

NONDESTRUCTIVE AND DESTRUCTIVE TESTING OF WELDED JOINS

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Abstract

The aim of this work was to identify and evaluate eventual defects in tube welded joints made from X10CrNiCuNb18-9-3 material. By the use of non-destructive testing (namely capillary test and ultrasound test) were identified defect joints which were further screened using light optical microscopy.

Keywords: Welded joints, destructive test, non-destructive test, optical microscopy, structure

1. INTRODUCTION

In this work were evaluated welded tubes which are manufactured from a material X10CrNiCuNb with the austenitic matrix, Rm 590 MPa, Rp_{0.2} 350MPa, A5 25, KCV 47 J/cm². Macro-micro structure of testing welded joints was evaluated. The evaluation was conducted by destructive and non-destructive testing methods.

According to Schaeffer the steel chemical composition corresponds to the unstable austenite. That's why martensite, respectively ferit apart from austenite, may therefore be present at the melting field. Other alloying elements are Cu and Nb. Copper does not affect the structure. Nb suppresses the formation of chromium carbides due to its higher affinity to carbon - thus preventing depletion regions close to the chromium grain boundaries. In addition, it can support the expansion of ferrite.

2. EXPERIMENTAL

On the welded samples following tests were performed:

2.1 Non-destructive testing

2.1.1 Ultrasonic testing with regard to ISO EN 11666 (051172)

During the measurement undesirable damping was observed due to the considerable amount of austenite. The noise signal on the display must be below 12 dB (into 25 % increments) and for detection of defects it is necessary at least 6 dB, that's why for this measurement 8 dB was elected (**Figs. 1-3**).

For tests it was necessary to provide special 4 MHz angle probe M37 4T70 Cylinder R36 Flyleaf due to the small tube diameter. For the tube wall thickness under 8 mm, UT is guided by individually developed procedure [1].

Semi-finished product:	welded tubes
Used equipment:	Panametrics EPOCH III
Probe:	angled probe 4MHz, 70° + Flyleaf
Admissibility of defects:	crossing the border 20dB, basic sensitivity of 65 db

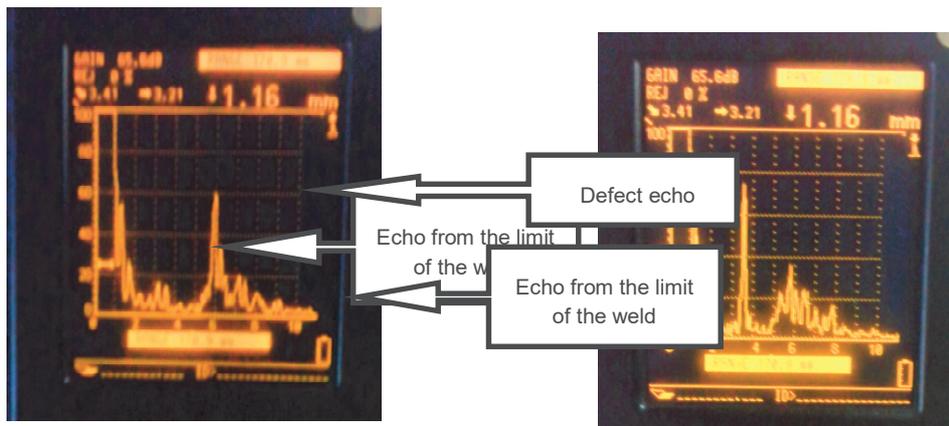


Fig. 1 Defectoscope display - echoes coming from defects

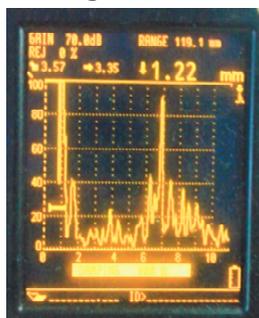


Fig. 2 Without defect

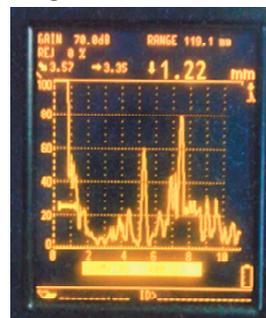


Fig. 3 Defect was found

It is necessary to bind the height of echoes coming from founded discontinuities to the corresponding defects seen on metallographic samples in relation to quantitatively specified findings from transmission RT.

2.1.2 Capillary test according to EN ISO 23277 (ČSN 05 1176)

All samples were inspected using capillary agents OVERCHEK Chemetall GmbH. The test was carried out at 250°C. The melt zone and heat-affected area with thickness of 10 mm was checked [2].

DEGREE OF ADMISSIBILITY	1	2	3	
Linear defect l max	2	4	8	mm
Point defect d max	4	6	8	mm

Only one point indication under 4 mm (subcritical) was found on some welds, the other welds met the most strict admissibility factor.

2.1.3 Visual test (VT) according to EN ISO 17637 (ČSN 051180)

For the measurement a multipurpose dipstick Cambridge CB1 6AL was used.

The test was conducted at 450 lux illumination observation angle was greater than 300°. Welds had to be clean for this test, be rid of non-metallic welding products and corrosion protective surface layers. Results were evaluated with regard to EN-ISO 17637 (ČSN 051180), see **Table 1** [3].

Table 1 Example of partial results on the tubes

Sample No.	Max. vertical weld rise [mm]	Min. vertical weld rise. [mm]	Max. weld-breadth [mm]	Min. weld-breadth [mm]
1	1.5	0	12.81	10.44
2	1.5	1	11.15	9.48
3	2	0	11.53	8.85
4	2	1	11.98	8.56
5	1	0.5	11.34	9.42

Visual inspection did not reveal any major errors on welds, only fluctuations in weld-breadth were observed.

3. DESTRUCTIVE TESTING

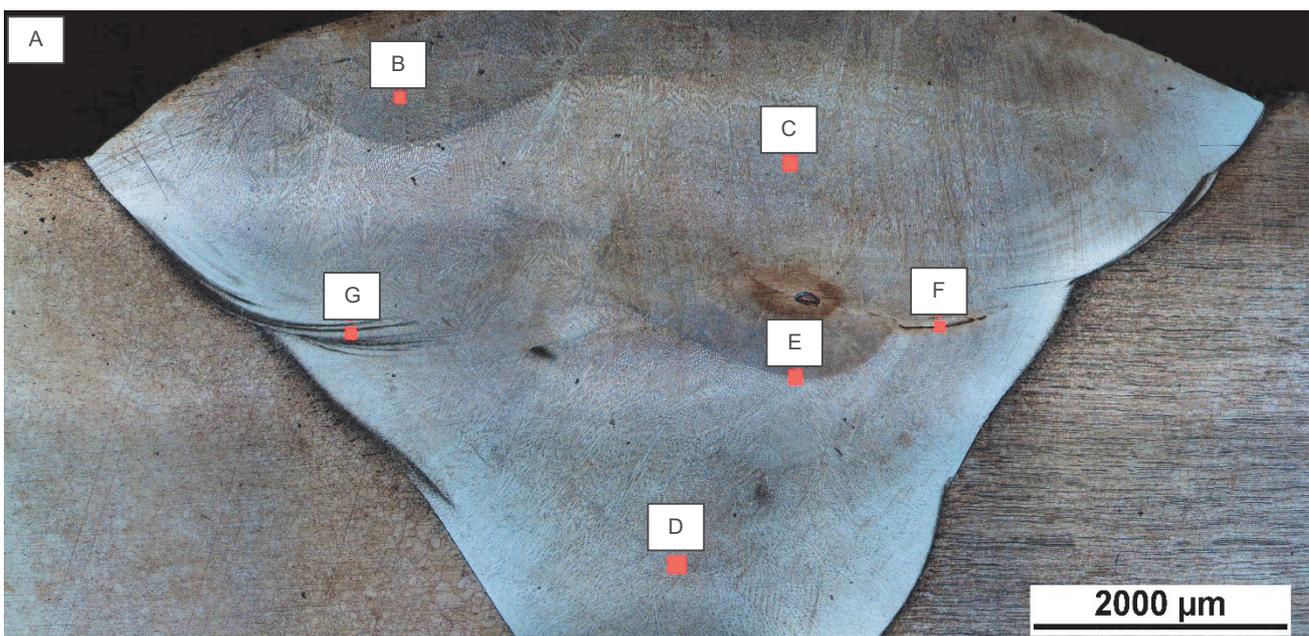
The weld tubes on which defects were identified by UT were selected for the destructive testing.

For metallographic sectioning was conducted perpendicular cut of the weld, then the sample was grinded on sandpapers grit of 320, 1200, 2000, polished (polishing canvases, diamond pastes of 9, 3 and 1 μm) and followed by etching by Rollason (5g FeCl_2 + 50 ml HCl + 100 ml H_2O). Melting zone (laying weld bead) and heat affected zone were assessed. For observation and photo-documentation was used optical microscope (see Fig 4). The hardness gradient was measured according to EN288 (**Fig. 5**) [4].

3.1 A melting zone

A significant amount of ferrite in examined material can be excluded because the material was not ferromagnetic. A small percentage of δ -ferrite in some very fine-grained weld areas, that do not cause measurable magnetism, may be accepted. These areas behave much as two-phase ($\gamma + \delta$).

For a detailed evaluation of these micrographs of microstructures would be necessary to have a detailed description of welding technology, further details about welding electrodes material and last but not least, the results of chemical microanalysis and XRD. With regard to the lack of knowledge of these data following metallographic evaluation is very brief.



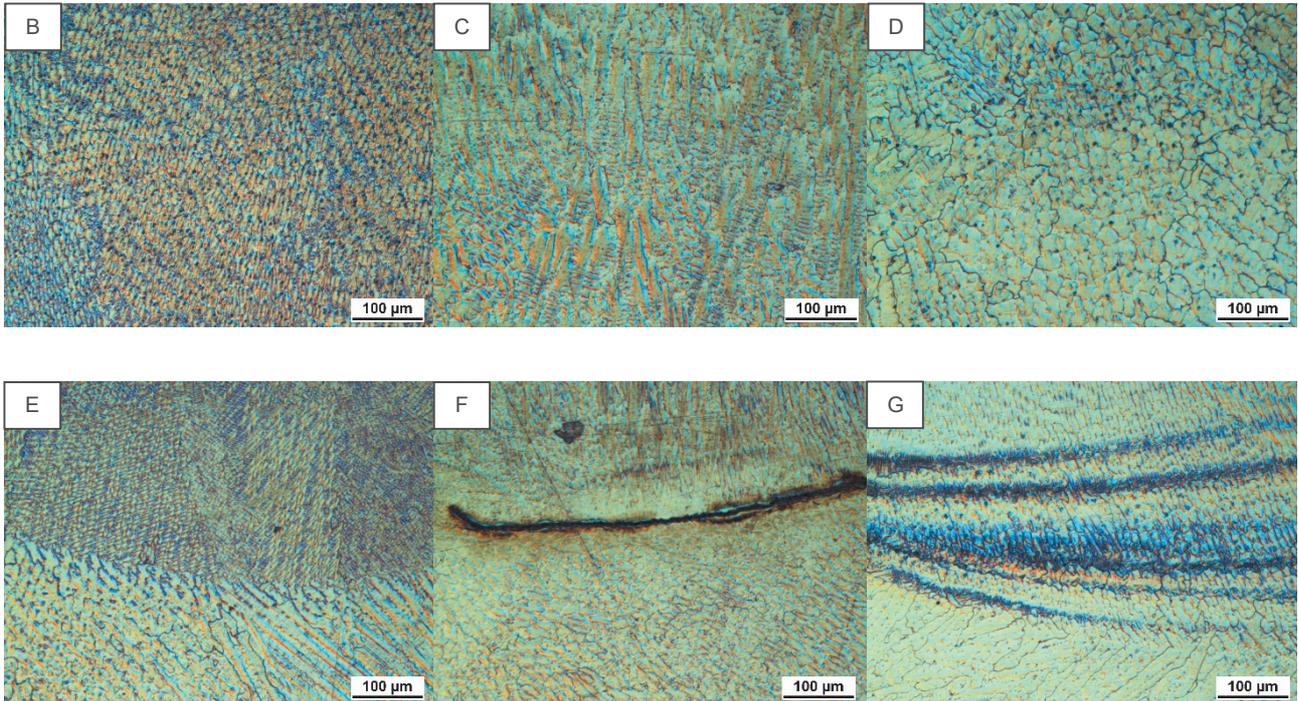


Fig. 4 Cut the weld with the finding of defect. A) Overview image; B-G) detailed images marked in 4A by red squares

The overview image in **Fig. 4A** documents the different anisotropy of welded joints and the position of the upper surface defect weld bead. It also shows the arrangement of dendritic structures in melting weld zone with different dispersions and different local orientation of dendrites. Locally at the top of the weld bead are several thin discontinuities (microcracks character).

In **Fig. 4B** we can see micro structure of upper weld bead with very fine grain, directionally oriented towards the surface of the weld. **Fig. 4C** shows significantly dendritic structure oriented toward to the surface of the weld. The austenite dendrites are predominantly uniaxial with an average length of 100 μm and maximum of 200 μm . In **Fig. 4D** there is almost purely austenitic structure (single phase) with grain size number according to ČSN 420462 6-7 [5], i.e. 0.035 to 0.04 mm. The structure in the upper part (**Fig. 4E**) is comparable to the very fine-grained two-phase area (**Fig. 4B**). This structure is the result of complicated temperature conditions during cooling and re-heating of the lower and upper solidification and cooling of weld bead. **Fig. 4F** shows the area which is a continuation of zone seen in **Fig. 4E**. This is the interphase between the solidifying dendritic structure of upper weld bead and again heated (annealed) structure of the bottom weld bead. In the upper part of **Fig. 4G**, there is visible fine-grained austenitic structure with elongated grains in the direction perpendicular to the joint of the two weld bead. In the bottom part of this **Fig. 4G**, there are three narrow bands of carbides (or even formations having δ -phase character).

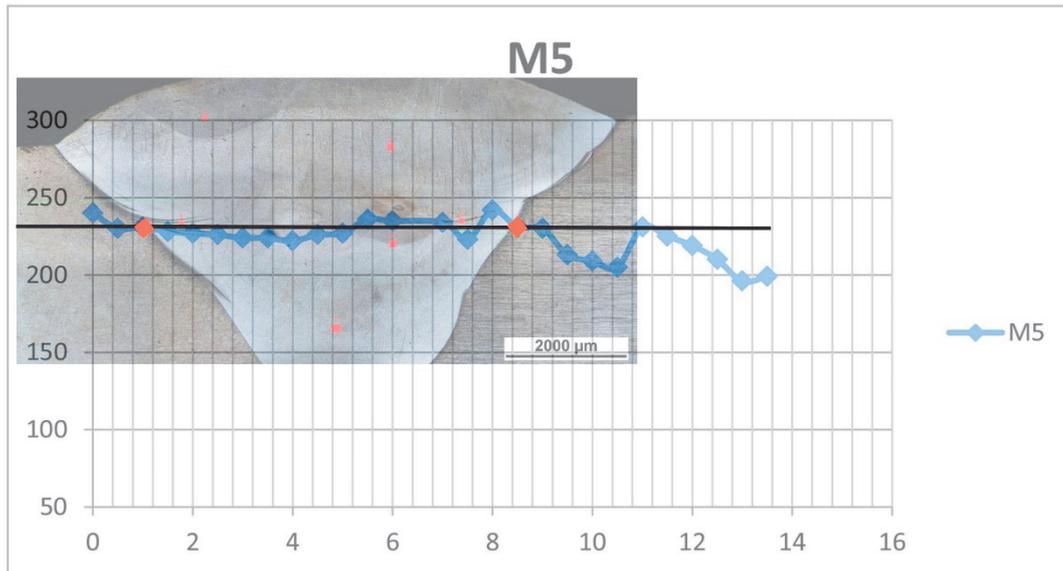


Fig. 5 Gradient of microhardness.

3.2 Heat affected zone

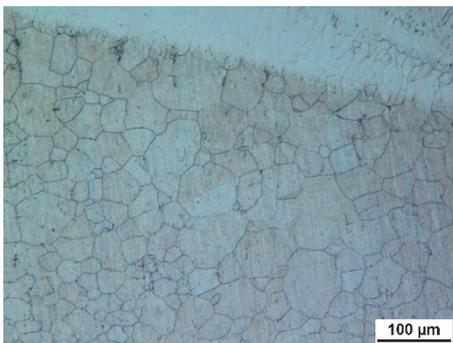


Fig. 6A crossing-weld matrix.

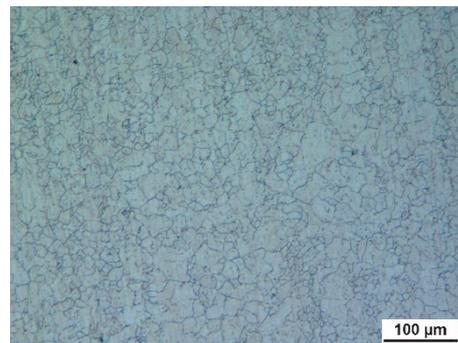


Fig. 6B matrix.

Fig. 6A represents transition of the weld zone into the tube matrix material. The area of recrystallized grains is followed by coarse of austenite grains (ČSN, No. 3), which gradually passes into the finer parts (ČSN - 4-5). Sometimes we can see on grain boundaries small Carbide formations.

On the image (**Fig. 6B**) is captures the heterogeneous austenitic structure in the heat-affected zone tube with large differences in grain size - sometimes no. 3-4, or 5-6, which gradually turns into a of fine- heat unaffected grain zone grained area with grain size no. 7 to 8.

According to ČSN 420,471 [6] the purity of the material was evaluated as acceptable, only point oxides degree no. 1 (OB1) were detected.

CONCLUSION

The result of this work was the development of methodology of proposals evaluation and quality control on tubes made from welded joints X10CrNiCuNb18-9-3 material.

For the evaluation of welding joints, the methodology uses general guidelines and tools and standards corresponding to the EN directives.

Ultrasonic method revealed internal defects, which were subsequently confirmed by the use of metallography. Non-destructive methods for searching of surface defects (capillary and visual test) in practical test revealed minor defects. Destructive metallographic investigation confirmed the UT findings, the structure of melting - heat affected and base zone correspond to the normal structures for a given type of austenitic steel.

ACKNOWLEDGEMENTS

The results of this project LO1201 were obtained through the financial support of the Ministry of Education, Youth and Sports in the framework of the targeted support of the "National Programme for Sustainability I" and the OPR&DI project Centre for Nanomaterials, Advanced Technologies and Innovation CZ.1.05/2.1.00/01.0005. The authors also thank to the SGS project "Innovation in Material Engineering" and by the project Nr. P108/12/1452 financed by the Grant Agency of Czech Republic.

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