This paper was presented at the Fourteenth Meeting
"New Trends in Fatigue and Fracture" (NT2F14)
Belgrade, Serbia, 15–18 September, 2014

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METHODOLOGY FOR REPAIRING DEFECTS ON INTERNAL SURFACES OF CRANKS OF GUIDE VANE APPARATUS IN HYDROELECTRIC GENERATING SET AT HYDROPOWER PLANT DJERDAP 1

METODOLOGIJA REPARACIJE GREŠAKA NA UNUTRAŠNJIM POVRŠINAMA GLAVČINE SPROVODNOG APARATA HIDROELEKTRIČNE GENERATORSKE JEDINICE HIDROELEKTRANE DJERDAP 1

Originalni naučni rad / Original scientific paper
UDK /UDC: 620.179:621.224.35
Rad primljen / Paper received: 25.09.2014

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Keywords
- hydro turbine
- crank
- sleeve
- damages
- repair methodology

Ključne reči
- hidro turbina
- glavčina
- rukavac
- oštećenja
- metodologija reparacije

Abstract

Vertical Kaplan turbines, made in Russia, are installed in 6 hydroelectric generating sets at 'Djerdap 1', with nominal power of 200 MW each. During the refurbishment of the hydroelectric generating set A4 at the hydropower plant Djerdap 1, experimental non-destructive tests on all of its components are performed in order to determine the state of the turbine as a whole.

During the tests, the damage and cracks are detected on internal surfaces of guide vane cranks and sleeves, which occurred as a consequence of turbine shaft vibration.

The results of experimental tests, as well as repair methodology for damaged internal surfaces of guide vane cranks are presented in this paper. Due to the structural solution used for the design of cranks and sleeves and their function during exploitation, it was necessary to define a large number of details, carefully reconsider them, and carry out all activities in order to enable the safe operation and continuous use of cranks.

Izvod

Vertikalne Kaplanove turbine nominalne snage 200 MW, izrađene u Rusiji, su montirane u 6 hidroelektričnih generatorskih jedinica hidroelektrane „Djerdap 1". Pri remontu hidroelektrične generatorske jedinice A4 hidroelektrane Djerdap 1, izvedena su eksperimentalna ispitivanja bez razaranja na svim komponentama radi utvrđivanja stanja turbine u celini.

Ispitivanjem su otkrivena oštećenja i prsline na unutrašnjim površinama glavčina i rukavaca sprovodnog aparata, koja su nastala kao posledica vibracije vratila turbine.

U radu su predstavljeni rezultati eksperimentalnih ispitivanja, kao i metodologija reparacije oštećenih unutrašnjih površina glavčina sprovodnog aparata. S obzirom na konstrukciono rešenje u projektovanju glavčina i rukavaca, i na njihovu funkciju u eksploataciji, bilo je potrebno definisati veliki broj detalja i pažljivo ih razmotriti, kako bi se izvele sve mere radi postizanja bezbednog i neprekidnog rada glavčina.

INTRODUCTION

Vertical Kaplan turbines, made in Russia, are installed in 6 hydroelectric generating sets at 'Djerdap 1', with nominal power of 200 MW each, /1/. They have been designed for the service life of 40 years due to the structural solution, or in other words because of the impossibility of performing periodic inspections and state analyses. Position of cranks and guide vanes is shown in Fig. 1. Guide vane cranks and sleeves are made of cast steel 25L, while guide vane body is made of steel St 3, in accordance with the standards, /2/.

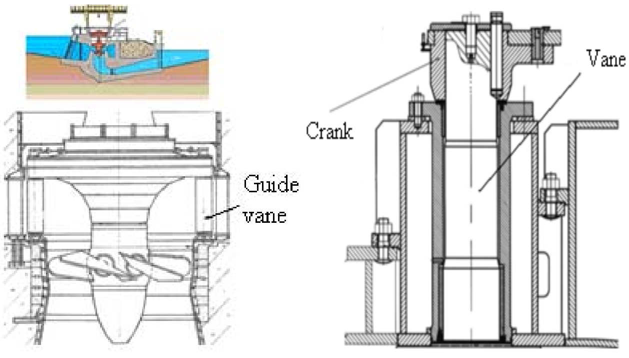

Figure 1. Guide vane cranks on vertical Kaplan turbine.
Slika 1. Glavčine sprovodnog aparata vertikalne Kaplan turbine

EXPERIMENTAL TESTS PERFORMED ON GUIDE VANE CRANKS AND SLEEVES

Non-destructive tests are performed in order to determine the current state of the internal surfaces of cranks and sleeves. Defects positioned along the circumference of cranks are measured by micrometer and detected by penetrant testing (PT) or magnetic particle testing (MT), while defects within the material are detected through the use of ultrasonic testing (UT). Defects positioned along the circumference of sleeves are detected visually and measured by micrometer. Characteristic damage on one of the cranks and on the sleeves of guide vane apparatus vanes is shown in Fig. 2.

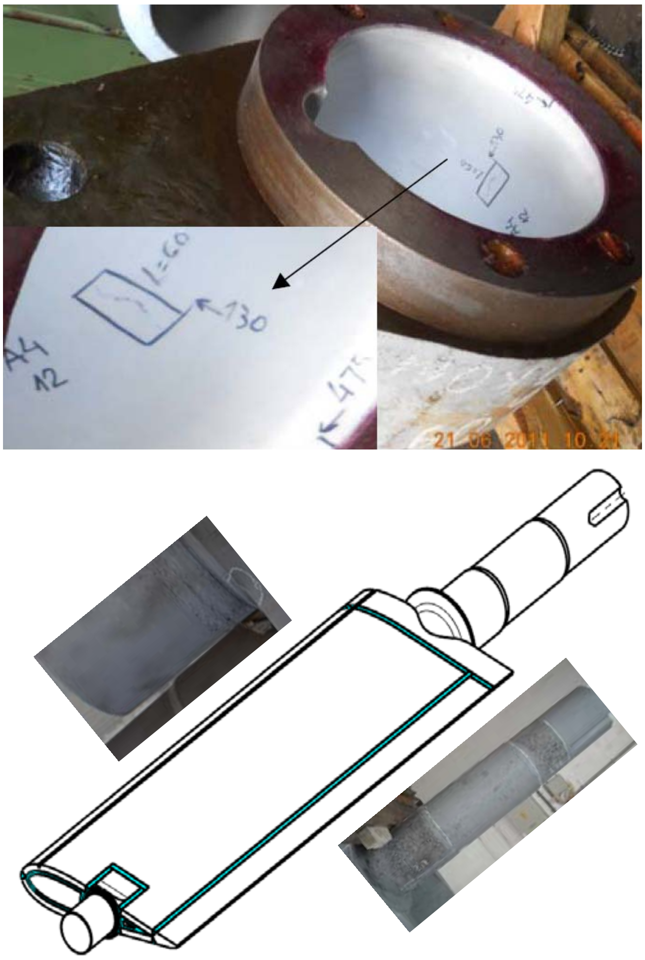

Figure 2. Appearance of defects at the internal area of a guide vane crank and damage on the sleeve.
Slika 2. Izgled grešaka na unutrašnjoj površini glavčine i oštećenje rukavca sprovodnog aparata

METHODOLOGY FOR REPAIRING DEFECTS ON INTERNAL SURFACES OF CRANKS AND GUIDE VANES

This technology refers to the activities performed during the reparation of cranks and sleeves, that required grinding out linear indications and performing welding/surface welding on internal surfaces of crank hubs, as well as on the surfaces of sleeves. Regardless of chemical composition /2/, crank hub thickness (d = 105 mm) and damage that had occurred at diameters Ø240 mm, Ø360 mm and Ø400 mm of guide vane sleeves, preheating was carried out by inductors in order to reach the temperature of 150°C, as suggested in Russian literature for cast steel 25L. Calculations showed that much larger preheating temperatures are needed due to crank thicknesses and sleeve diameters.

Technology of surface welding in areas of crank hubs

The first step was to eliminate detected cracks by grinding. Visual testing and magnetic particle testing (or dye-penetrant testing) were performed continuously during crack elimination. Preparation of grooves was performed after grinding, and finally welding/surface welding was carried out. Based on parameters that influence the selection of welding procedure (weldability of base material, energetic characteristics of the welding procedure, geometric complexity of the structure, comparative economic analysis), welding was carried out through the use of the coated electrode E 42 4 B 32 H5 (EVB 50 – Elektrode Jesenice d.o.o.), in accordance with standard, /3/, and through utilization of procedure 111. Preheating to 150°C was performed through the use of induction heaters, as suggested in Russian literature. Preheating temperature inspection was performed by IC thermometers, /4/.

Figure 3. Device ID Weld 2501 for surface welding performed at the openings of guide vane cranks.
Slika 3. Uređaj ID Weld 2501 za navarivanje otvora glavčina sprovodnog aparata

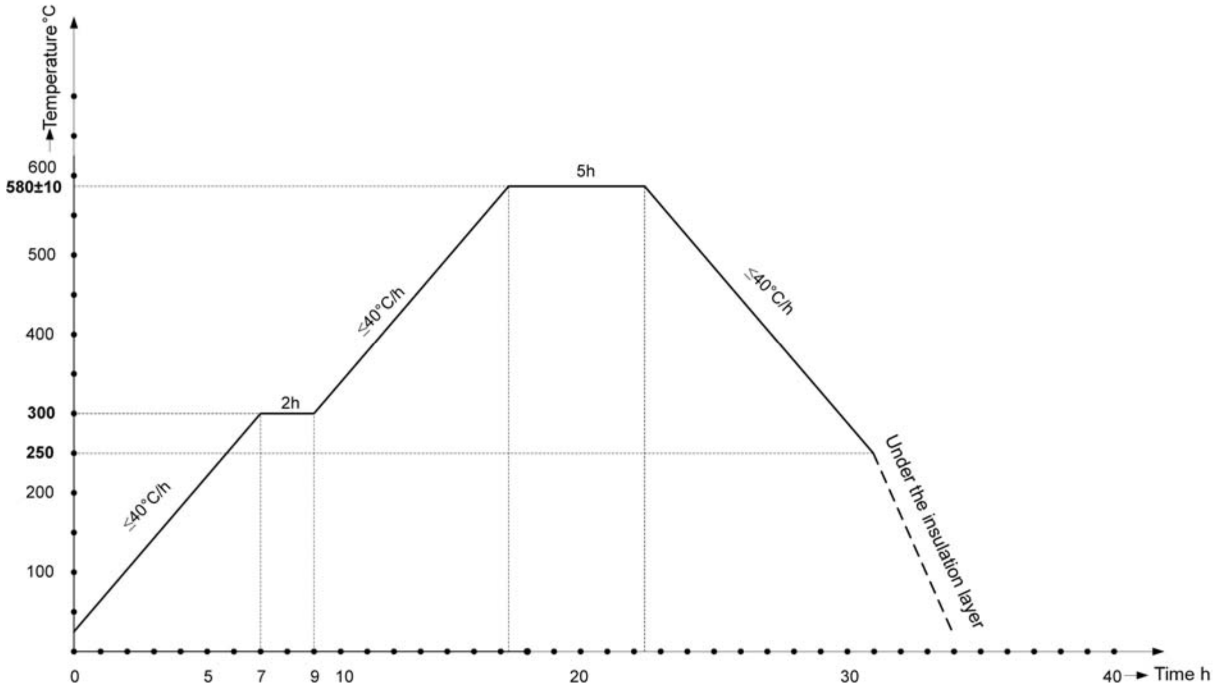

Figure 4. Heat treatment diagram.
Slika 4. Dijagram termičke obrade

Surface welding technology performed at damaged internal surfaces of crank hubs

Surface welding was performed through the use of ID WELD 2501 device on internal surfaces of crank hubs and utilization of procedure 131, by TIG Mo wire, 1.2 mm in diameter (Elektrode Jesenice d.o.o.) according to standard /5/, and with the use of protection gas M21 according to standard EN 439 /6/, Fig. 3. Optimum surface welding parameters, determined through a series of tests performed on components made of same material and of similar thickness, are as follows /4/: number of revolutions during surface welding: 0.5–1 min^{-1}, surface welding: continuous, I = 200 A, current source: any standard source for MIG/MAG welding process, voltage: U = 20–30 V, shielding gas flow: 10–20 l/min.

Heat treatment of cranks

In order to reduce the level of residual stresses and eliminate the possibility of occurrence of deformation after welding/repair welding and finish machining, cranks have been heat-treated through the use of technology with the parameters presented in Fig. 4, /4/.

Surface welding technology for damaged outer surfaces of guide vane sleeves

On the basis of parameters on which the procedure for surface welding of sleeves of guide vanes depends, procedure 131 that involves the use of 1.2 mm wire diameter (TIG Mo – Elektrode Jesenice d.o.o.) and shielding gas M21 is selected. Preheating to 150°C is performed by induction heaters, as suggested in Russian literature for cast steel 25L. Preheating temperature inspection is performed by IC thermometers. Surface welding was carried out by MIG-MAG multi-process welding machines with two welders and symmetric and combined directions of weld bead depositing. The vanes were rotated periodically. The surface welded areas were divided into 150×150 mm sectors, /4/. Optimum surface welding parameters, determined ex-


Figure 5. Repaired and machined areas at sleeves.
Slika 5. Reparirane i mašinski obrađene oblasti rukavca

perimentally through welding procedures performed on components made of the same material and of similar thickness are as follows: surface welding current: direct, I = 200 A, current source: any standard MIG/MAG multi-process welding machine, voltage U = 20–30 V, shielding gas flow rate 10–20 l/min. The machining and dimensions measurements of repaired areas on sleeves of guide vane apparatus are performed on the lathe, through the use of special centring tools and micrometer screw gauge, Fig. 5.

RESULTS AND DISCUSSION

After performed welding/surface welding in areas at internal surfaces of crank hubs and on the surface of vane sleeves where cracks were detected, the inspection of the quality of performed repairs has been carried out.

All cracks on cranks were detected through the use of magnetic particle testing (MT) or penetrant testing (PT), performed during and after finish machining, while dimensions of damaged areas were measured by a micrometer.

Sizes of damages detected on vane sleeves have been determined through visual inspection and measured by micrometer. In cases when defects were detected at crank hubs and vane sleeves, the welding procedure was repeated after every machining phase.

It should be noted that after the finalization of every phase, the surface has been inspected by magnetic particle testing method or penetrant testing method. Inspection of heat treatment quality has been carried out by measuring the hardness of the weld metal which should, by technical conditions, range from 130–240 HB.

Also, a test has been performed in order to determine whether the hardness of the base material of the crank after the heat treatment was within the required range for given base material. It should be noted that basic principles of surface welding technology for guide vane sleeves were used in some papers /8, 9/.

CONCLUSION

The success of the performed repair methodologies for damages detected at internal surfaces of crank hubs and sleeves of guide vane apparatus vanes from turbine A4 at the hydro power plant ‘Djerdap 1’ are confirmed by the equipment manufacturer *Силовые машины* from Saint Petersburg, because they guarantee that the equipment can be used safely until the next refurbishment, or to put it differently – for the next 40 years.

ACKNOWLEDGEMENT

Authors wish to thank the Ministry of Education, Science and Technological Development of Serbia for supporting projects TR 35002 and TR 35006.

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