UDRUŽENJE INŽENJERA SRBIJE ZA KOROZIJU I ZAŠTITU MATERIJALA
SERBIAN SOCIETY OF CORROSION AND MATERIALS PROTECTION
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Belgrade, 27.03.2023.

Dr Vujadin Aleksić
Institut za Ispitivanje materijala A.D.
11000 Beograd, Bulevar vojvode Mišića 43

Subject: **The Invitation of the Scientific Committee of The Serbian Society of Corrosion and Materials Protection for Invited lecture**

Dear dr Aleksić,

This year, the XXIV YUCORR named ***»Meeting Point of the Science and Practice in the Fields of Corrosion, Materials and Environmental Protection«*** will be held from 28. to 31. May 2023., on mountain Divčibare in hotel "Divčibare". The organizers of this traditional International Conference are: Serbian Society of Corrosion and Materials Protection; Institute for Chemistry, Technology and Metallurgy from Belgrade; Engineering Academy of Serbia and Serbian Chamber of Engineers, under auspices of Ministry of Science and Technological Development Republic of Serbia [sponsored Meeting by European Federation of Corrosion (EFC) and International Society of Electrochemistry (ISE)]. The main goal of the Conference is to exchange the newest information and investigation data between scientists and engineers dealing with corrosion and protection of different types of materials, as well as with environment protection and the alternative energy conversion.

All the details about this Conference can be found on: www.sitzam.org.rs

Respecting your work in mentioned fields of the Conference and regarding your name in this world, it would be our pleasure if you would accept to be the invited lecturer on this Conference.

Best regards from us and we sincerely hope that your answer for the participation on the Conference would be positive.

The president of the Scientific Committee

Prof. dr Miomir Pavlović

XXIV YuCorr, 28.-31. May 2023, Hotel DIVČIBARE, Divčibare, Serbia

Meeting Point of the Science and Practice in the Fields of Corrosion, Materials and Environmental Protection

structure of the pontoon for transshipment of petroleum products, >Transnafta< corp., Pancevo, Serbia

18.20-18.35	**Prezentacija kompanije MIKROLUX d.o.o., Zapresic, Hrvatska**

TUESDAY | Utorak 30.05.2023.

Plenary lecture | *Plenarno predavanje*

10.00-10.35	***Plenary lecture: Vesna S. Cvetkovic,*** **Towards sustainable rare earth elements recovery**, Institute of Chemistry, Technology and Metallurgy, National Institute, Department of Electrochemistry, University of Belgrade, Belgrade, Serbia

Invited lectures | *Predavanja po pozivu*

10.35-11.00	***Vujadin Aleksic***[1*], *Bojana Zecevic*[2], *Srdjan Bulatovic*[1], *Ana Maksimovic*[2], *Ljubica Milovic*[3]**, The Finite Element Method in the function of corrosion damage assessment of pipelines,** [1]*Institute for testing of materials-IMS Institute, Belgrade, Serbia,* [2]*Innovation Centre of the Faculty of Technology and Metallurgy, Belgrade, Serbia,* [3]University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia

Oral presentations | *Usmena saopstenja*

11.00-11.15	***Slobodan Cvetkovic***[1], *Jovana Perendija*[1], *Aleksandra Radomirovic*[2]**, Assessment of Emissions into the Atmosphere from Biogas Cogeneration Plant in Serbia** [1]Institute of Chemistry, Technology and Metallurgy, National Institute, Department of Electrochemistry, University of Belgrade, Belgrade, Serbia, [2]Society "Chemical and Energy Engineering", Belgrade, Serbia
11.15-11.30	***Zoran Karastojkovic***[1]**,** *Ognjen Ristic*[2], *Mladen Mladenovic*[2], **When the oxygen might be applyied for corrosion protection at steel surface,** [1]Society for ethics and evaluation in culture and science, Belgrade, Serbia, [2]Institute IMS, Belgrade, Serbia
11.30-11.45	**Prezentacija kompanije HELIOS SRBIJA A.D., Gornji Milanovac**

16.00-18.00 POSTER SESSION | *POSTER SEKCIJA*

1. ***Katarina Bozic***[1,2,*], *Miroslav M. Pavlovic*[1,2], *DJordje Veljovic*[3], *Marijana R. Pantovic Pavlovic*[1,2], **The influence of the voltage on formation and morphology of hydroxyapatite/titanium oxide composite coatings,** [1]Institute of Chemistry, Technology and Metallurgy, National Institute of the Republic of Serbia, Department of Electrochemistry, University of Belgrade, Belgrade, Serbia, [2]Center of Excellence in Environmental Chemistry and Engineering - ICTM, University of Belgrade, Belgrade, Serbia, [3]Faculty of Technology and Metallurgy, University of Belgrade, Belgrade,Serbia

INTERNATIONAL CONFERENCE

MEĐUNARODNA KONFERENCIJA

MEETING POINT OF THE SCIENCE AND PRACTICE IN THE FIELDS OF CORROSION, MATERIALS AND ENVIRONMENTAL PROTECTION

STECIŠTE NAUKE I PRAKSE U OBLASTIMA KOROZIJE, ZAŠTITE MATERIJALA I ŽIVOTNE SREDINE

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The Finite Element Method in the function of corrosion damage assessment of pipelines

Metoda konačnih elemenata u funkciji procene korozionog oštećenja cevovoda

Vujadin Aleksić[1*], Bojana Zečević[2], Srđan Bulatović[1], Ana Maksimović[2], Ljubica Milović[3]

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Abstract

Pipelines, with specifics in design, construction, testing and safety requirements must be designed based on all relevant influences to ensure that they are safe during their working life. Allowable stresses must be limited by possible errors in working conditions, in order to completely eliminate the uncertainty arising from the production, the calculation model, the actual working conditions and the characteristics and behavior of the material. In the paper, on the example of modeling and calculation of the corrosion-damaged structure of the ammonia (NH3) transfer pipeline, a methodological approach to the calculation using the Finite Element Method (FEM), is shown, in accordance with the methods defined by the new and general approach to standardization and technical harmonization for pressure equipment (Pressure Equipment Directive - PED 97/23 EC). The paper uses advanced modeling techniques of corroded surfaces, based on FEM, with the aim of developing a procedure for assessing the residual strength of steel pipelines operating in the environmental conditions of the chemical products industry. The presentation of possible damages and consequences caused by the corrosion of steel pipelines in the chemical products industry is also given, and the possibility of taking measures to prevent such occurrences is discussed.

Keywords: *pipeline; corrosion-damage; measurement; corrosion assessment; FEM*

Izvod

Cevovodi, sa specifičnostima u projektovanju, izradi, ispitivanju i zahtevima u pogledu bezbednosti mora da budu projektovani na osnovu svih relevantnih uticaja kako bi se obezbedilo da budu bezbedni tokom radnog veka. Dozvoljena naprezanja moraju biti ograničena mogućim greškama u radnim uslovima, kako bi se potpuno eliminisala neizvesnost koja nastaje od proizvodnje, modela proračuna, stvarnih radnih uslova i karakteristika i ponašanja materijala. U radu je na primeru modeliranja i proračuna korozijom oštećene strukture cevovoda za pretakanje amonijaka (NH_3) prikazan metodološki pristup proračunu Metodom Konačnih Elemenata (MKE), a u saglasnosti sa metodama definisanim novim i opštim pristupom standardizaciji i tehničkom usaglašavanju za opremu pod pritiskom (Pressure Equipment Directive – PED 97/23 EC). U radu se koriste napredne tehnike modeliranja korodiranih površina, bazirane na MKE, sa ciljem razvoja procedure za procenu preostale čvrstoće čeličnih cevovoda koji rade u uslovima sredine industrije hemijskih proizvoda. Takođe je dat i prikaz mogućih oštećenja i posledica izazvanih korozijom čeličnih cevovoda u industriji hemijskih proizvoda, a razmotrena je i mogućnost preduzimanja mera da se takve pojave preventivno spreče.

Ključne reči: *cevovod; koroziono oštećenje; merenje; procena korozije; MKE*

Introduction

The steel pipelines of the chemical industry in Serbia are in a very bad condition due to irregular maintenance. Due to neglect, most of the steel pipelines need to be recovery due to significant corrosion damage. Before recovery, it is necessary to carry out a visual inspection and tests using non-destructive methods. Based on the obtained test results, it is necessary to make a report on the current state of the corrosion-damaged steel structure of the pipeline, and then begin the rehabilitation. The construction of steel pipelines depends on the working fluid for transport (flowing), working pressure and temperature, as well as operating conditions and working environment. Figure 1 shows constructions of steel spherical tanks and pipelines for pouring and filling in the chemical industry.

(a) spherical tanks *b) pipelines for streaming and filling*

Figure 1. *Steel constructions of spherical tanks and pipelines in the chemical industry are daily exposed to external and internal corrosion [1]*

Corrosion of steel pipeline elements in the chemical industry

Despite numerous protection methods due to the harsh environmental conditions in the chemical industry, corrosion of steel pipelines is inevitable. It occurs in different forms such as general corrosion with equal loss of wall thickness or pitting corrosion corresponding to a local reduction in wall thickness. In practice, it happens that the steel embedded in the pipeline corrodes partially or completely, reducing the cross-section and thus the load-bearing capacity of the structure. In more severe cases, an accident can occur with catastrophic consequences for production, facilities, means of production, devices and human lives. Such accidents result in pollution and harmful effects on flora and fauna, air, watercourses and groundwater. Drastic examples of corrosion degradation of steel pipeline structures in the chemical industry are shown in the photographs of Figure 2.

Figure 2. *Examples of corrosion damage to pipeline steel structures [1, 2]*

Corrosion manifests itself in the following way: the appearance of cracks, a decrease in strength, the appearance of swelling and loss of mass, corrosion spots and a weakening of the cross-section. Visual signs of destruction are: erosion, peeling and crumbling, crushing, softening, cracking, crystallization, appearance of "popcorn". Spot corrosion on parts of the structure that are exposed to tension is

particularly dangerous. Due to the reduction of the cross-section and the high degree of stress, occasional damage can lead to the formation of cracks and stress concentration [3].
The direct and indirect costs caused by corrosion in the chemical industry are enormous. In the USA, the total annual direct costs of corrosion in this industrial area are estimated at 1.7 billion dollars, which is about 8 percent of the total capital costs [4]. No calculations have been made of the indirect costs of stopping production due to failure or catastrophic destruction, but it is estimated that they are several times higher.

Characteristics of the corrosion environment in the assessment of corrosion damage of steel pipelines

The durability of steel for pipelines in the chemical industry depends on the characteristics of the corrosive environment and the ability to resist internal and external influences, the character and intensity of which depend on the conditions of exploitation of steel pipelines. The internal influence is reflected through the purpose and type of fluid in steel pipelines, which can be of different aggressiveness, toxicity and explosiveness, of different pressures, temperatures and flows. The external influence depends on the type, composition and temperature of the waste gases and air surrounding the objects in question, the speed, flow and pressure of the gases, as well as the powdery substances in the gas stream.
External influences also include: the chemical effect of water - the environment and substances dissolved in it, the alternating effect of temperature changes (which leads to expansion changes on steel), alternating wetting and drying of steel and the action of dissolved salts in contaminated water. The emission of harmful substances, which are almost always present in the surrounding atmosphere of the chemical industry, has a major impact. It contains gases O2, CO, CO2, SO2, NO, NO2, NOx, H2S, water vapor, as well as particles of solid substances such as KCl, K2SO4, (NH4)2SO4, CO(NH2)2. and others Also, the composition of waste gases and solid substances, their speed, flow and increased concentration affect the rate of corrosion and erosion of steel pipelines.

Production of steel pipelines

For the construction of steel pipelines, pipes of appropriate diameter and wall thickness are used, as well as various profiles in some of the qualities of general and fine-grained structural steel.
Steel pipelines made of steel elements require precision, great attention, trained and professional workforce during production. They are made by welding or joining pipe flanges of appropriate quality. They are equipped with appropriate equipment such as manometers, level gauges, safety valves, filling, emptying and overflowing valves, etc.
Depending on the aggressiveness of the transported fluid, steel pipelines are exposed to internal corrosion, that is, depending on the environmental conditions and the effect of external corrosion.
The side of steel pipelines that faces the sources of emissions of harmful substances, supported by air flow from that direction, is more exposed to corrosion due to the direct application of harmful substances to the structure of the steel pipeline. When there is poor air circulation, steel pipelines can be exposed to constant moisture, which, together with the emission of harmful substances, can be disastrous for the construction.

Testing and control using non-destructive methods

Steel pipelines in the chemical industry are subject to inspection, which means that before use they must be properly inspected in order to obtain a work permit. During exploitation, legally prescribed controls are also carried out in order to ensure safe and reliable operation of steel pipelines [3, 5].
All defects, whether built in or caused during the explosion, are examined in a certain period of time, which gives a realistic insight into the possible progression of damage, which directly affects the

reduction of the number of breakdowns and the planning of plant downtime, and thus a significant reduction total costs.
In order to avoid defects and ensure safe operation, corrosion should be detected, measured and assessed for the remaining strength of the corroded surface of the element and, based on the assessment, appropriate measures should be taken in order to eliminate harmful consequences and preserve the environment.
Before the inspection, it is necessary to familiarize yourself with the technical documentation of the steel structure of the pipeline in detail and to determine the critical elements and places that should be paid particular attention to during the inspection.
Control and tests should be documented with sketches and photographs for repeatability of tests and updating of files, i.e. the "passport" of the steel pipeline.
In order to assess the residual strength of corroded elements of steel pipelines using one of the existing methods, it is necessary to accurately measure the corrosion defect. The ultrasonic method with associated devices is currently the most widely used for testing corrosion damage on steel pipelines.
Test and control results are processed manually or automatically using computer programs. The programs can work in such a way that we provide them with data collected by the classic method of measuring the maximum depth of corrosion (that is, the minimum thickness of the pipe wall) or the program is integrated with a measuring instrument that scans the tested surface, and compares the obtained results with the standard prescribed acceptance criteria. As a result, we obtain, by classical calculation or automatically, the remaining strength of the tested steel pipeline, and based on it we determine the maximum permissible working pressure.

Methods for assessing corrosion damage of steel pipelines

There are various methods used to assess the residual strength of corroded pipes. Some of them are very simple and rely only on the length and depth of the fault, while others are much more complicated, based on finite element modeling (FEM).
ASME B31G [3] is one of the most widely accepted solutions for assessing corrosion damage in steel pipelines. The improvement of the method [6, 7] was achieved by introducing the damage factor, material load, detailed consideration of the form of damage using calculations. This method is included in the program known as RSTRENG (Remaining Strength of Corroded Pipe). ASME B31G and RSTRENG have found wide application in the assessment of corrosion damage of steel pipelines in industry.
The presented methods enable the assessment of longitudinally oriented corrosion defects. The role of transversely propagated faults is usually denied. For transversely oriented faults, Kastner's norm can be used for the decrease in plasticity at the point of the defect [8].
However, these criteria are too conservative when applied to damage to steel pipelines made of high resistance materials. Based on experimental observations, a specific finite element rulebook called PCORRC was developed, and solutions were proposed for the evaluation of pipes made of moderate to high strength steel based on a large series of FEM experiments and calculations.

Data for the calculation of corrosion damage of the steel pipe of the pipeline

The data required for the calculation of pipe corrosion damage, Fig. 3, using the RSTRENG method and MKE are as follows:

- ✓ Nominal value of the outer diameter of the pipe, D=125 mm;
- ✓ Nominal pipe wall thickness, t=5 mm;
- ✓ Maximum depth of corrosion damage, d=2 mm;
- ✓ Measured (longitudinal) length of corrosion damage, L_m=70 mm;

The pipe is made of steel with the following mechanical characteristics:

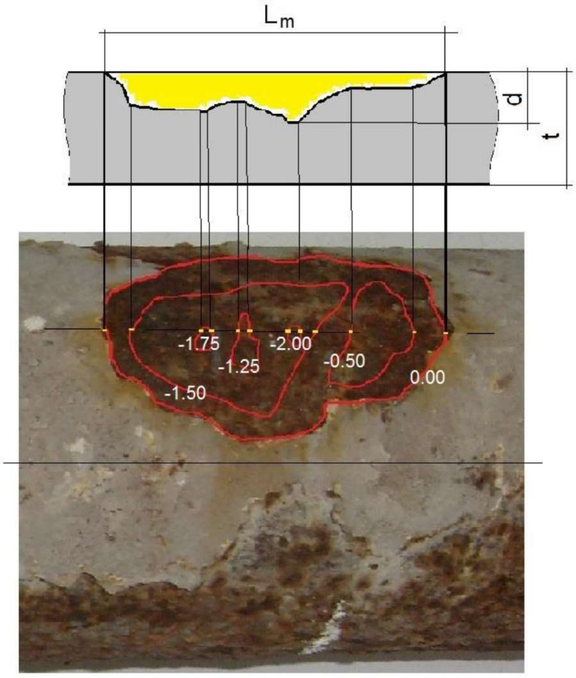
- ✓ Modulus of elasticity, E=211500 MPa;

- ✓ Poisson's coefficient, $\nu=0.3$;
- ✓ Lower yield stress, $S_{eH}=813.4$ MPa;
- ✓ Tensile strength, $S_M=854.8$MPa.

The pipe is exposed to pressure during operation, P=60 MPa (N/mm^2).

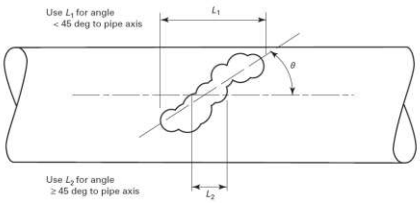
Corrosion damaged pipe

Irregular length, width and depth of a typical corrosion defect [9]

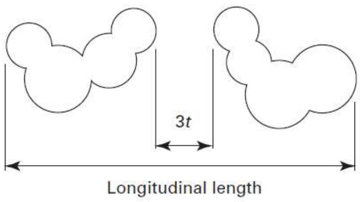


Measured values of asymmetric corrosion damage

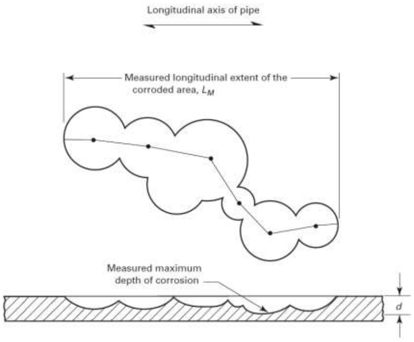
Figure 3. *Data for assessment of corrosion damage*



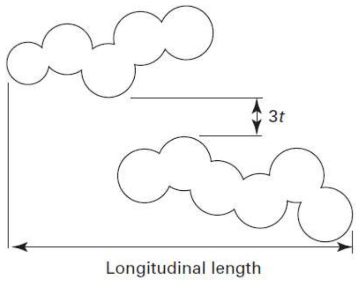
Orientation of corrosion damage



The influence of the distance between corrosion damages



Measured values used for corrosion damage analysis



The influence of the distance between corrosion damages

Figure 4. *Recommendations of standards for the assessment of corrosion damage [3]*

Determination of the maximum acceptable length of corrosion damage using the RSTRENG method

The depth of corrosion damage can be expressed as a percentage of the nominal value of the pipe wall thickness. When the corrosion depth of the part is greater than 10% or less than 80% of the nominal value of the pipe wall thickness, the length of the corrosion damage must not be greater than the value obtained by equation (1).

$$L = 1.12 \cdot B \cdot \sqrt{D \cdot t} \qquad (1),$$

where: L - maximum permitted length of corrosion damage;
B - value determined using equation (2).
The maximum depth of corrosion damage is: d=2 mm, 40%=100·2/5.

$$B = \sqrt{\left(\frac{d/t}{1.1 \cdot \frac{d}{t} - 0.15}\right)^2 - 1} = \sqrt{\left(\frac{2/5}{1.1 \cdot \frac{2}{5} - 0.15}\right)^2 - 1} = 0{,}949998 \qquad (2)$$

The maximum length of corrosion damage is:

$$L = 1.12 \cdot B \cdot \sqrt{D \cdot t} = 1.12 \cdot 0.949998 \cdot \sqrt{125 \cdot 5} = \mathbf{26.6\ mm}$$

Figure 5 shows the relationship between corrosion damage and the acceptance criteria for pipe corrosion damage. The criterion is that they should withstand a pressure equal to the lower yield stress SeL. The image represents a parabolic section of the corroded part where the value of the maximum depth of corrosion damage divided by the thickness of the pipe wall is shown on the y axis and on the x axis the length of the corrosion damage is given divided by the square root of the product of the pipe radius and pipe wall thickness.

$$d/t = \mathbf{0.400};\ \frac{L}{\sqrt{R \cdot t}} = \frac{26.6}{\sqrt{\frac{125}{2} \cdot 5}} = \mathbf{1.505} \qquad (3)$$

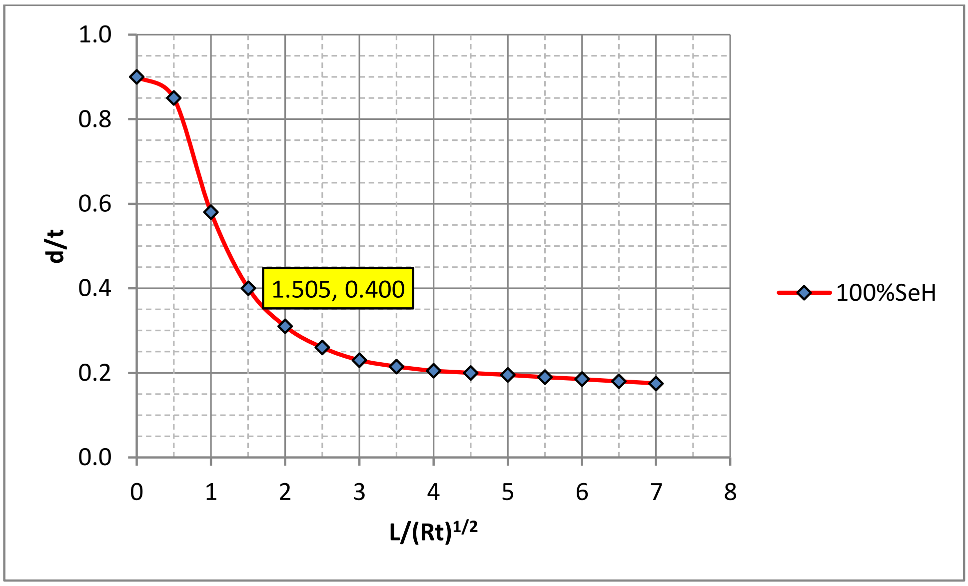


Figure 5. *Diagram for assessment of corrosion damage*

The coordinates of the point from equation (3) are located on the very line of the diagram, fig.5. Given that the actual measured length of corrosion damage is L=70 mm, the working pressure should be reduced or the pipe with corrosion damage should be replaced or repaired.
If the maximum measured depth of corrosion damage is greater than 10% of the nominal value of the pipe wall thickness and less than 80% of the nominal value of the pipe wall thickness, and the measured length of the corrosion damage is greater than the value determined based on equation 1, it is necessary to calculate:

$$P' = 1.1 \cdot P\left[\frac{1-\frac{2}{3}\cdot\left(\frac{d}{t}\right)}{1-\frac{2}{3}\left(\frac{d}{t\cdot\sqrt{A^2+1}}\right)}\right] \qquad (4),$$

where: P' - maximum allowable pressure for Lm and cannot be greater than P;
P - determined pressure value in the pipe or:

$$P = 2 \cdot SeH \cdot t \cdot F \cdot \frac{T}{D} = 2 \cdot 813.4 \cdot 5 \cdot 1 \cdot \frac{1}{125} = \mathbf{65.1\ MPa} \qquad (5),$$

where: F - corresponding factor from ASME B31.4 [10], ASME B31.8 [11];
T - corresponding temperature value based on the B31 rulebook (if not specified, T=1).

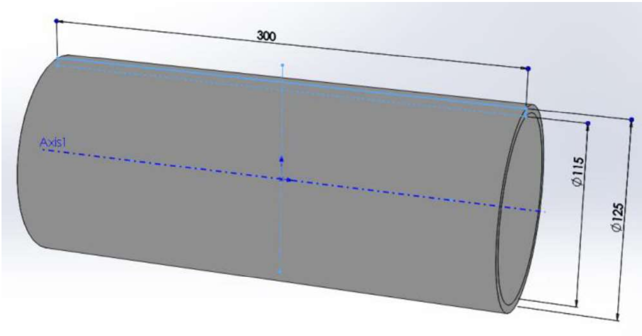
$$A = 0.893\left(\frac{L_m}{\sqrt{Dt}}\right) = 0.893\left(\frac{70}{\sqrt{125\cdot 5}}\right) = 2.50 \qquad (6)$$

For a depth of damage of 40% of the nominal thickness of the pipe wall, the maximum permitted length of corrosion damage of L=26.6 mm was calculated. This length of corrosion damage is smaller than the actual measured length of corrosion damage, which is L=70 mm, so it is necessary to calculate the maximum allowable pressure (P') of the corroded pipe for this case of damage and it is:

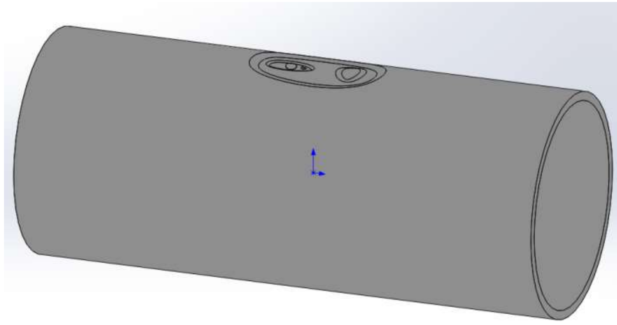
$$P' = 1.1 \cdot P\left[\frac{1-\frac{2}{3}\cdot\left(\frac{d}{t}\right)}{1-\frac{2}{3}\left(\frac{d}{t\cdot\sqrt{A^2+1}}\right)}\right] = 1.1 \cdot 65.1\left[\frac{1-\frac{2}{3}\left(\frac{2}{5}\right)}{1-\frac{2}{3}\left(\frac{2}{2\sqrt{2.50^2+1}}\right)}\right] = \mathbf{3.9\ MPa} \qquad (7)$$

Assessment of the residual strength of steel pipelines using the FEM

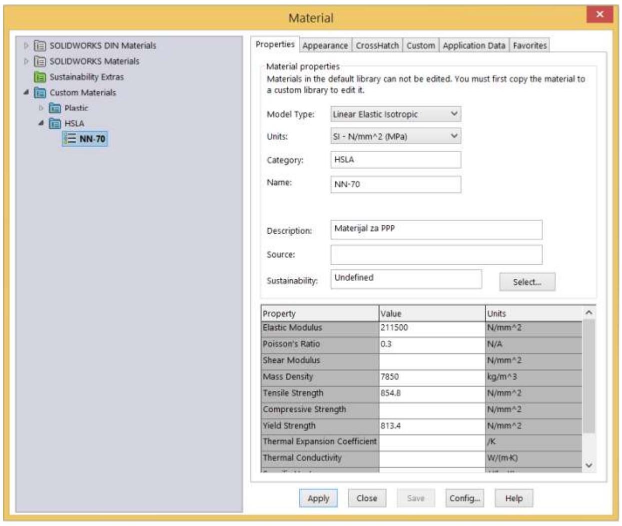
In order to assess the residual strength of steel pipelines using the FEM [2, 7], the processed test results can be implemented in the form of a model in one of the commercial programs for calculation using the FEM. Due to the asymmetry of corrosion damage, a part of the pipe with corrosion damage is modeled in an approximate shape to the actual shape (rectangular, elliptical, spherical...). The model is made by connecting isoparametric elements, and the number of elements depends on the size of the corrosion damage. It is necessary to represent the bottom of the damaged area with a sufficient number of elements determined by the previous section analysis. The inside of the model is subjected to operational, i.e., test pressure. Planes of symmetry are places where boundary conditions are set (displacements in certain planes are limited). Figure 6 shows the sequence of procedures before calculating the FEM of pipes with corrosion damage.
Figure 7 shows the calculation results of a pipe with asymmetric corrosion damage. The calculation was made for pressures in the pipe of 60 MPa (working pressure of an undamaged pipe), 3 MPa (calculated pressure according to ASME B31.G, and a pressure of 22 MPa which ensures the operation of the pipe with safety level 1, which means that the pressure in the pipe does not it must not exceed this value at any one time.



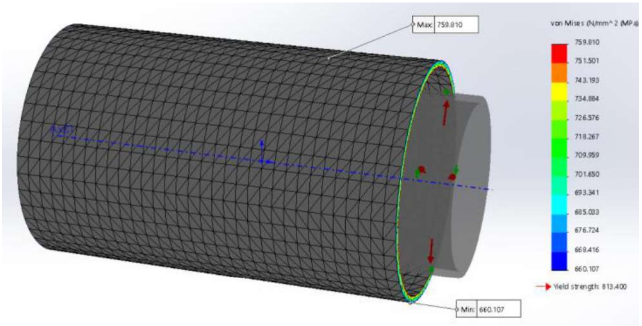
Pipe model without corrosion damage



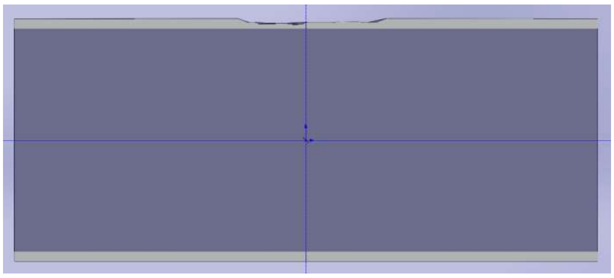
Pipe model with corrosion damage



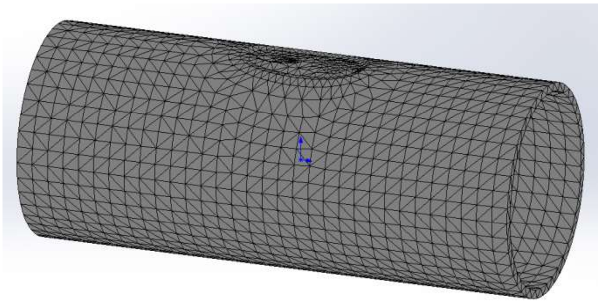
Pipe material data and boundary conditions



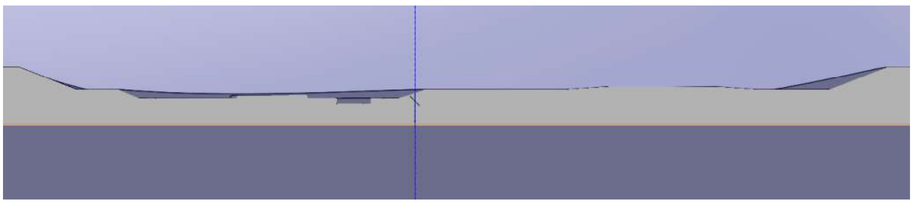
The Finite Element mesh on the pipe without corrosion damage and a pressure value of 60 MPa



Cross-section of a pipe model with corrosion damage

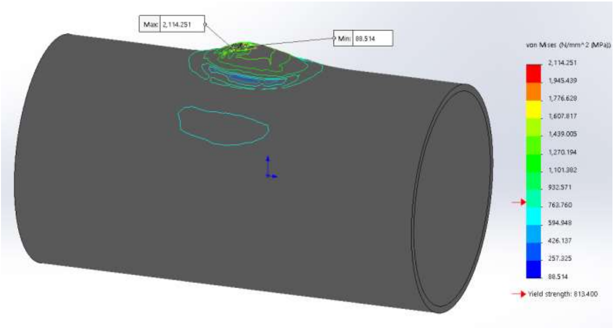


Finite Element mesh on a pipe with corrosion damage

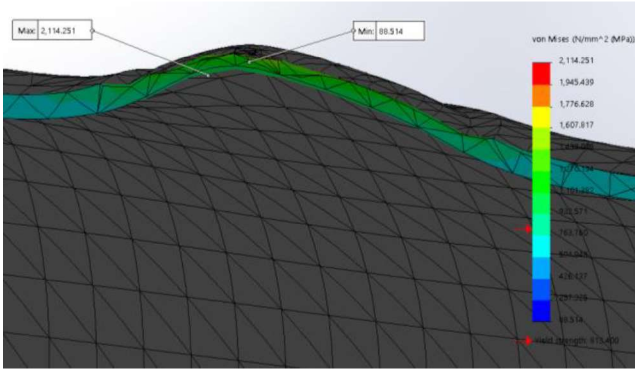


Section through the corrosion damage model

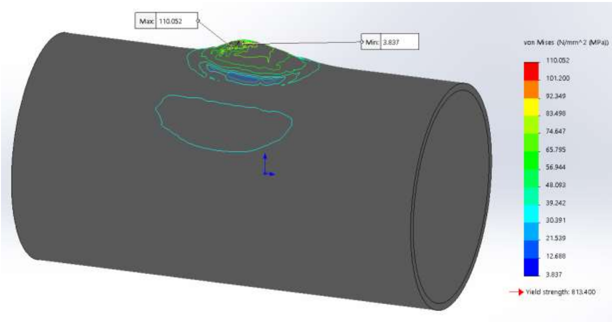
Figure 6. *Data entry for the calculation by the FEM of corrosion-damaged pipe of the pipeline*



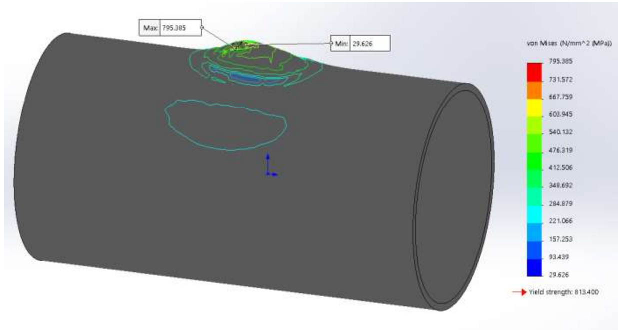
Distribution and stress values on pipes with corrosion damage for a pressure of 60 MPa



Section through the model of corrosion damage on a pipe loaded with a pressure of 60 MPa



Distribution and stress values on pipes with corrosion damage for a pressure of 3 MPa



Distribution and stress values on pipes with corrosion damage for a pressure of 22 MPa

Figure 7. *Calculation by the FEM and stress distribution on the corrosion damage of pipeline pipe*

Measures to protect steel pipelines against corrosion

From the previous consideration of the danger of corrosion to which parts of the steel structure of the pipeline are exposed due to the action of various attacking agents, a number of corrosion protection measures are imposed even in the construction phase: the use of clean and uncorroded sheets, profiles and binding material with anti-corrosion protection done in workshop conditions, which immediately after installation, it should be properly protected on the construction site itself. In addition, before installation, the parts should be protected from the effects of any corrosive agent that could be found on the construction site. Preservatives that can be easily removed (oils, fats, non-drying agents) can significantly slow down the access of gaseous attack substances (hydrogen sulphide).

Modern protective coatings made of epoxy resin adhere very well to the surfaces of steel parts where cracks do not appear on elements exposed to tension almost to the limit of their strength.

Steel pipelines are subject to inspection, which means that before use they must be properly inspected in order to obtain a work permit. During exploitation, legally prescribed controls are also carried out in order to ensure safe and reliable operation of the steel pipeline.

In addition to proper and timely maintenance, it is also necessary to monitor corrosion processes during exploitation. These processes can be monitored directly or indirectly. Direct monitoring controls the condition of the steel surface and the aggressiveness of the environment surrounding the steel construction of the pipeline. Indirect monitoring involves measuring the corrosion effect on coupons made of the same type of material as the steel structure of the pipeline.

Even during the construction of steel pipelines, it is necessary to install sensors and measuring tapes to monitor changes in the aggressiveness of the environment, voltage and elongation of the responsible supporting parts of the steel pipelines, which would be in conjunction with a computer on which the received information would be processed and appropriate decisions would be made.

Conclusion

Corrosion damage, in which the bearing capacity of the section is reduced, greatly endangers the steel pipeline as a whole. Failure to comply with prescribed regular and emergency controls and inadequate maintenance can lead to destruction with catastrophic consequences.

Improper maintenance of steel pipelines from the aspect of corrosion protection entails very expensive repairs, so in this regard it is necessary to thoroughly investigate the issues of protection, durability and maintenance of steel pipelines and the possibility of monitoring corrosion aggression in exploitation. In this regard, it is necessary to assess the state, or the assessment of the remaining strength, of the steel pipeline threatened by corrosion after long-term use, which should be followed by certain tests using non-destructive methods, in order to determine the actual degree of damage to the vital parts of the structure. Control and testing by non-destructive methods of the corroded zones of the bearing elements of the steel construction of pipelines must be followed by control calculations using methods, standard and MKE, to assess the remaining strength of steel pipelines, with opinions and recommendations. In uncertain situations, calculations need to be confirmed by experimental analyses.

Control and testing by non-destructive methods must be preceded by the process of cleaning the steel structure of the pipeline (eg sandblasting), and immediately after the necessary interventions in terms of changing critical elements, anti-corrosion protection follows.

Acknowledgements

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