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## ENGINEERING, ENVIRONMENT AND MATERIALS IN PROCESS INDUSTRY

## EEM2023

# PROCEEDINGS

JAHORINA
MARCH 20-23, 2023

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**UNDER THE AUSPICES OF**

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# PARAMETER PROGRAMS FOR 3D MODELING IN THE FUNCTION OF NON-DESTRUCTIVE TESTING AND DETERMINATION OF THE LIFETIME OF PRESSURE VESSELS

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***Abstract***

*Preparation for non-destructive testing (NDT), preparation of test reports, as well as control calculation of a pressure vessel (PV) using the finite element method (FEM), with or without identified irregularities, requires the use of commercial programs for parametric modeling, which allow the rapid creation of three-dimensional (3D) model of the test object. 3D modeling programs enable the determination of one or more rappers in order to orient the test object, accurately define the established irregularity or error after NDT, as well as the most critical part of the PV construction after FEM calculation with the possibility of optimization.*
*Programs for 3D modeling also enable modeling of determined irregularities after performed tests that occurred during the construction, calculation, production or exploitation of the PV construction itself. Irregularities are reflected in the form of improperly performed welded joints, cracks, corrosion, erosion or cavitation of materials, and are used for the preparation of test reports and control calculations of the PV structure with and/or without established irregularities and errors, with the aim of making the correct decision on the continuation of exploitation construction of PV or about its degree of rehabilitation.*

***Key words:*** *NDT, PV, FEA, parametric modeling, 3D model.*

## Introduction

Structural integrity is a relatively new scientific and engineering discipline. It includes analysis of the condition and diagnosis of behavior and yielding, life assessment and revitalization of the structure. This means that, apart from the usual situation in which the life of a structure should be assessed when a defect is detected by non-destructive testing, this discipline also includes stress state analysis. In this way, a precise and detailed distribution of displacements, deformations and stresses is obtained, which makes it possible to determine critical places in the construction. This approach is especially important for structures that are exposed to complex loading, such as PVs.

In our conditions, no or very little attention is paid to the preparation for PV NDT tests. The quality of the performed test depends on the preparation, as well as the quality of the test report, which must contain traceability and repeatability, which is not often the case. One of the aspects of the preparation is the creation of a sketch, two-dimensional (2D) or axonometric, of the object of examination with a defined orientation in space and certain rappers in order to define the identified errors and irregularities.

In order to prepare for NDT tests and create a test report, the use of commercial programs for parametric modeling enables the rapid creation of a 3D model of the test object and the determination of one or more rappers in order to orient the test object and accurately define the determined irregularity or error. (Aleksić V., Milović, 2011 /11/)

The possibility of an unlimited number of views, as well as the possibility of an unlimited number of sections of the entire PV construction or part of it, frees us from creating complicated 2D sketches for the purpose of NDT or control calculation of the PV FEA structure.

In connection with other computer programs, for text and image processing, or for FEA calculation statically or dynamically (fracture mechanics, fatigue), PVs models made in 3D, enable the creation of a quality test report with the defined traceability and repeatability required by the SRPS ISO 17025 standard, as and making the right decision about the exploitation and lifetime of the PV structure.

## PV integrity assessment

### *Controlling PV*

The evaluation of the life of the PV (assessment of the integrity of the PV), after a certain time spent in exploitation, is carried out in accordance with the legal and technical regulation, according to which the application of agreed standards for the equipment assessor is optional.

The increased responsibility of testers and evaluators, as well as designers and manufacturers, gives greater freedom in the choice of methods for evaluating the integrity of equipment, and in function of the required safety, safety in exploitation and economy.

The requirements can be fulfilled by applying one of the following methods, as appropriate at the given moment, if necessary as a supplement or combination with another method: using formulas, using special computer programs, using the finite element method, various analyses, fracture mechanics parameters, etc.

The assessment of the integrity of the PPP in operation depends on the ability to detect and determine the type, position and size of the defect in the base material (BM) and welded joints (WJ). Figure 1 shows the scheme of control and testing activities without (NDT) and with destruction (DT), PV.

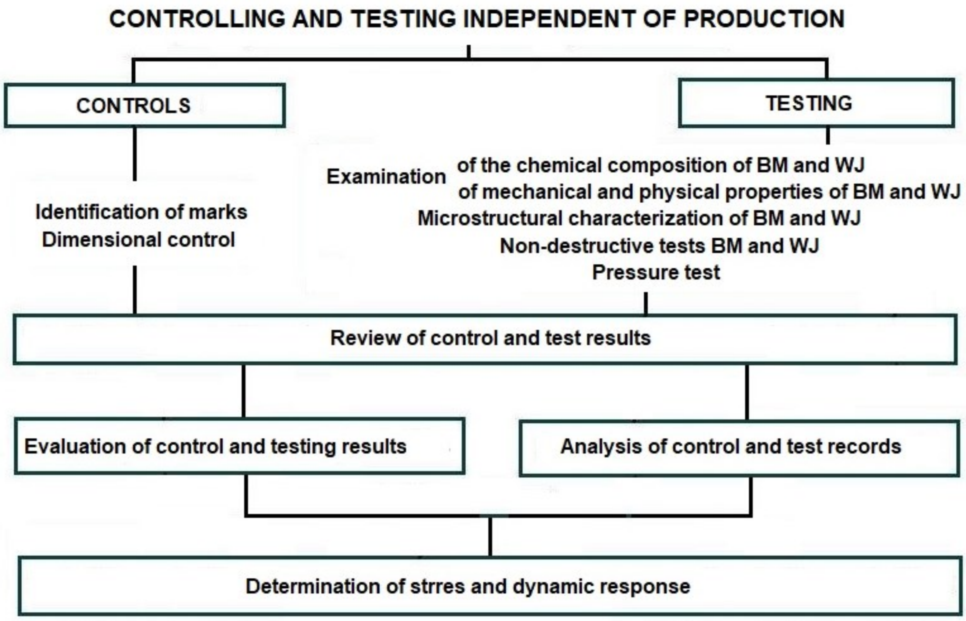



*Fig. 1. Scheme of activities for controlling and testing pressure vessels*

### *Program SolidWorks*

SolidWorks is a parametric program for modeling, Tickoo, Saravanan (2008) /18/, solid bodies based on elements, which not only unites three-dimensional parametric elements with two-dimensional tools, but also covers all phases - from design to model creation and finite element calculation of elements, Maneski (1998) /16/, Aleksić B. et al., (2017) /3/, which is very interesting for the preparation, preparation of reports when testing with IBR methods and checking the integrity of the pressure vessel or its specific part with an established error. Also, the models can be used to determine the causes and consequences of accidents. (Aleksić V. et al., 2011, 2015, 2016, 2021 /9, 10, 12, 13/, Bulatović et al., 2013 /14/, Aleksić V., 2009, 2010, 2011 /4-8/)

Two-dimensional technical drawings are easily generated in Drawing mode. The views that can be generated include detail and section views, orthographic view, isometric, auxiliary and other views. In addition to displaying model measurements in technical drawings, or adding reference elevations and other markings, parametric components and callouts can also be added to technical drawings.

If a component of an element or assembly is replaced, removed, or a new component is added, the change will be automatically reflected on the component placed in the drawing document.

Due to the two-way connection of this software, every change made on the model will be automatically applied to the technical drawings, and after every change of measurements on the technical drawings, the model will be automatically updated.

The main operating modes in SolidWorks are: Part mode, Assembly mode, and Drawing mode. For the sake of illustration in fig. 2 shows the 3D model and 2D drawings used in the preparation and creation of reports for IBR testing of pressure vessel elements and assemblies.

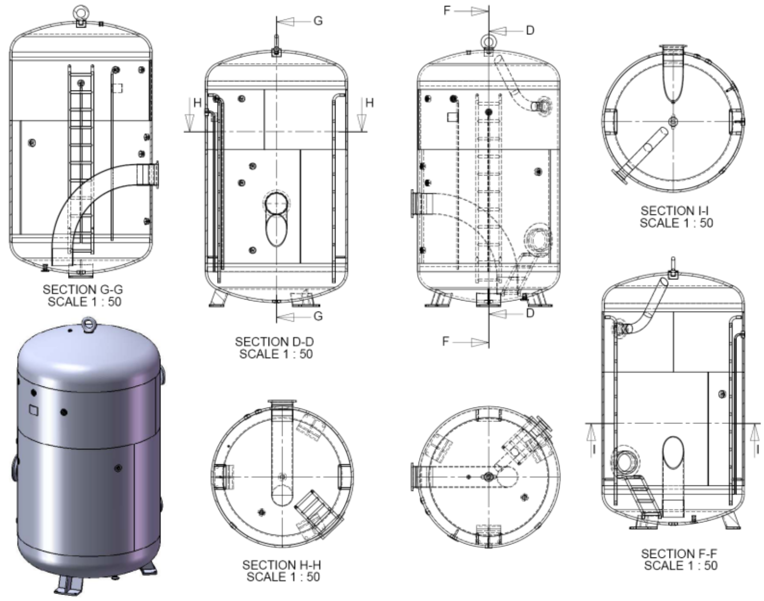



*Fig. 2. 3D, 2D drawing and various sections of a PV* (Aleksić V. et al., 2015 /9/)

***Program COMPRESS***

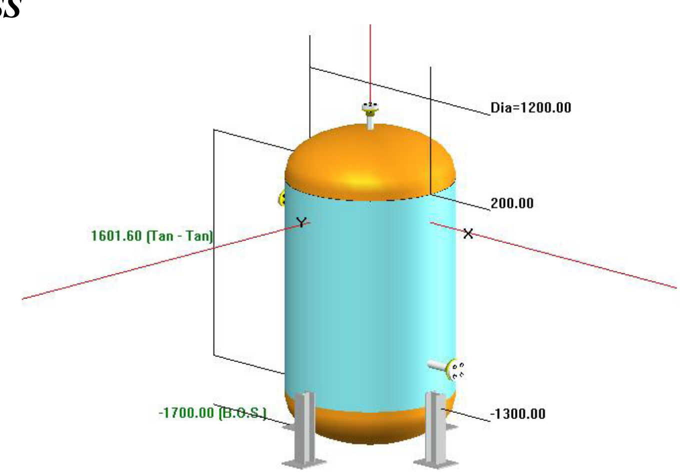



*Fig. 3. Presentation of the model of the air tank in the environment of the program COMPRESS* (Aleksić V. et al., 2011 /7/)

COMPRESS for Windows, Aleksić V. (2011) /7/, is a fully interactive system for constructing a PV, unique in that the PV is drawn to scale in 3D with rendered graphics on the screen during its construction, fig.3.

When designing new or evaluating existing PVs, it is possible to model almost all existing geometries.

If the rules of the standard are violated (eg, the size of the welded joint is too small), COMPRESS warns us by giving a warning message, but it does not have to stop the execution of the task. It is the user's responsibility to heed warning messages and take appropriate action.

The COMPRESS task is to design or evaluate an existing PV and heat exchanger, using industry standard calculation methods. These are standard, factory calculation methods for the calculation of the body of the PV and the exchanger, as well as the finite element method used for the calculation of the stress state of the injection in the PV or the heat exchanger.

COMPRESS will help us in designing PV, but it will not think for us, nor make good decisions. The user of the program is responsible for thinking and adequate training.

***Calculation using the finite element method (FEM)***

The finite element method belongs to the modern methods of numerical analysis. The rapid development of FEA went hand in hand with the development of modern electronic computers and their application in various fields of science and engineering practice. (Maneski, 1998 /16/) A constantly present modeling problem is the choice of finite element type and the fineness of discretization of the physical model. The concept of modeling and calculation is shown in Figure 4. When we do not know the model well enough, it is necessary to first do the calculation with a rough model (minimum number of nodes and elements). Static and dynamic identification, with a rough model, gives an assessment of the validity of the model from the point of view of boundary conditions, choice of type or types of finite elements, discretization and modeling of loads. This approach saves time. A rough model can be a reduced model at the same time. It is desirable to have several rough models for one construction. It usually serves to determine the global response of the structure. (Maneski, 2002 /17/)

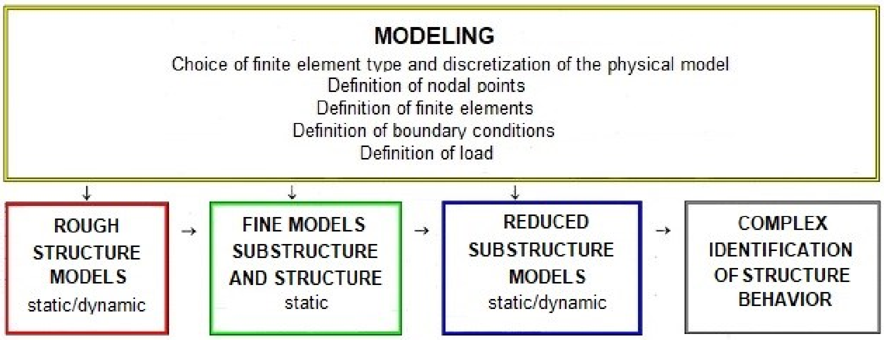



*Fig. 4. Concept of FEA modeling and calculation* (Maneski, 2002, Aleksić B., 2015 /17, 2/)

**NDT methods and established irregularities (defects)** (Aleksić V. et al., 2015 /9/)

Non-destructive testing methods are a set of different procedures for determining the homogeneity or the presence of defects in the materials of semi-finished products, finished products, devices, plants and objects. The test is performed directly on the control items, without taking samples and destroying them. Today, two important engineering fields are intertwined: NDT and fracture mechanics, creating a new period of fatigue research, the so-called. "life with mistakes". (Tot, 2000 /19/)

What is the reliability of the test?, What is the probability of detecting an error? and How reproducible is the test result? are the main issues in the application of NDT methods. If the answers to these questions are known, it is not difficult to apply the principles of fracture mechanics to the reliability assessment of cracked components. Unfortunately, these questions are very complicated and cannot be easily answered, Tot (2000) /19/, without a certain knowledge and a lot of experience in using NDT and fracture mechanics methods. (Aleksić V. et al., 2015) /9/

In the general case, there are two types of defects, volumetric and planar. Volumetric defects can be described with three dimensions or volume. Planar (plane) defects are thin, i.e. they have more pronounced two dimensions compared to the third. Surface cracks are more significant for assessing the reliability of a pressure vessel than other types of cracks, so their detection and analysis is the most important problem. If a crack-type defect is detected, then many questions should be answered, such as: Is repair immediately necessary?, Can the pressure vessel continue to operate?, If so, under what conditions? Many additional questions can be asked and must be answered to assess the risk of a final decision. In order to ensure reliable operation of a pressure vessel with an established crack, the cooperation of specialists in NDT, mechanical testing and fracture mechanics is necessary.

The continuous introduction of modern methods has made it possible to observe and control smaller and smaller defects with an increasing degree of reproducibility and to detect defects in components that were previously thought to be absent.

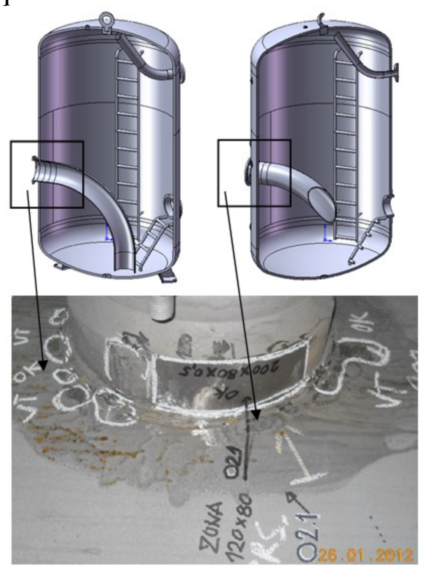
For PVs exposed to external (environmental influence, Fig. 5) or internal (influence of media in PV) corrosion during exploitation, it is necessary to take into account corrosion and other PV damages caused during exploitation during the control calculation after the prescribed inspection of the vessel.

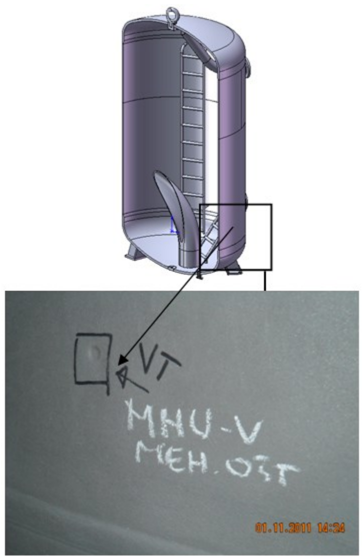
*Fig. 5. Examples of corrosion damage to the construction of a spherical tank* (Aleksić V., 2009 /5/)

## Results and Discussion

### *Examples of NDT*

By combining the photograph of the established defect or irregularity on the pressure vessel and the model made in SolidWorks, it is possible to unambiguously define the position, size and appearance of the established defect or irregularity, as shown in Fig. 6. Considering the unlimited possibilities of cutting and rotating the pressure vessel, the connection with the photo taken of the identified defect or irregularity is limited by the technical capabilities of the photographic apparatus.




*a) detected defects* *b) mechanical damage*

*Fig. 6. NDT of base material and pressure vessel welds* (Aleksić V. et al., 2015 /9/)

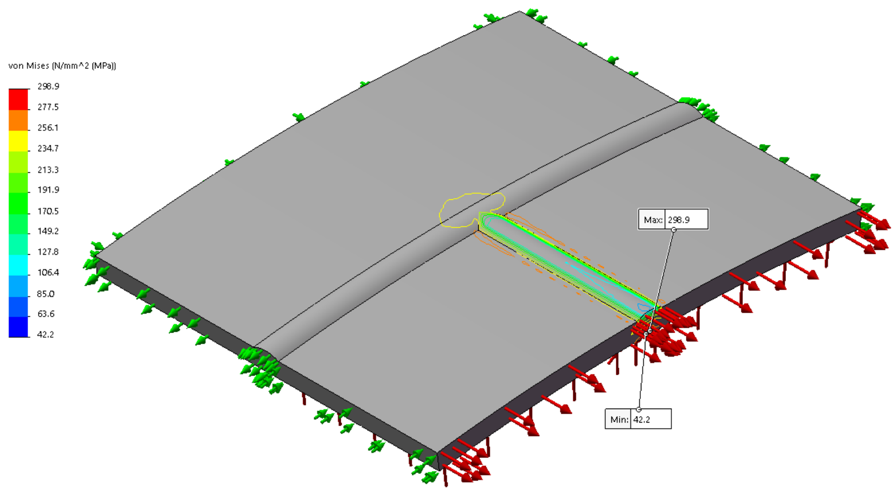
Processing and analysis of measurement results are performed according to the instructions for data processing, defined by the test method. During the processing, and especially during the analysis and interpretation of the results, the theoretical knowledge and practical experience of the test participants come to the fore. After the test, a record of the performed test is drawn up and certified by the person ordering the test.

The record in free form contains: data about the object being tested, test method, test conditions, applied equipment, test parameters, findings and other parameters that ensure traceability and reproducibility of the test. (Aleksić V. et al., 2015 /9/)

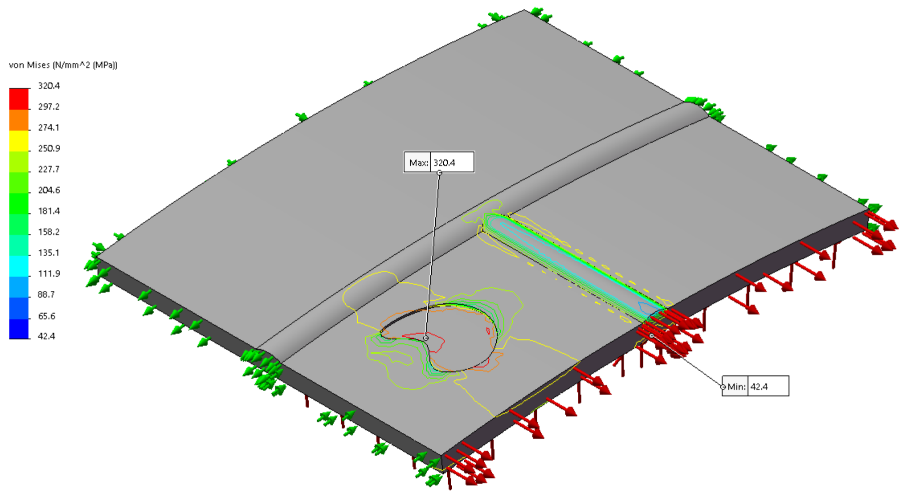
The outcome of the processing and analysis of the results of control, tests and measurements are 3D models, sketches, tables of processed data, diagrams, selected photos, etc. After determining defects such as cracks, corrosion or mechanical damage, or some other type of defect or irregularity, the model, after modeling the identified defect or damage, can be used to assess the integrity of the pressure vessel or its component using the SolidWorks program module, COSMOSWorks, for calculation using the finite element method elements.

***Examples of FEA timelife estimation***

Welded joints (WJs) and corrosion damage due to their shape cause stress concentration in their vicinity, which is illustrated by the FEA calculation on the model of the part of the pressure tank's formwork without and with WJ and corrosion damage 1 mm deep and of arbitrary shape and position in relation to the model of the part of the formwork, Fig. 6.




*a) with cross WJ without corrosion damage* (Aleksić B., 2017 /3/)




*b) with cross WJ and corrosion damage*

*Fig. 6. Stress distribution on the model of part of the pressure tank formwork*

As can be seen from Fig. 6, the model of WJ and corrosion damage on the tank significantly affects the stress distribution in the entire structure of the tank, i.e. PV, and thus the life of the PV structure.
Table 1 gives illustrative values of stresses obtained by FEA calculation on the part of the tank formwork exposed to the test pressure.

*Table 1. Comparative stress values on part of the pressure tank formwork*

| Part of the tank's formwork exposed to a pressure of 2.6 MPa | | | FEA (von Mises stresses) | | Formula, Dennis R. Moss (2004) /15/, (normal stresses) |
|---|---|---|---|---|---|
| | | | $\sigma_{min}$, MPa | $\sigma_{max}$, MPa | $\sigma$, MPa |
| Without WJ and corrosion damage | transversely | | 241.6 | 245.9 | 245.7 |
| | longitudinally | | | | 122.8 |
| With WJ without corrosion damage | cross WJ | Fig. 4a | 42.2 | 298.9 | / |
| | | | | | / |
| | | | | | / |
| With WJ and corrosion damage | | Fig. 4b | 42.4 | **320.4** | / |
| | | | | | / |
| | | | | | / |

## Conclusions

In order to prepare for NDT tests and create a test report, the use of commercial programs for parametric modeling enables the rapid creation of a 3D model of the test object and the determination of one or more benchmarks in order to orient the test object and accurately define the determined irregularity or defect.

The possibility of a large number of views on and into the pressure vessel as well as the possibility of a large number of sections frees us from creating complicated 2D sketches.

In connection with other computer programs for processing text and images, models made in 3D enable the creation of a quality test report with defined traceability and repeatability required by standard 17025. (Aleksić V. et al., 2015 /9/)

An already made model with subsequently modeled established defects and irregularities can be used for calculations using the finite element method and determination of the integrity and life of the pressure vessel.

The essential requirements for the safety of pressure equipment are defined and established in Annex I of the Rulebook on technical requirements for the design, manufacture and conformity assessment of pressure equipment. (2011, Pravilnik (in Serbian) /1/)

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## References

(2011). Pravilnik o tehničkim zahtevima za projektovanje, izradu i ocenjivanje usaglašenosti opreme pod pritiskom (Službeni glasnik RS broj 87/2011)

Aleksić B. (2015). *Primena numeričkog postupka u optimizaciji noseće konstrukcije posude pod pritiskom*, Završni master rad, Univerzitet u Beogradu, Tehnološko-metalurški fakultet, Beograd.

Aleksić B., Aleksić V., Milović Lj. (2017). *Analysis of the effects of butt welded joints on a* *carrying capacity of a structure tank*, časopis Zaštita Materijala 58 (4), 2017, pp. 462–468. ISSN 0351-9465, eISSN 2466-2585.

Aleksić V. (2009). *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, 14.10. – 16.10. 2009, CD, str. 98–102.

Aleksić V. (2009). *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, 17. – 20.05.2009, str. 109–114.

Aleksić V. (2010). *Metodološki pristup utvrđivanja uzroka i posledica vetrom srušenog čeličnog vodotornja*. Zbornik. Treći internacionalni naučno stručni skup " Građevinarstvo – nauka i praksa", (Knj.1), Žabljak, Crna Gora, pp. 567-572.

Aleksić V. (2011). *Compress u funkciji ocene integriteta opreme pod pritiskom*, Zbornik na CD-u. II Međunarodni kongres, Inženjerstvo, ekologija i materijali u procesnoj industriji, Jahorina, Bosna i Hercegovina, 09.03. – 11.03. 2011, str. 272–279.

Aleksić V. (2011). *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, 05.04.-08.04.2011, str. 163–168.

Aleksić V., Aleksić B., Momčilović D., Milović Lj., Sedmak A. (2015). *Non - desctructive testing of pressure vessels – Application of SolidWorks*, − Proceedings of 12th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology DEMI 2015, Republika Srpska, 2015, pp. 125–130.

Aleksić V., Jaković D., Kovačević Z. (2011). *SolidWorks used for the process of optimization of supporting structure of a pressure vessel*. International virtual journal for science, technics and innovations for the industry „MTM MACHINES TECHNOLOGIES MATERIALS", YEAR V, Issue 6/2011, str. 3-6.

Aleksić V., Milović Lj. (2011). *The application of the parametric programmes for modelling in preparation for ND Testing and preparation of the testing report*. Proceedings International conference "Innovation as Function of Engineering Development", Niš, Srbija, 2011, p. 1-6.

Aleksić V., Momčilović D., Aleksić B., Milović Lj., Sedmak A. (2016). Analysis of the steam line damages, − *Annals of Faculty Engineering Hunedoara-International Journal of Engineering*, Tome XIV (2016) - Fascicule 1 (February), pp. 121–124.

Aleksić V., Zečević B., Bulatović S., Maksimović A., Milović Lj. (2021). *3D Modeling in the Function of Cavitation Demage Testing at Hydropower Plants*, Monografija ENERGETIKA 2021: U susret zelenom oporavku, Zbornik radova, 22. – 25. jun 2021., Hotel Palisad, Zlatibor, str. 360–363.

Bulatović S., Aleksić V., Milović Lj. (2013). Failure of steam line causes determined by NDT testing in power and heating plants, *Frattura ed integrita strutturale, The International Journal of the Italian Group of Fracture*, Anno VI, Numero 26, Ottobre 2013, pp. 41–48.

Dennis R. Moss (2004). *Pressure vessel design manual, third edition*, Elsevier.

Maneski T. (1998). *Kompjutersko modeliranje i proračun struktura*, monografija, Mašinski fakultet, Beograd.

Maneski T. (2002). *Rešeni problemi čvrstoće konstrukcija, monografija*, Mašinski fakultet, Beograd.

Tickoo S., Saravanan D. (2008). *SolidWorks 2008 za mašinske inženjere*. Mikro knjiga (prevod Jasmina Đorđević). Beograd.

Tot L.. (2000). *Zamorni lomovi konstrukcija – Prošlost, sadašnjost i budućnost. Prof. dr Šćepan Uščumlić, Eksperimentalne i numeričke metode mehanike loma u oceni integriteta konstrukcija*, TMF, Beograd, p. 93-118.

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