresses in the XY plane [3]

Obtain results from FEM model was compared with experimentally measured values of critical Shear stresses. Model confirmed that stresses caused by bending will be lower than critical. At the base of those results real bend was made.

Bending

Experimental bend was realized on bending machine with inductor heating of tube. Inductor heat small ring of material which is preferably used for location of deformation. Photos taken during bending are shown below.

Fig. 6 Side view during bending

Fig. 7 Upper view during bending

Microscopy

The goal for light microscopy was to confirm that there are no imperfections. SEM was used for micro investigation of layers surface and for measurement of chemical composition around the surface between close layers.

Light microscopy

Photo taken by light microscopy is shown in Fig.8 There are documented carbon depleted zone and cladding surface with no imperfections.

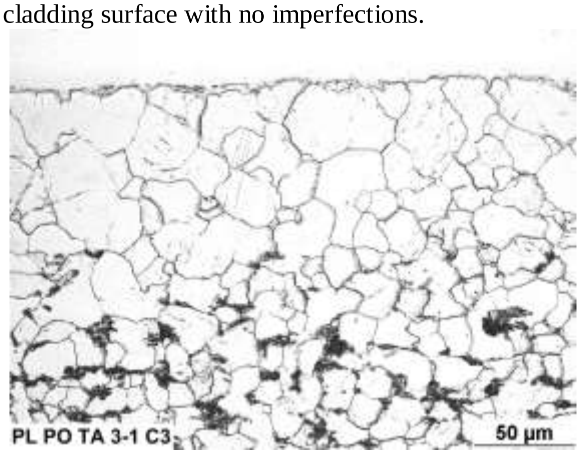

Fig.8 Structure around the cladding surface

SEM

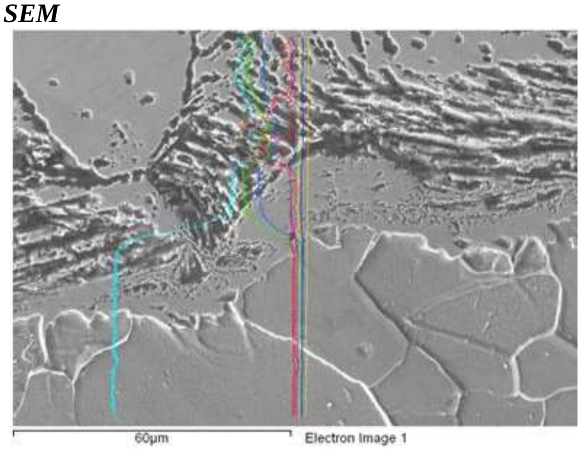

Fig.9 Line analysis around cladding surface

In figure 9 are shown differences of chemical composition across cladding surface. The strongly deformed and etched area is at upper part of picture. Between strongly etched nickel alloy and base steel material is quite inert midlayer (40-50µm). Midlayer is rich for alloying elements.

RESULTS AND DISCUSSION

Values of shear stresses are listed in table 4. Calculated stresses caused by bending are lower than measured critical stress for delamination of layers of cladding tube. That gave chance for successful realization of bend.

Table 4. Shear stresses* [MPa] *in the plains [3]

Position specification	xy	yz	zx
Pulled wall	67	0	0
Pushed wall	80	0	0
Neutral wall	107	1	12

Measurement of hardness through the wall of tube shows that hardness increased by bending just in part of tube made from Sanicro 38. That result is in agreement with calculated values of deformation. No significant difference between pushed and pulled wall aren't occur.

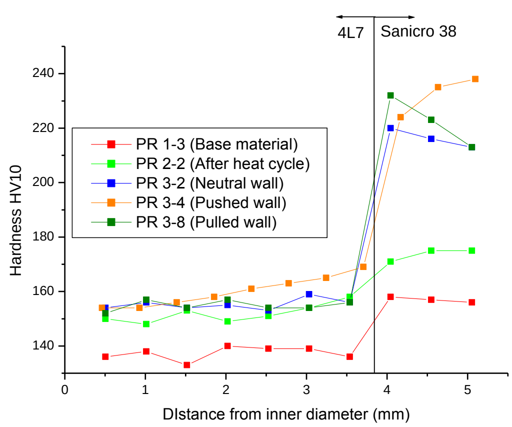

Fig. 10 Hardness through the wall

Measurement of microhardness around cladding surface pointed out increase of hardness in close area around cladding surface. That can be caused by redistribution of chemical elements. In figure 12-15 are plotted difference of chemical elements content in counts from EDX analysis. Area from 40 to 50 µm is rich for all alloying elements which contain Sanicro 38. It confirm diffusion from Sanicro 38 into 4L7. On the other hand Figure 9 had shown carbon diffusion from 4L7 into Sanicro 38. These two changes was caused by heat cyclus and caused increasing of hardness around cladding surface.

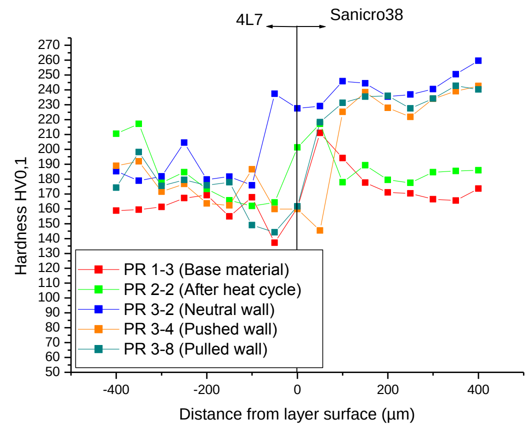

Fig. 11 Microhardness around cladding surface

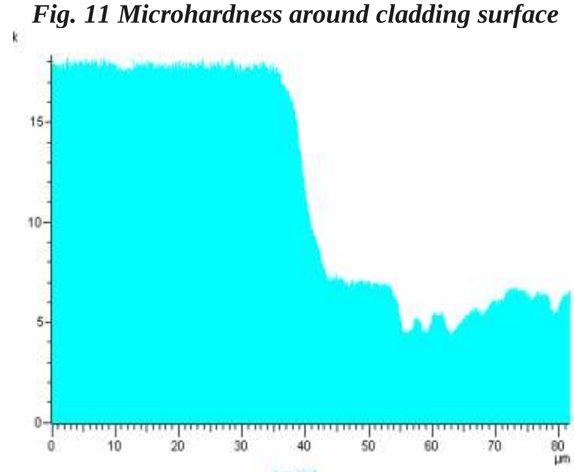

Fig. 12 Difference of Fe content across interface

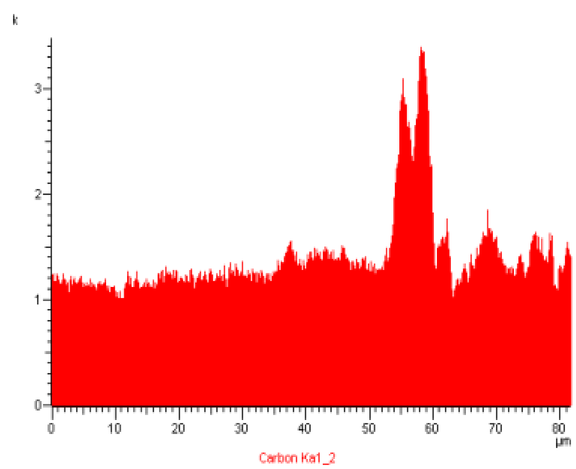

Fig. 13 Difference of C content across interface

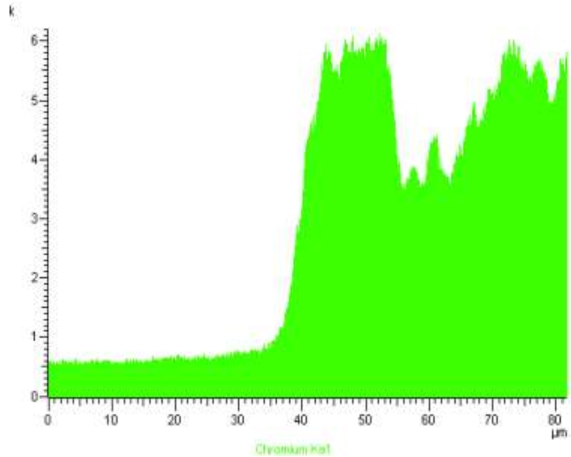

Fig. 14 Difference of Cr content across interface

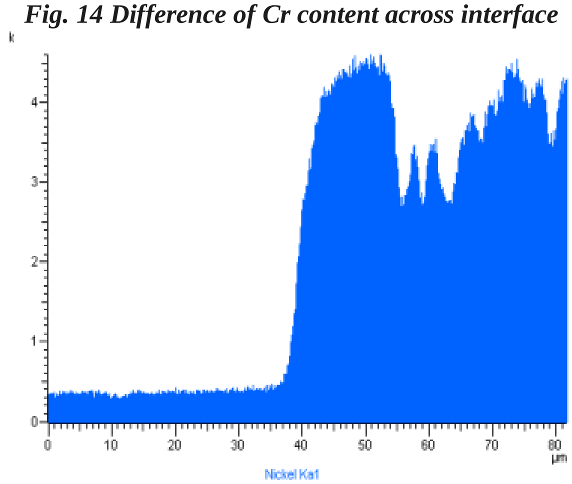

Fig. 15 Difference of Ni content across interface

CONCLUSION

Obtained results shows:

1. It is possible to model process of bending with induction heating by software PMD®. There is possible of together modelling of instationary thermal field during bending under inductor and large plastic deformation of cladding tube.
2. Distribution and extremes of shear stresses and deformations at cladding surface can be determined at base of computations.
3. The methodology of direct measurement of shear stresses at cladding surface was successfully handled.
4. Critical shear stress at cladding surface was experimentaly measured.
5. With backsolution were determined parameters of quality bend.
6. A bend with the parameters proven by the calculation was made.
7. Metallographic analysis confirmed, that in the bending process and its associated thermal exposure was prevent a damage to the clad pipes or in different layers of metal, or at the place of its connection.
8. This post demonstrates the possibility of using FEM modeling to selection parameter of bend clad pipes.

ACKNOWLEDGEMENTS

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REFERENCES

[1] HORVÁTH, Ladislav, Marie SVOBODOVÁ, Tomáš CHMELA, Irena ANDRŠOVÁ a Jakub HORVÁTH. *Odborná zpráva o postupu prací a dosažených výsledcích za rok 2013, Číslo projektu: TA03010150: Výzkum vlastností a chování tlustostěnných plátovaných trub-kových ohybů v podmínkách ekonomicky významných aplikací, včetně zvládnutí jejich výroby ověřené certifikovaným orgánem s evropskou působností*. Praha, 2014

[2] Sandvik Sanicro ® 38/4L7* Composite tube. Sandvik [online]. 2014 [cit. 2014-12-05]. available from: http://www.smt.sandvik.com/PageFiles/49754/S-12126-ENG-2003-02.pdf

[3] SMEJKAL, Martin. *Stanovení odhadu plastické defrmace plátované trubky z materiálů Sanicro 38 a 4L7 při ohybu s indukčním ohřevem*: 786-S628-14. Praha, 2014.