energija

| ekonomija | ekologija

ENERGETIKA 2021

MONOGRAFIJA

ENERGETIKA 2021

U SUSRET ZELENOM OPORAVKU

ZBORNIK RADOVA
CONFERENCE PROCEEDINGS

22 - 25. jun 2021.
Hotel Palisad, Zlatibor

SAVEZ ENERGETIČARA
Prof. dr Nikola Rajaković
Elektrotehnički fakultet Univerziteta u Beogradu
Bulevar kralja Aleksandra 73
11120 Beograd
Srbija
info@savezenergeticara.org

www.savezenergeticara.org

energija | ekonomija | ekologija

Energija / Ekonomija / Ekologija
Monografija savetovanja
ENERGETIKA 2021 - U SUSRET ZELENOM OPORAVKU
Zbornik radova

Izdavač:	Savez energetičara Bulevar kralja Aleksandra 73, 11020 Beograd E-mail: info@savezenergeticara.org www.savezenergeticara.org
Glavni i odgovorni urednik:	Prof. dr Nikola Rajaković
Priprema i tehnička obrada:	BBN Congress Management d.o.o.
Produkcija:	BBN Congress Management d.o.o.
Tiraž:	150
Godina izdavanja:	2021.

CIP - Каталогизација у публикацији - Народна библиотека Србије, Београд

621.31(082)(0.034.2)
502.131.1:620.9(082)(0.034.2)
338.4:621.31(082)(0.034.2)

САВЕТОВАЊЕ Енергетика (2021 ; Златибор)
U susret zelenom oporavku [Elektronski izvor] : monografija : zbornik radova = Conference proceedings / [Savetovanje] Energetika 2021, 22 - 25. jun 2021. Zlatibor ; [glavni i odgovorni urednik Nikola Rajaković]. - Beograd : Savez energetičara, 2021 (Beograd : BBN Congress Management). - 1 elektronski optički disk (DVD) : ilustr. ; 12 cm. - (Energija, ekonomija, ekologija)

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Stv. nasl. u kolofonu: Monografija savetovanja Energetika 2021 - U susret zelenom oporavku. - Radovi na srp. i engl. jeziku. - Tiraž 150. - Bibliografija uz svaki rad. - Abstracts.

ISBN 978-86-86199-03-4

a) Електроенергетика - Зборници b) Енергетска политика - Зборници c) Енергетски извори - Одрживи развој - Зборници

COBISS.SR-ID 41228553

ORGANIZACIONO – PROGRAMSKO – NAUČNI ODBOR

Kopredsednici organizaciono-programsko-naučnog odbora:
Prof. dr Milun Babić, Predsednik Skupštine Saveza energetičara
Prof. dr Nikola Rajaković, Predsednik Saveza energetičara

Sekretarijat organizaciono-programsko-naučnog odbora:
dr Ilija Batas-Bijelić, naučni saradnik, v.d. Generalni sekretar Saveza energetičara
Prof. dr Dušan Gordić, v.d. Glavni i odgovorni urednik časopisa "Energija"
Sandra Alagić, Portparol ODS EPS Distribucija Beograd
Marko Popović, Direktor BBN Congress Management

Članovi:
Dr Matthias Jochem, Mitsubishi Hitachi Power System Europe GmbH, Germany
Dr Jean Rizzon, Mitsubishi Hitachi Power System Europe GmbH
Dr Patrick Weckes, Mitsubishi Hitachi Power System Europe GmbH
Prof. dr Jovica V. Milanović, The University of Manchester, Manchester Christian Kissling
Dejan Popović, Predsednik Agencije za energetiku Republike Srbije
Prof. dr Adriana Sida Manea, Politehnica-Universitety of Temisoara, Romania
dr Ivan Souček, Prague Institute of Chemical Technology, Czech Republic
Prof. dr Miloš Banjac, pomoćnik ministra u Ministarstvu Rudarstva i energetike Republike Srbije
Prof. dr Branko Kovačević, predsednik Nadzornog odbora JP Elektroprivreda Srbije
Prof. dr Miloš Nedeljković, Mašinski fakultet u Beogradu
Prof. dr Aleksandar Gajić, Mašinski fakultet u Beogradu
Prof dr Damir Đaković, Fakultet tehničkih nauka u Novim Sadu
prof. dr Zlate Veličković, Vojna akademija, Univerzitet odbrane u Beogradu
Mirko Petković, Rafinerija ulja Modriča a.d. Modriča, Republika Srpska, BiH
Mladen Simović, direktor Energoprojekt ENTEL
Prof. dr Valentino Stojkovski, Faculty of Mechanical Engineering u Skopju, Republika Severna Makedonija
Prof. dr Zoran Markov, Faculty of Mechanical Engineering u Skopju, Republika Severna Makedonija
Ass. mr Marija Lazarevikj, Faculty of Mechanical Engineering u Skopju, Republika Severna Makedonija
Prof. dr Vlatko Cingoski, Goce Delcev University of Šdr Goce Vasilievski, Rudarski institut, u Skopju, Republika Severna Makedonija
Prof. dr Atanasko Tuneski, Faculty of Mechanical Engineering u Skopju, Republika Severna Makedonija
dr Aleksandar Levkoski, ELEM Macedonian Power Plants u Skopju, Republika Severna Makedonija
doc. dr Vladimir Rajs, Fakultet tehničkih nauka u Novom Sadu
Prof. dr Neven Dujić, Fakultet strojarstva i brodogradnje u Zagrebu
Prof. dr Mirko Komatina, Mašinski fakultet u Beogradu
Prof. dr Željko Đurišić, Elektrotehnički fakultet u Beogradu
Slobodan Babić, Poslovno udruženje Elektromašinogradnja, Beograd
prof. dr Mirjana Laković, Mašinski fakultet u Nišu
Prof. dr Milan Petrović, Mašinski fakultet u Beogradu
Prof. dr Dejan Ivezić, Rudarsko-geološki fakultet u Beogradu
Prof. Daniela Marasova, CSc. Technical university of Kosice Faculty of Mining, Ecology, Czech Republic
Prof. dr Беляков Алексей Васильевич, Российская Федерация
Mr Milenko Nikolić, direktor Instituta Mihailo Pupin - Automatika, Beograd
Olga Stavskaya, Lead Engineer JSC «ZiO-COTES», Russian Federation
Prof. dr Danijela Milošević, dekan Fakulteta tehničkih nauka u Čačku
Prof. dr Milo Tomašević, dekan Elektrotehničkog fakulteta u Beogradu
Prof. dr Radivoje Mitrović, dekan Mašinskog fakulteta u Beogradu
Prof. dr Dobrica Milovanović, dekan Fakulteta inženjerskih nauka u Kragujevcu
Prof. dr Ozren Ocić, Savez energetičara
dr Miodrag Arsić, IMS Beograd
Prof. dr Željko Despotović, Institut Mihailo Pupin Beograd
Prof. dr Zoran Rajić, Poljoprivredni fakultet Beograd
Prof dr Silvana Ilić, Fakultet za menadžment Zaječar
Jovica Budimir, izvršni direktor JP Srbijagas
Prof. dr Pavlović Vladimir, Rudarsko-geološki fakultet
dr Radoslav Raković, "Energoprojekt Entel" a.d. Beograd
prof. dr Martin Ćalasan, Elektrotehnički fakultet Podgorica
Prof. dr Nenad Đajić, Akademija inženjerskih nauka Srbije
Prof. dr Petar Đukić, Tehnološko-metalurški fakultet u Beogradu
Ljubo Maćić, specijalni savetnik Ekonomskog instituta iz Beograda

3D Modeling in the Function of Cavitation Damage Testing at Hydropower Plants

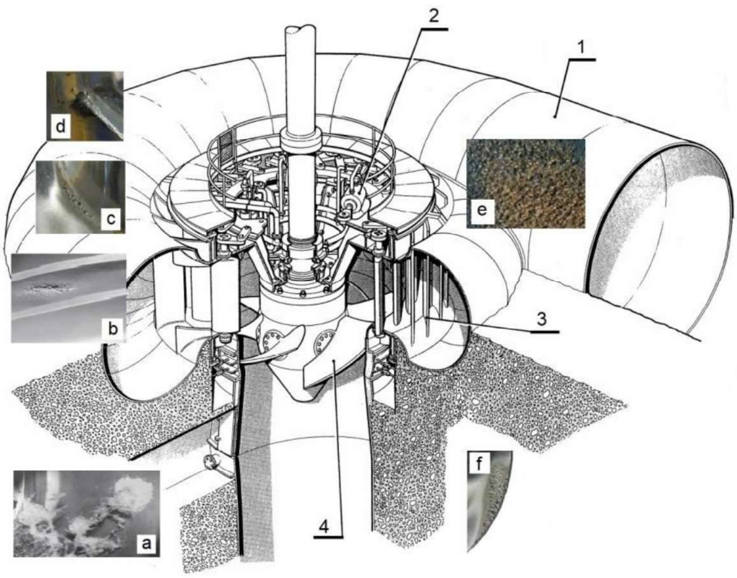
Vujadin Aleksić[*], Bojana Zečević[**], Srđan Bulatović[*], Ana Maksimović[**], Ljubica Milović[***]

[*] Institute for materials testing, Bulevar vojvode Mišića 43, Belgrade, Serbia
[**] Innovation Centre, Faculty of Technology and Metallurgy, Karnegijeva 4, Belgrade, Serbia
[***] University of Belgrade, Faculty of Technology and Metallurgy, Karnegijeva 4, Belgrade, Serbia

***Abstract*-**Very little attention is being paid to conditions of surface preparation prior to the execution of non-destructive testing. The quality of the performed test also depends on the preparation, as well as the quality of the test report, which must include traceability and repeatability, which is not often the case.
One of the aspects of preparation is making of a sketch, 2D or axonometric, of the object of examination with a defined orientation in space and certain benchmarks in order to define the identified defect and imperfections.
Damage caused by cavitation erosion is a current problem in parts of hydropower plants which elements are exposed to the effects of rapid water flow.
Analysis of the cavitation effect and an adequate approach to solving the problem requires a comprehensive picture of the places that are most exposed to cavitation, and this is achieved by controlling and testing parts of hydropower plants by non-destructive methods.
The paper shows the usage of a parametric drawing and modeling program, SolidWorks, on the example of testing parts of large hydropower equipment exposed to cavitation, in order to prepare for non - destructive testing and report on the performed test.
***Index Terms*-**Nondestructive testing (NDT), cavitation damage, 3D modeling

I. INTRODUCTION

Liquids have the property to change from liquid to gaseous state and vice versa under specific conditions. This phenomenon is a physicochemical process of cavitation, which in some areas of economy and science is an unwanted process or phenomenon, and in others it is quite the opposite. Cavitation is an extremely positive process in cosmetic surgery, while it is negative in dentistry and hydropower plants.
The process of compression of the cavitation bubble takes place at high speed and is accompanied by a hydraulic shock. Such impacts can cause the destruction of metals in microvolumes if the impact force exceeds the ultimate strength of the metal of individual microsections [1].
Cavitation occurs as an unwanted process or phenomenon in turbomachines, and mostly on hydraulic machines such as water turbines, Fig. 1, pumps or marine propellers.
Damage caused by cavitation erosion is a current problem in parts of hydropower plants which elements are exposed to the effects of rapid water flow.



1 – Spiral housing; 2 – Steering apparatus blade control mechanism; 3-Stator blades; 4 – Variable angle impeller blades;
a – cavitation jet; b, c, d, e, f – cavitation damage to parts of the hydro turbine during high water;

Figure 1. Kaplan hydro turbine with vertical shaft

Cavitation cannot be avoided, but its harmful consequences can be reduced to a minimum. Scientists, engineers and businessmen use different techniques, more or less successfully, to detect cavitation. Cavitation effect analysis and an adequate approach to problem solving, requires a comprehensive picture of the places most exposed to cavitation, and this is achieved by controlling and testing parts of hydropower plants by non-destructive methods.

II. TESTING OF CAVITATION DAMAGE BY NDT METHODS

Non-destructive testing methods are a set of different procedures for determining the homogeneity or presence of defects in the materials of semi-finished products, finished products, devices, plants and facilities. Testing is performed directly on the objects of control, without taking samples and destroying them.
These procedures include testing, inspection and control, which are similar in that they measure something on the object, determine some characteristic of the object or determine whether the object contains irregularities, discontinuities or defects. Parts of hydro turbines are exposed to cavitation erosion where surface damage is visible to the naked eye. Such surfaces should be

examined by NDT methods. Most often, these are methods by which surface defects can be detected, and these are: visual dimensional testing (VT), penetrant testing (PT) for non-magnetic materials and magnetic particle testing (MT) for magnetic materials.

VISUAL DIMENSIONAL OPTICAL TESTING (VT-D) is used to detect defects of any nature and cause, but only on the surface of the test object. It is often used to select critical locations on an object that will later be tested by other NDT methods. There are great possibilities for its automation and application and for inaccessible places to the human eye. It is applied to practically all types of technical materials. In the case of confirmed cavitation damage, the VT-D method measures the surface of that damage, depth and roughness.

LIQUID PENETRANT (PT) TESTING is used to detect surface defects. Due to the capillary effect, which is the physical basis of this method, it is necessary to degrease and clean the examined surface well. In this way, cracks, porosity and notches can be detected. The advantage of the method is that it is relatively cheap and simple, and with proper execution, sensitivity to small surface errors in all types of classic technical materials is obtained. In cavitation damage of welded joints, turbine blades and other parts of the hydro turbine, it is used to detect cracks and porosity in non-magnetic materials (austenitic materials).

MAGNETIC PARTICLE TESTING (MT) is based on the ejection of a scattering magnetic flux caused by the presence of a surface or subsurface fault such as cracks, notches, inclusions and other sharp planar faults. The advantage of the method is that it requires moderate costs, and with the correct performance, a very good sensitivity is achieved for the detection of surface, and with the correct choice of parameters and subsurface errors. The disadvantage of this method is limited application only to ferromagnetic materials as well as the need for demagnetization after testing. Accordingly, MT is used in cavitation damage of welded joints, turbine blades and other parts of the hydro turbine to detect surface and subsurface cracks on magnetic materials.

III. PREPARATION FOR NDT CAVITATION DAMAGE ON HYDROTURBINES

Very little attention is being paid to conditions of surface preparation prior to the execution of non-destructive testing. The quality of the performed test also depends on the preparation [2, 3, 4], as well as the quality of the test report, which must include traceability and repeatability [5, 6, 7, 8], which is not often the case. One of the aspects of preparation is making of a sketch, 2D or axonometric [9], of the object of examination with a defined orientation in space and certain benchmarks in order to define the identified defect and imperfections.

Non-destructive testing methods require the preparation of samples, in accordance with the standard prescribed method of sample preparation. Preparation consists of studying the drawings and making appropriate sketches of the test object, preparing the test surface and checking and calibrating the test equipment. NDT methods are used for tests without physical-mechanical separation from the whole, so the test elements are marked on the object itself (chalk, kirner, marker). Marking is performed by the Team leader in consultation with the Ordering party of testing. Samples are marked on the basis of object data temporarily or permanently with letters and numbers. Preparation of samples (surfaces) on which the test is performed, is done if the test method requires it, in accordance with the standard prescribed method of preparation. As part of the preparation of the test, before each test, the examiner checks the equipment on the basis of standards, regulations and procedures from the equipment manufacturer's instructions and instructions for use of the equipment.

IV. MAKING A MODEL OF THE TEST FACILITY (TEST SUBJECT)

Parametric drawing programs [9] are used for machine design and automation of processes based on parametric modeling of solids. CAD programs (Computer Aided Designing) use the graphical environment of personal computers (PC). Using the function of dragging objects with the mouse, it is very easy to master any CAD package. The PC graphical user environment allows mechanical engineers to develop their new ideas and implement them in the form of virtual prototypes or models of solids, large assemblies, subassemblies, details and drawings. Numerous CAD programs that can be found on the market also serve as platform software for many other programs that help engineers in their daily work. This means that you can use other compatible programs within these programs. These programs can also use additional modules for animation, simulation and calculation. For the purpose of NDT testing, these programs can assist in NDT testing, and later use the test results in order to control calculations of test objects [10, 11, 12, 13].

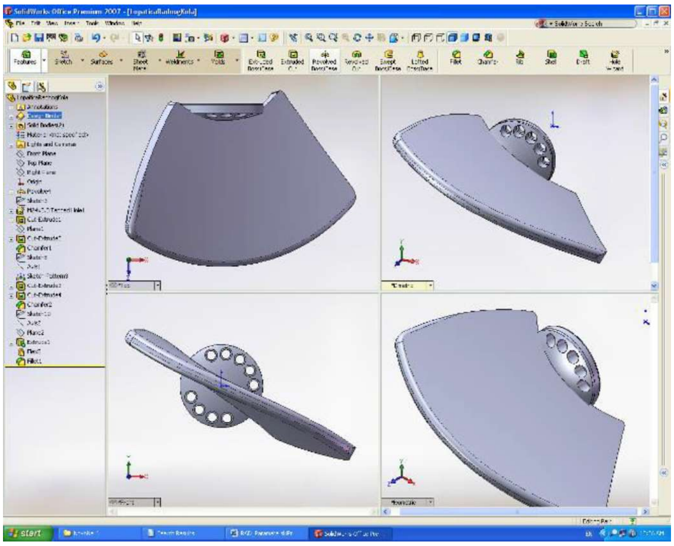


Figure 2. Impeller blade of a vertical Kaplan hydro turbine

CAD programs allow you to turn a basic 2D sketch into a full-body model using simple but highly efficient modeling tools, fig. 2 and fig. 3. CAD programs are not limited to 3D models, but also generate technical drawings of interconnected elements, parts and assemblies, from fig. 4.-7.

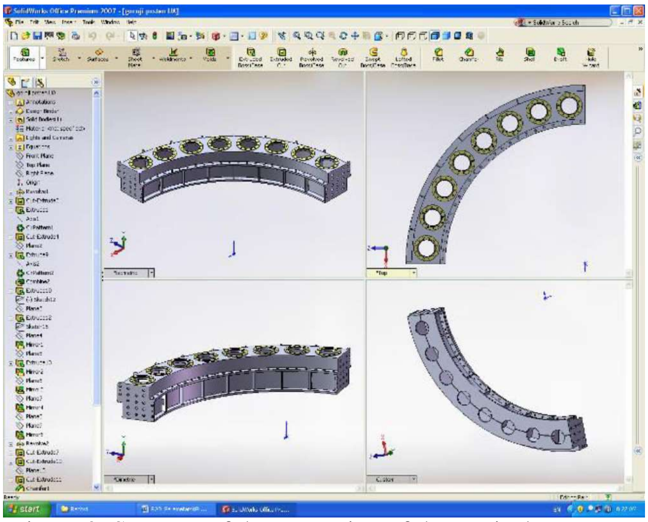


Figure 3. Segment of the upper ring of the vertical apparatus of a vertical Kaplan hydroturbine

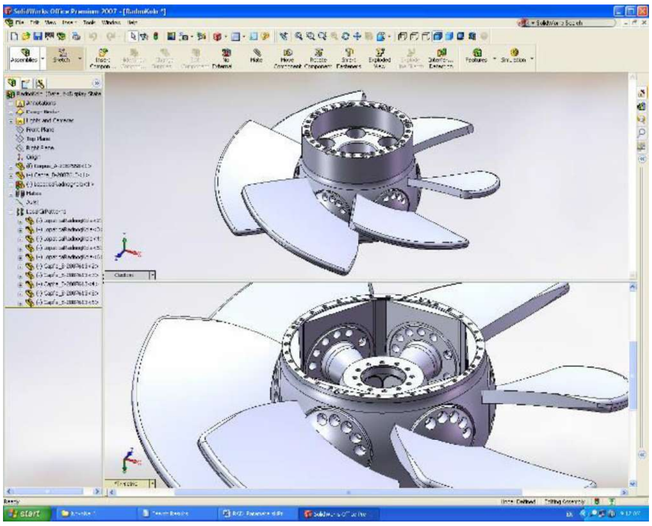


Figure 4. Kaplan hydroturbine impeller blade assembly

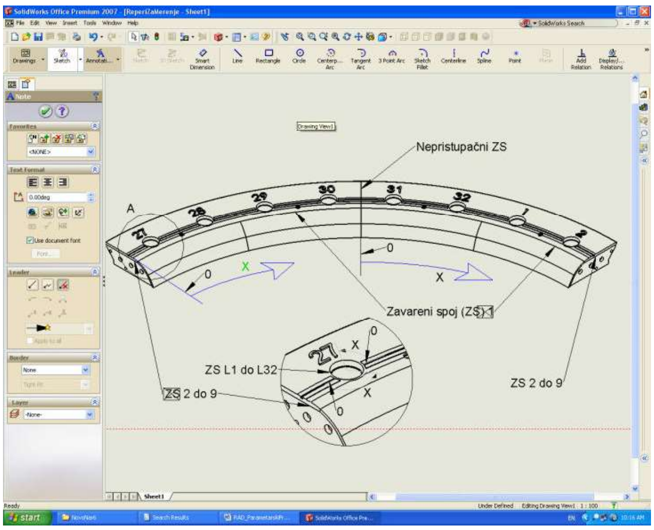


Figure 5. Segment of the lower ring of the vertical apparatus

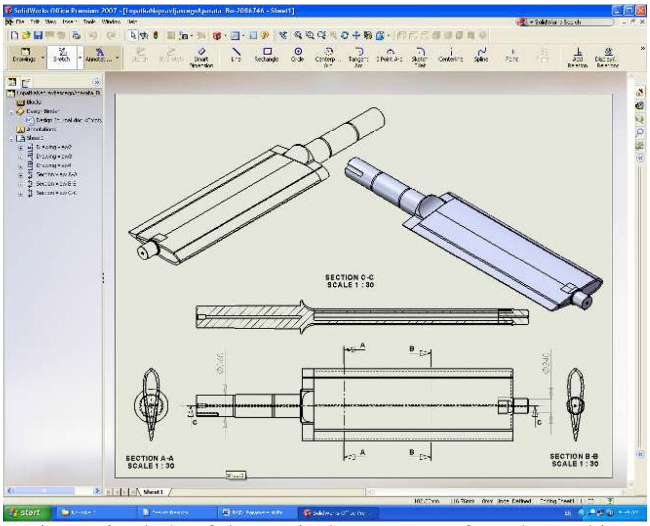


Figure 6. Blade of the vertical apparatus of Kaplan turbine

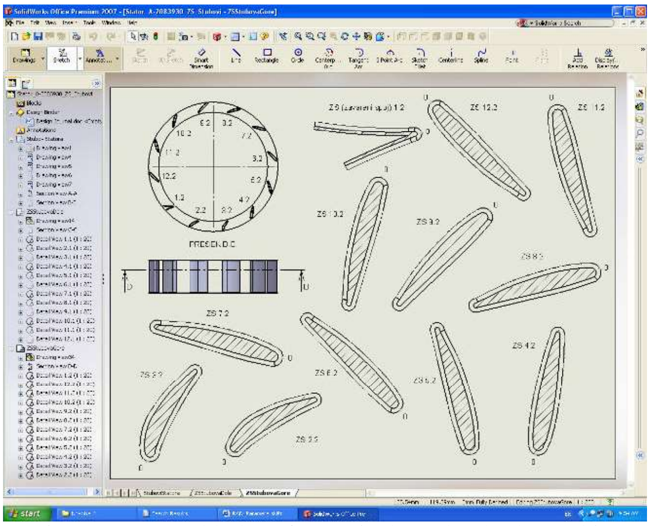


Figure 7. Stator blades of a vertical Kaplan hydro turbine

V. 3D MODEL IN FUNCTION OF NDT CAVITATION DAMAGE

CAD programs are very useful for the preparation and production of reports when using NDT methods. Because it is mainly based on user feedback, this full body modeling tool is extremely easy to use and enables high productivity. Two-dimensional technical drawings are easily generated in Drawing mode. Generalized representations include detail and cross-sectional representations, orthographic representations, isometric, auxiliary, and other representations. Any predefined standard drawing document can be used to generate technical drawings. In addition to showing the model dimensions in technical drawings, or adding reference elevations and other markings, parametric components and bubbles can also be added to technical drawings. If an element or assembly component is replaced, removed, or a new component is added, the change will automatically affect the component placed in the drawing document. Due to the two-way connection of this software, any change made to the model will be automatically applied to the technical drawings, and after each change of dimensions on the technical drawings, the model will be automatically updated. For illustration fig. 8 shows a 3D model used in the preparation and reporting of NDT cavitation damage tests on a vertical Kaplan hydro-turbine. Cavitation damage is examined for the purpose of proposing damage repair technology or for the purpose of monitoring the progress of damage. In both cases, the 3D model of the examined object allows us to precisely define the position and characteristics of cavitation damage with good input data for the control calculation of the damaged object for the purpose of making a decision on repair or monitoring of damage in operation.

VI. CONCLUSION

The use of commercial programs for parametric modelling, allows rapid creation of 3D model of test object and determine one or more benchmarks in order to orient the test object and accurately define the identified imperfections. In the case of this work, it refers to cavitation damage within the surface with possible cracks, pores and cavities. The possibility of looking at the object of examination as well as making a large number of cross-sections, release us from developing complicated 2D sketches. In connection with other computer programs for word processing and images, models made in 3D, enable the production of a quality test report with a defined required traceability and repeatability [6, 8].

ACKNOWLEDGEMENT

This research is supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contract No. 451-03-68/2020-14/200012).

REFERENCES

[1] Фомин В. В. Гидраэрозия металлов. М., «Машиностроение», 1977.

[2] Aleksić V., Milović Lj.: The application of the parametric programmes for modelling in preparation for ND Testing and preparation of the testing report, International conference "Innovation as Function of Engineering Development", Niš, Srbija, 2011, pp. 1-6.

[3] Aleksić V., Vistać B., Milović Lj.: Ispitivanja turbinskih vratila u funkciji donošenja odluke o sanaciji, 2. Konferencija "ODRŽAVANJE 2012", Zenica, B&H, pp. 73-80.

[4] Aleksić V., Milović Lj., Bulatović S.: Testing of metals in the function of determining the failure of turbine shaft – methodological approach, 11th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology DEMI 2013, Banja Luka, Republika Srpska, pp. 1153-1158.

[5] SRPS ISO 9001:2015 - Sistemi menadžmenta kvalitetom – Zahtevi.

[6] SRPS ISO/IEC 17025:2017/Ispr.1: 2018 - Opšti zahtevi za kompetentnost laboratorija za ispitivanje i laboratorija za etaloniranje.

[7] ASM Handbook, Volume 17 Nondestructive evaluation and quality control.

[8] IMS Procedura o sprovođenju laboratorijskih ispitivanja.

[9] Sham Tickoo, D.Saravanan: SolidWorks 2008 za mašinske inženjere, prevod Jasmina Đorđević, Mikro knjiga, Beograd, 2008.

[10] Aleksić V.: Uzroci i posledice korozionih oštećenja čeličnih sfernih rezervoara i cevovoda u hemijskoj industriji, XI YUCORR , Međunarodna konferencija, Saradnja istraživača različitih struka na području korozije, zaštite materijala i životne sredine, Tara, 2009, pp. 109-114.

[11] Aleksić V.: Procena preostale čvrstoće metodom konačnih elemenata korozijom oštećenih čeličnih cevovoda u hemijskoj industriji, I Međunarodni kongres, Inženjerstvo, materijali i menadžment u procesnoj industriji, Jahorina, Republika Srpska, 2009, pp. 98-102.

[12] Aleksić V.: Modeliranje i procena preostale čvrstoće korozijom oštećenih čeličnih sfernih rezervoara, XIII YUCORR , Međunarodna konferencija, Razmena iskustava u oblasti korozije, materijala i zaštite životne sredine, Tara, 2011, pp. 163-168.

[13] Aleksić V.: Compress u funkciji ocene integriteta opreme pod pritiskom, II Međunarodni kongres, Inženjerstvo, ekologija i materijali u procesnoj industriji, Jahorina, Bosna i Hercegovina, 2011, pp. 272-279.

AUTHORS

Vujadin Aleksić, PhD, vujadin.aleksic@institutims.rs
Bojana Zečević, MSc, baleksic@tmf.bg.ac.rs
Srđan Bulatović, PhD, srdjan.bulatovic@institutims.rs
Ana Maksimović, MSc, aprodanovic@tmf.bg.ac.rs
Ljubica Milović, PhD, acibulj@tmf.ac.rs

Correspondence Author – Vujadin Aleksić, vujadin.aleksic@institutims.rs, +381637757011.

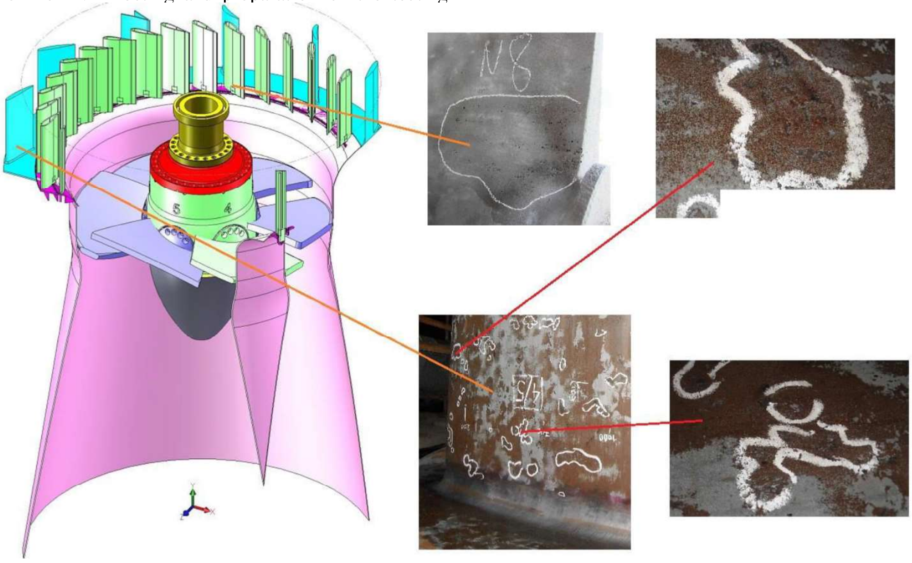


Figure 8. Cross-section of the impeller assembly of a vertical Kaplan hydro turbine with marked places of cavitation damage

Tehnički sekretarijat konferencije:

BBN CONGRESS MANAGEMENT
OSNOVANO / FOUNDED IN 1989

BBN Congress Management d.o.o. Beograd
www.bbn.co.rs

www.savezenergeticara.org