CAUSE OF LAMELLAR TEARING OF PARENT MATERIAL AND DEGRADATION OF WELDED JOINTS AT VITAL WELDED STRUCTURES OF THE TURBINE AT HYDRO POWER PLANT 'ĐERDAP 1'

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Key words: welded structure, non-destructive test, lamellar tearing of parent material, degradation of the welded joint

Abstract:

Vertical Kaplan turbines, manufactured in Russia, are installed in 6 hydroelectric generating units at 'Djerdap 1', with nominal power of 176 MW each. Because of the structural solution and inability of performing periodic inspections and state analyses, 40 years long service life of the turbine and upper ring of guide vane apparatus was predicted. Welded structures of the turbine cover and upper ring of guide vane apparatus consist of 4 segments made of steel St 3, in accordance with GOST 380-94. Flux-cored arc welding was used in order to merge the segments.

Non-destructive and destructive tests were performed on parent material and welded joints during the rehabilitation of the hydroelectric generating set A4, in order to carry out the condition analysis and assessment of the level and cause of eventual degradation of structures of the turbine cover and upper ring of guide vane apparatus at hydro power plant 'Djerdap 1'.

In this paper the analyses that refer to determination of the cause of lamellar tearing of parent material in the area of welded joints based on results of magnetic particle testing and ultrasonic testing are presented.

1 INTRODUCTION

Vertical Kaplan turbines, manufactured in Russia, are installed in 6 hydroelectric generating units at "Djerdap 1", with nominal power of 176 MW each, figure 1 [1]. Turbine and hydromechanical equipment of hydro power plants is subjected to stresses that occur during the production of components and assembly of equipment (residual stresses), during the process of performing functional taska (stationary and dynamic loads), as well as during a disturbed process of exploitation (non-stationary dynamic loads). Effects of working environment and exploitation (corrosion, erosion, cavitation) should also be taken into account, and it's clear that stress to which certain components and equipment as a whole are subjected can not be represented by a model which demands that parameters evenly change under certain working conditions.

During the rehabilitation of the turbine of the hydroelectric generating set A4 at hydro power plant 'Djerdap 1' condition analyses that referred to turbine cover and the upper ring of guide vane apparatus were carried out. Destructive and non-destructive tests were performed on parent material and weld metal. Turbine cover and the upper ring of guide vane apparatus were assembled by welding and consist of 4 segments each (designations of segments are 1-2, 2-3, 3-4, 4-1). Segments were made of steel St 3 (GOST 380-94), figures 2 and 3. The analysis that referred to the cause of occurrence of lamellar tearing of parent material in the areas where welded joints were formed was based on results of magnetic particle testing (MT) and ultrasonic testing (UT).

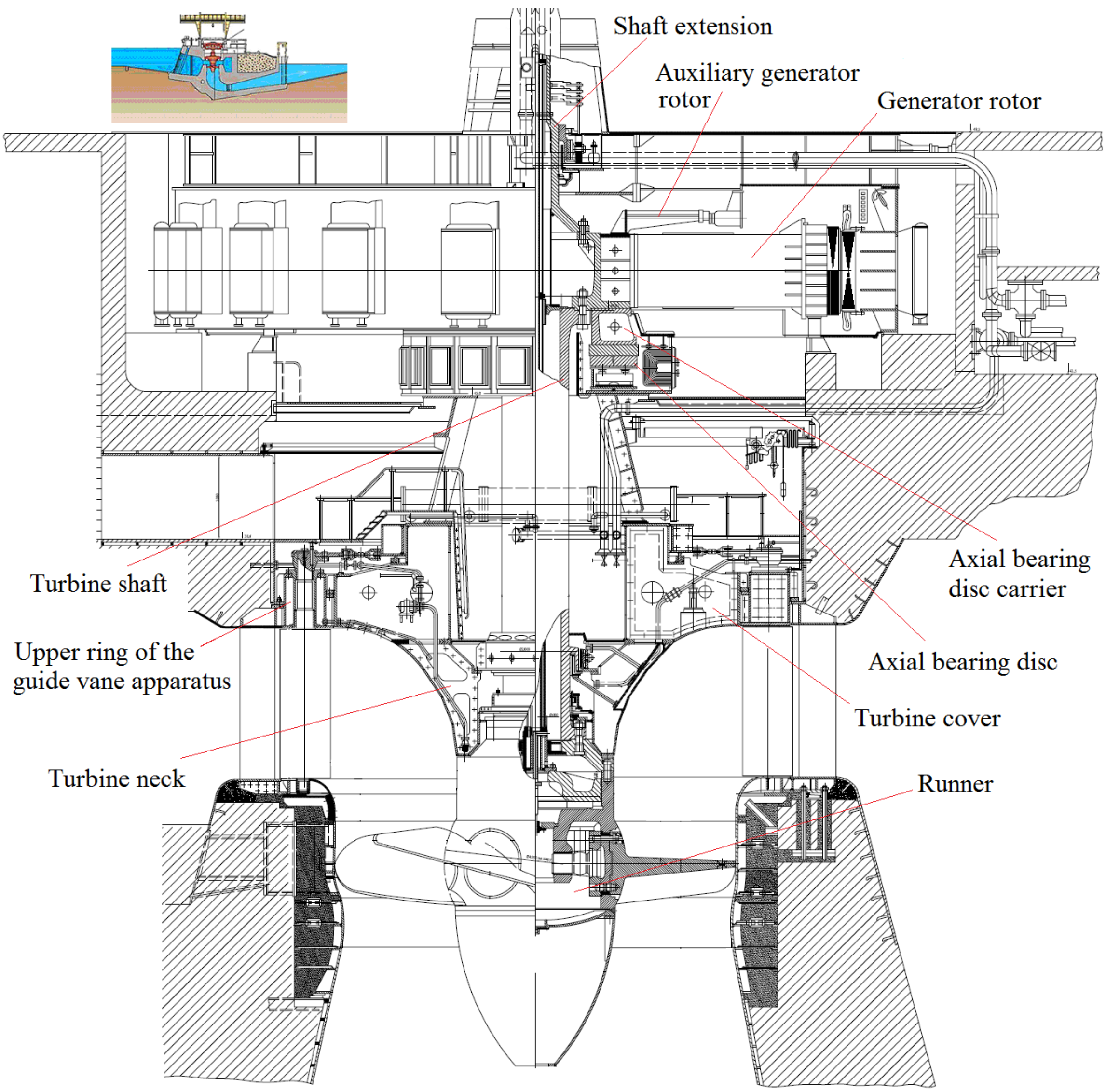


Figure 1. Basic components of the Kaplan turbine with nominal power of 176 MW

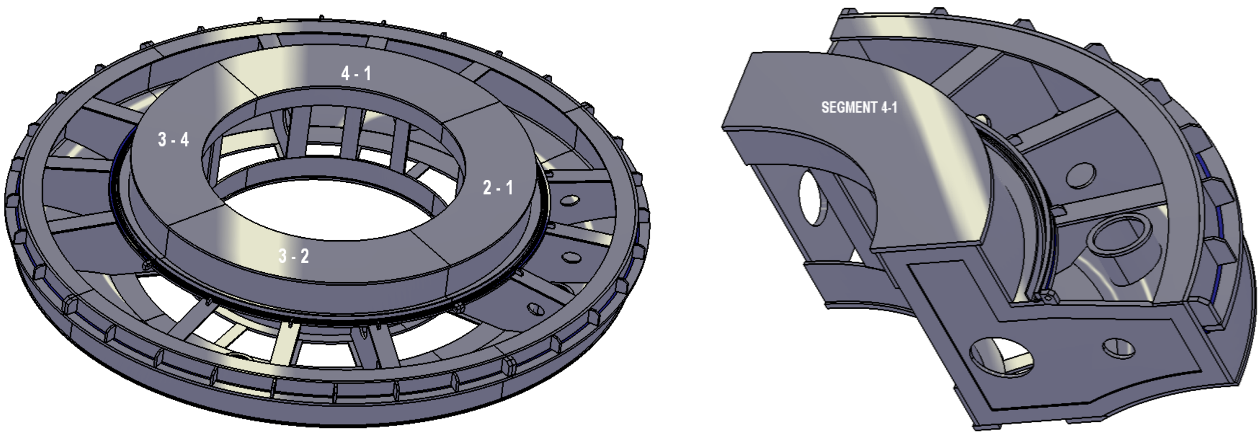


Figure 2. Model of the turbine cover and segment 4-1

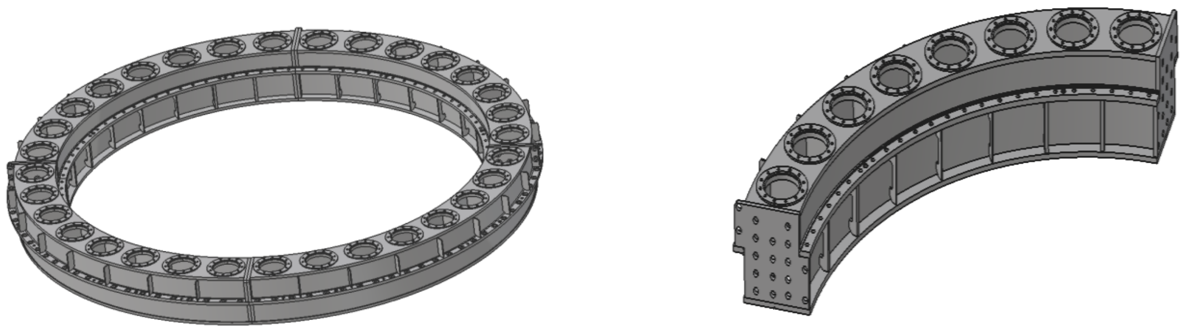
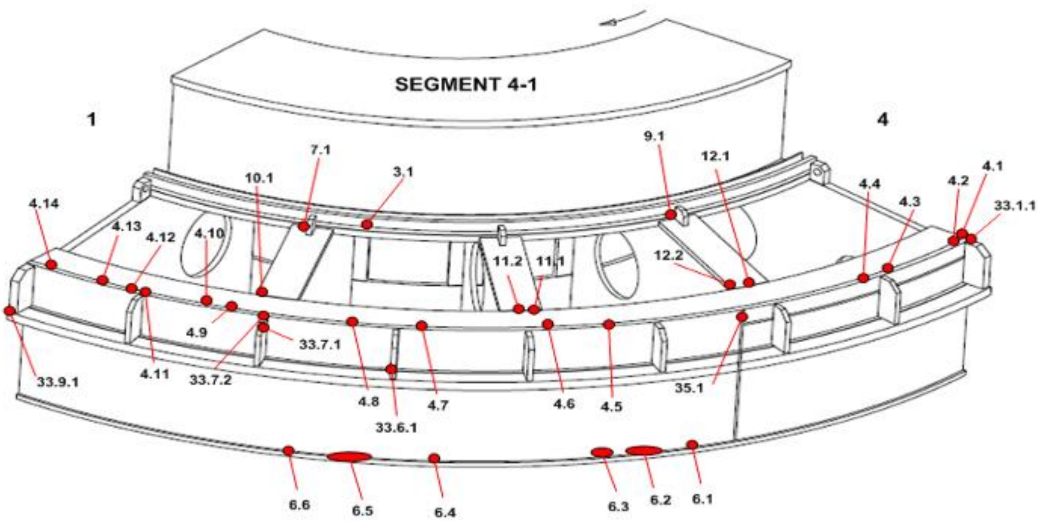


Figure 3. Model of the upper ring of guide vane apparatus and of a segment

2 TESTS PERFORMED ON TURBINE COVER AND UPPER RING OF GUIDE VANE APPARATUS

Experimental tests by non-destructive methods were carried out on parent material and welded joints in order to determine the current condition of the turbine cover [2] and upper ring of guide vane apparatus [3]. Obtained test results, relevant for the analysis of the cause of occurrence of lamellar tearing of parent material in the areas where welded joints were formed, are presented in figures 4-7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3.1
9.1
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4.14
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4.12
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11.1
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4.4
4.3
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4.9
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4.11
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4.8
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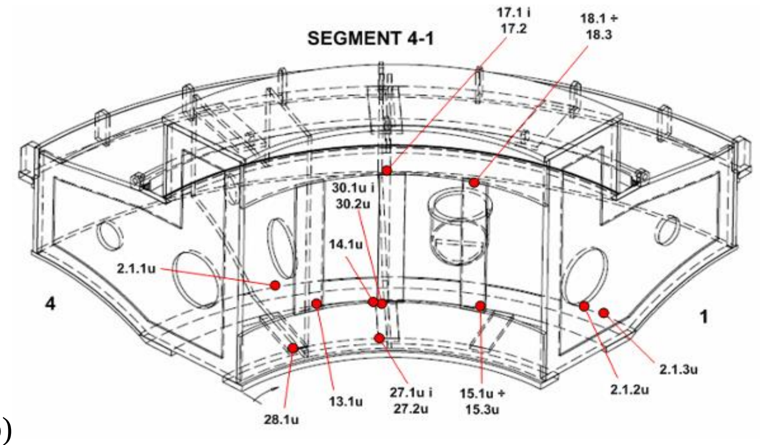
a)


SEGMENT 4-1
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27.1u i
27.2u
15.1u ÷
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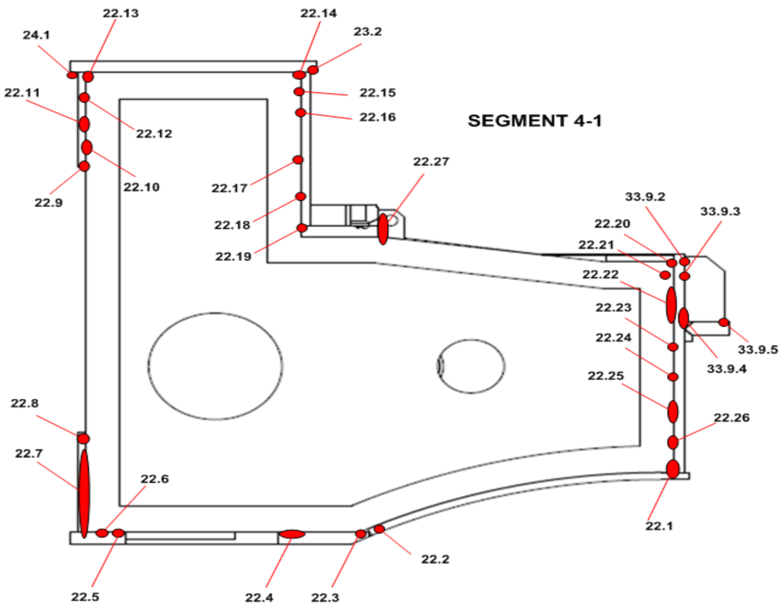
b)


22.13
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SEGMENT 4-1
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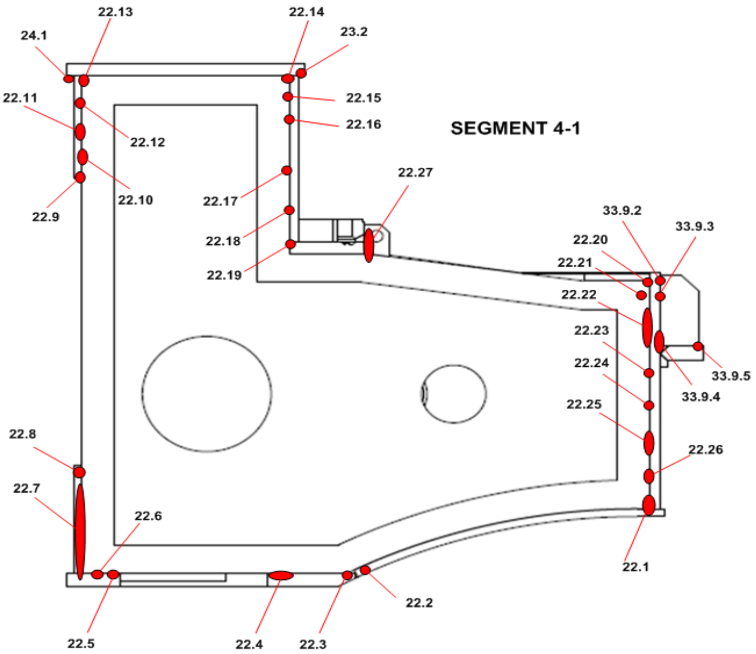
c)



d)

Figure 4. Locations of surface defects detected by magnetic particle testing at a segment of the turbine cover

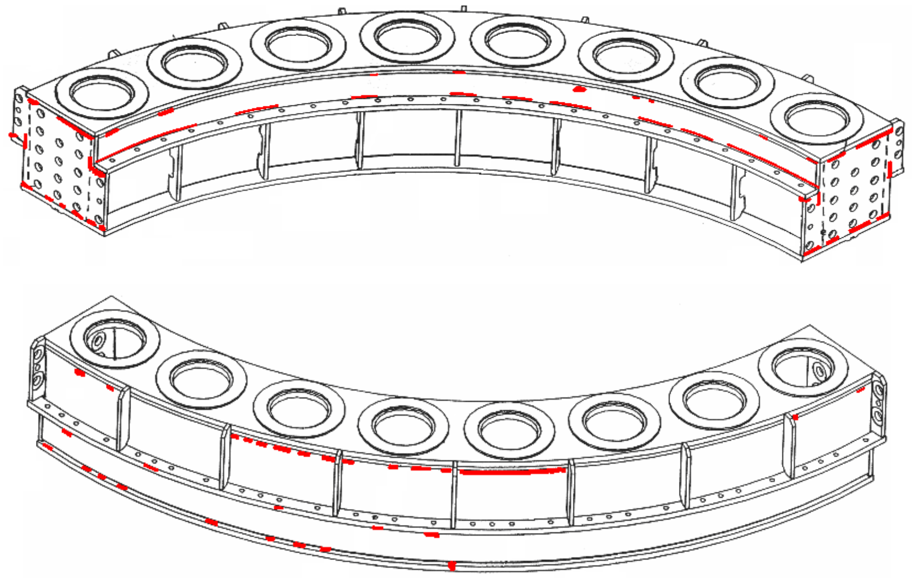


Figure 5. Locations of surface defects detected by magnetic particle testing at a segment of the upper ring of guide vane apparatus

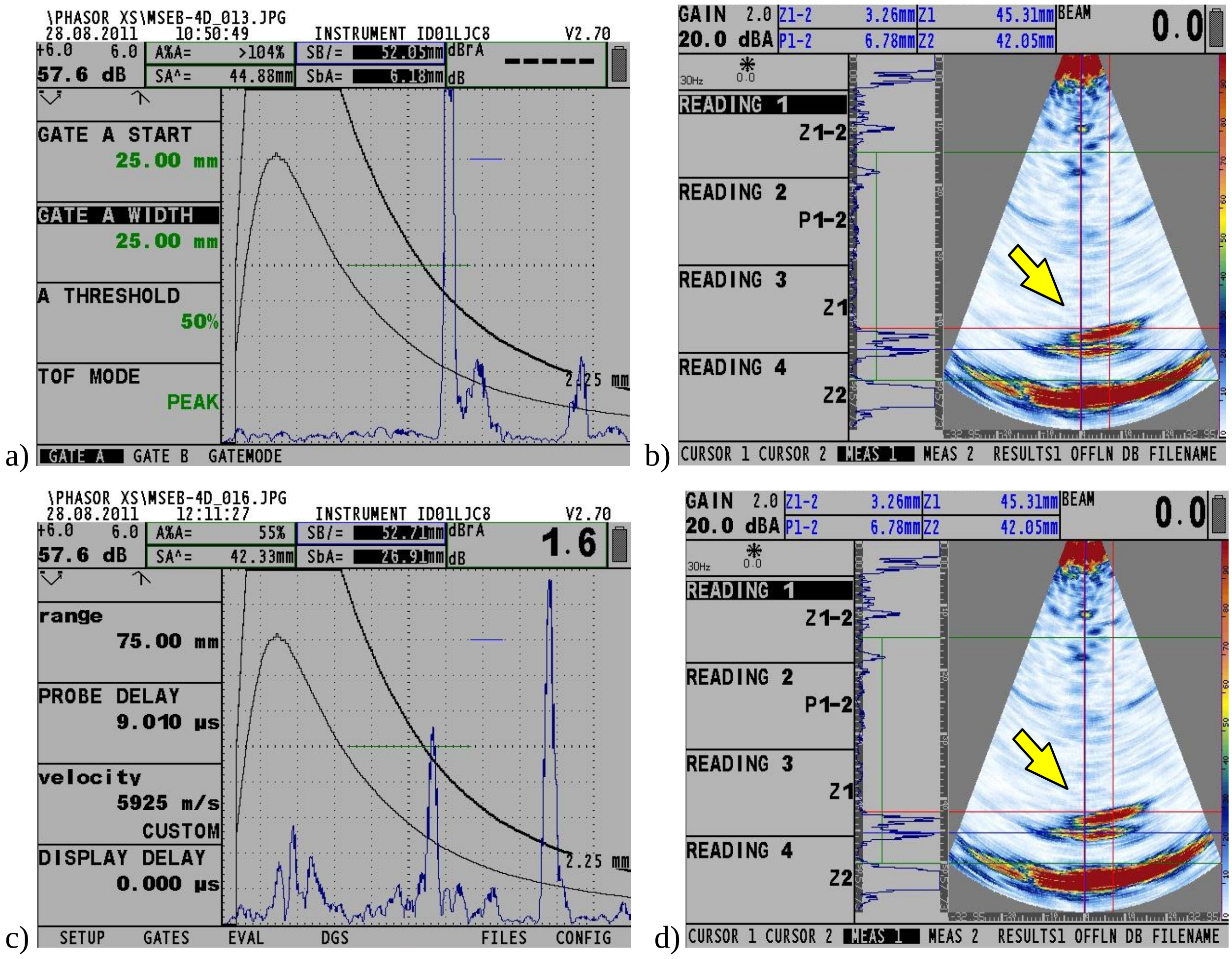


Figure 7. Echographs of indications of lamellar tearing of parent metal in the area of welded joints of the upper ring of guide vane apparatus (detected by ultrasonic testing)

3 ANALYSIS OF THE CAUSE OF OCCURRENCE OF LAMELLAR TEARING

Proneness of parent material to lamellar tearing can be determined by obtaining impact energy for material taken from z-direction. Reduction of the risk of occurrence of lamellar tearing at welded structures requires close cooperation between steel manufacturer, designer, technologist and welding engineer. Taking into account the proneness to lamellar tearing, steels are being classified with respect to the boundary value of the parameter of crack closure Z:

– steels insensitive towards lamellar tearing with Z > 25%;

– steels partially sensitive towards lamellar tearing with 10 < Z < 25%;

– steels sensitive towards lamellar tearing with Z < 10%.

The proneness of structural material towards lamellar tearing can vary a lot, depending on differences in production and chemical composition. Non-homogeneity of material is a metallurgical cause for crack occurrence, even when it comes to structural and austenitic steels. Lamellar tearing is being caused by high concentrations of sulphides, silicates and aluminates, mostly in highly solid structural steels, while oxides, carbides and eventually titan sulphides cause lamellar tearing in austenitic steels.

Large deviations of strength and ductility in z-direction, with respect to the direction of rolling, may occur in thick metal sheets due to the production procedure. Differences mainly depend on the type and shape of impurities in steel. Inclusions of mangan-sulphide have a particularly negative influence on isotropy of steels. Mangan sulphides are present in the form of plate-like inclusions. Due to having highest elongation in the plane of rolling they form pronounced discontinuities in the direction of Z – axis.

Due to deviations in structure listed above, which refer to the reduction of strength and ductility, thick metal sheets are prone to lamellar tearing. It is a well known fact that inclusions which originate during the welding process are responsible for the initiation of cracks.

Impurities which originate in steels are suitable for accumulation of hydrogen, therefore the higher concentration of hydrogen in steels and weld metal due to the process of dissolution, diffusion and segregation can be very stimulating when it comes to crack initiation.

Metal sheets welded perpendicularly towards the the plane of a metal sheet (T and cruciform welded joints) are especially prone to lamellar tearing, which is the case with the turbine cover.

Lamellar crack is a defect which occurs in a form of terrace-like distributed cracks, parallel to the surface. Causes for the occurence of lamellar cracking are as follows:

- level of contamination of material due to the large content of mangan-sulphide (quantity and shape of segregation depend on the level of contamination and deformation), as well as due to the presence of oxide and sillicate inclusions (which occur during the production of steels, process of deoxidation and reactions between fireproof material and liquid steel),
- residual stresses that occur due to welding and stresses that occur in the direction of metal sheet thickness due to assembly,
- forming of hard structures caused by welding technology, associated with resulting proneness towards cold cracking,
- stimulating action of the process of dissolution, diffusion and hydrogen segregation.

4 CONCLUSION

On the basis of results of experimental and theoretical researches associated with lamellar tearing it was concluded that welded structure of the turbine cover of the hydroelectric generating set A4 at hydro power plant ’Djerdap 1’ is an example of a situation when 2 equally significant causes of degradation of parent material and weld metal exist, which are:

- degradation caused by a flaw in steel production technology,

- degradation caused by a flaw in technology which refers to the execution of a welded structure.

ACKNOWLEDGEMENT

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