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PREFACE

Modern product development is no longer just an engineering process – it is a strategic activity that connects technology, the market, design, user experience, and sustainability. Market success depends on the ability to develop innovative solutions quickly, efficiently, and intelligently, using the latest technologies. For this reason, product development must be at the core of educational programs, research centers, and industrial strategies. Today's technological trends – including artificial intelligence, additive manufacturing methods, digitalization, and environmentally sustainable industry – open up a broad range of new perspectives and opportunities for the advancement of this dynamic profession.

The 11th International Scientific Conference – IRMES 2025 – Research and Development of Mechanical Elements and Systems is organized by the Chair of Mechanical Constructions, Development, and Engineering at the Faculty of Mechanical Engineering, University of Niš, and the Association for Design, Elements and Constructions – ADEKO. With a tradition of over three decades, IRMES remains committed to its mission – to bring together researchers, engineers, industry representatives, and students with the aim of enhancing knowledge and its application in industry.

At the previous ten IRMES conferences (the first held in 1995), around one thousand papers were presented, with participation from over one thousand individuals from across the globe. This long-standing and successful tradition forms a solid foundation for organizing this and future IRMES conferences.

All submitted papers for IRMES 2025 underwent international peer review, and 37 papers met the high standards required for publication in the Conference Proceedings. The accepted papers are categorized into four thematic areas of the conference: Mechanical Elements and Systems, Product Development Process, Advanced Technologies in Mechanical Engineering and Mechanical Engineering Education.

We are especially pleased that a significant number of participants from abroad have registered for IRMES 2025. In total, 119 authors from 11 countries are participating. During the two plenary sessions, lectures will be delivered by distinguished professors:

- Prof. Dr.-Ing. Dr. h.c. Bernd-Robert Höhn, Technical University of Munich, School of Engineering and Design
- Prof. Dr. Dražan Kozak, University of Slavonski Brod, Faculty of Mechanical Engineering
- Prof. Dr. Damjan Klobčar, University of Ljubljana, Faculty of Mechanical Engineering
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- Prof. Dr. Milan Banić, University of Niš, Faculty of Mechanical Engineering

In today's rapidly changing world, influenced by global economic, environmental, and social factors, it is essential that all of us involved in mechanical engineering in various capacities remain aware of our responsibility. In this context, engineering ethics, quality of work, and lifelong learning play a vital role. Although scientific research is fundamental to economic progress, the education of new generations of mechanical engineers is equally important.

As part of the conference, a Panel Session will be held under the title: The Future of Mechanical Engineering Education: Mechanical Engineering in the Era of Artificial Intelligence.

We are confident that the work at IRMES 2025 will be fruitful and that each of you will leave the conference with new ideas, knowledge, and contacts that will support your further professional development. This is an opportunity not only to learn from one another but also to jointly build the foundation for future research projects and industrial innovations.

Moreover, we hope that in the coming days, we will have the opportunity to get to know each other better, discuss common challenges, and establish new forms of collaboration. In this sense, we emphasize that all your suggestions and proposals are more than welcome and will be carefully considered by the Organizing and Scientific Committees with the aim of improving future conferences.

IRMES 2025 will be further enriched by additional events to support the effective exchange of knowledge and experiences, as well as to ensure a pleasant stay in Vrnjačka Banja in June 2025.

We would like to thank all authors, committee members, reviewers, and others who contributed to the organization and relevance of this conference. Without their support, the organization and realization of IRMES would not have reached the level that its importance and reputation deserve. Special appreciation goes to the Ministry of Science, Technological Development and Innovation and to our general sponsor DB-RAZVITAK d.o.o. Veternik, whose support was crucial.

We wish all participants a successful IRMES 2025 and a pleasant stay in Vrnjačka Banja.

Niš, June 12th, 2025

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11th International Scientific Conference

IRMES 2025

Research and Development of Mechanical Elements and Systems

Faculty of Mechanical Engineering

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STRAIN AND STRESS/FORCE-CONTROLLED FATIGUE TESTING OF METALLIC MATERIALS, POST-PROCESSING OF EXPERIMENTALLY OBTAINED RESULTS AND APPLICATION IN FEA

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Abstract: *Fatigue of metals is a very complex phenomenon, which is still not fully understood and is also the topic of much active research. Fatigue testing is a method used to evaluate how a material behaves under repeated stress and cyclic loading. The aim of this paper is to show strain and stress/force-controlled testing of metallic materials using developed procedures according to relevant standards. The paper has presented a very useful developed software application for the determination of fatigue properties of metallic materials, whereas the user is enabled to display the corresponding fatigue properties of the tested material as well as the corresponding ε-N or S-N curves. The obtained fatigue properties of the tested materials can be used with great success in numerical calculations, especially FEA, to estimate the endurance limit and fatigue life of various types of metallic structures.*

Keywords: *structural fatigue tests; fatigue life; S–N fatigue curves; ε–N fatigue curves.*

1. INTRODUCTION

There is no exact data, but many books and scientific articles have suggested that 50% to 90% of all mechanical failures are fatigue failures. Fatigue is the appearance of a gradual destruction of materials under periodic variable load. Fatigue tests measure the resistance of materials to damage, losing strength, and failure under the repeated application of load [1]. There are many experimental methods for fatigue testing. Experimental methods for fatigue testing are very expensive and time-consuming.

Despite the development of new alloys and composite materials, steels are still the most widely utilized materials in mechanical and civil engineering. Steels still represent the most used group of mechanical materials for constructing bridges, buildings, ships, cars, rail vehicles, railways, and etc. Steel structural elements and constructions are frequently subjected to varying loads over their service (fatigue) lives [2], [3].

In this paper, the cyclic deformation behaviour and fatigue life of metallic materials under strain and stress/force-controlled fatigue testing studied experimentally.

Another idea of this paper is to develop a software solution for post-processing of experimentally obtained fatigue properties of metallic materials in accordance with the appropriate standard for statistical analysis and application fatigue properties in Finite element Analysis (FEA) for prediction of fatigue life of different steel structures.

2. FATIGUE BEHAVIOR ASSESSMENT

The fatigue approaches may be divided into three classes (approaches): fatigue tests and stress-life (*S–N*) approach, cyclic deformation and the strain-life (*ε–N*) approach and linear elastic fracture mechanics-based approach (LEFM) [1].

Stress-life (*S–N*) approaches are most useful at high cycle fatigue, where the applied stresses are elastic, and no plastic strain occurs anywhere other than at the tips of fatigue cracks. At low number of cycles, scatter in the fatigue data makes these methods increasingly less reliable. *S–N* approach is a global approach that relates the stress range (e.g. nominal, structural or geometric) applied to the component with the fatigue life [4]. The *S–N* approach is the basis of many standards for assessing the fatigue life, such as the Eurocode 3, part 1-9 [5]. For most stress-life calculations, the math is relatively easy, since there is only one stress component. In strain life calculations, the math is more difficult, as the elastic and plastic components of the strain must be dealt with separately.

Strain life (*ε–N*) approach and linear elastic fracture mechanics approach (LEFM) belong to local approach and it can be used for low cycle and high-cycle fatigue. The local approaches, recognizing the localized nature of the fatigue damage, propose the correlation of a local damage parameter (e.g. strain, energy) with the number of cycles required to initiate a macroscopic crack. LEFM approach represents an alternative approach to fatigue, based on the fatigue crack propagation phenomena [6],

[7]. This approach is based on crack propagation laws, with Paris' law [8] and residual life computation of a structural component with an initial crack.

2.1. Basic equations

Mathematical model used to describe fatigue behavior of material under cyclic strain-controlled tests to obtained cyclic stress-strain (σ-ε) curve is given by Ramberg–Osgood approach presented by equations (1) and (2):

$$\varepsilon_a = \frac{\Delta\varepsilon}{2} = \varepsilon_{a,e} + \varepsilon_{a,p} = \frac{\Delta\varepsilon_e}{2} + \frac{\Delta\varepsilon_p}{2} \tag{1}$$

$$\varepsilon_a = \frac{\Delta\sigma}{2E} + \left(\frac{\Delta\sigma}{2K'}\right)^{\frac{1}{n'}} = \frac{\sigma_a}{E} + \left(\frac{\sigma_a}{K'}\right)^{\frac{1}{n'}} \tag{2}$$

The total strain-life (ε-N_f curve) is therefore expressed as the sum of elastic Basquin's and plastic Manson-Coffin's part by equations (1) and (2):

$$\varepsilon_a = \varepsilon_{a,e} + \varepsilon_{a,p} = \frac{\Delta\varepsilon_e}{2} + \frac{\Delta\varepsilon_p}{2} = \frac{\sigma_f'}{E}\left(2N_f\right)^b + \varepsilon_f'\left(2N_f\right)^c \tag{3}$$

In equations (1-3) ε_a, $\varepsilon_{a,e}$, $\varepsilon_{a,p}$ are, respectively, the total, elastic and plastic strain amplitude; K', n' are, respectively, cyclic strain coefficient and cyclic strain hardening exponent; σ_f', b, are, respectively, fatigue strength coefficient and fatigue strength exponent; ε_f', c are, respectively, fatigue ductility coefficient and fatigue ductility exponent; $2N_f$ is the number of reversals to failure; σ_a is true stress amplitude; E is the Young's modulus.

All constants in equations (1-3) will be determined from fatigue tests of smooth specimens under strain-controlled conditions for Strain life (ε–N) approach.

For Stress-life (S–N) approach results relating directly a global definition of stress range (stress amplitude) to the total number of reversals to failure. Often, Basquin's part of equation (3) is adopted for representing the Wöhler curve as a straight line in a double logarithmic plot.

2.2. Fatigue Analysis Using the Experimental Method

This section describes a complete fatigue characterization of metallic materials, carried out according to the internal procedures of the Centre for engineering software and dynamic testing at Faculty of Engineering University of Kragujevac, based on the ASTM E468-90 [9], ASTM E466-96 [10] and ASTM E606-92 [11] standards.

Before fatigue testing it is necessary to determine monotonic mechanical properties (minimum yield stresses, minimum tensile strength and Young's modulus) in accordance to the standards EN ISO 6892-1 [12] and ASTM E8M-01 [13].

All tests (the uniaxial tensile tests and fatigue tests) were performed using a SHIMADZU type EHF EV101K3-070-0A servo-hydraulic testing machine (Shimadzu Corporation, Tokyo, Japan) with a force of ±100 kN and a stroke of ±100 mm.

Uniaxial tensile tests must be performed on representative flat specimens for each metallic material, with the same thickness in all cross-sections to investigate the static strength properties. Uniaxial tensile tests perform at room temperature with a constant stroke control rate without a change in the speed of testing. One of the investigated specimens at the end of the uniaxial tensile test is presented in Figure 1a. An MFA25 extensometer with a gauge length of 50 mm was used to determine the Young's modulus (Figure 1b).

(a) (b)

Fig.1. Testing equipment: (a) SHIMADZU servo-hydraulic machine, (b) MFA25 extensometer

All specimens utilized to determine the fatigue properties were prepared according to the standard E468-90 [9]. The technical drawing and real shape of one of the investigated specimens for fatigue testing, before testing, is shown in Figure 2. All nominal dimensions of the specimen shown in Figure 2 are in millimetres (mm). All specimens were finely polished to minimize surface roughness effects. The mean roughness level achieved on the surface of the gauge length of the specimens was in the range of 1–5 µm.

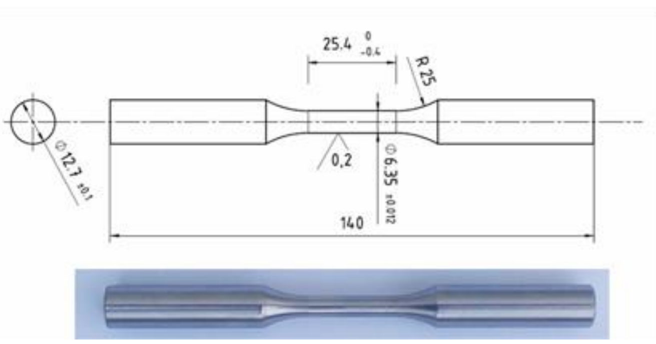

Fig.2. Technical drawing of fatigue testing specimen and real specimen (unit: mm)

One series for any uniaxial fatigue test consists of a minimum of 15 specimens. The specimens are exposed to high cycle fatigue under force/stress-controlled, fully reversed (tensile-compression) testing conditions The stress levels used to control the fatigue tests must be chosen from the previously performed monotonic uniaxial tensile test.

For strain-controlled fatigue tests, for investigating low-cycle fatigue, and for controlling testing conditions SHIMADZU DYNASTRAIN TCK-1-LH dynamic extensometer with *a* ±1 mm working range (Figure 3.) is necessary.

The uniaxial tension-compression test planning (stress or strain-controlled fatigue tests) is minimum five levels, three repetitions per level with a range of stress or strain amplitude. The test frequency in the characterization is in the range of 3–10 Hz (low cycle fatigue) and 10-15 Hz (high cycle fatigue). The crack initiation criterion (failure criterion) was quick stiffness loss (load amplitude loss of about 10%).

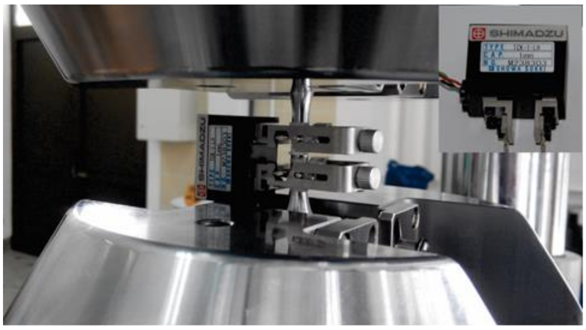

Fig.3. SHIMADZU DYNASTRAIN TCK-1-LH dynamic extensometer

After the fatigue testing of all specimens in the series, all testing results must be presented in accordance with ASTM: E468-90 [9] (Figure 4.).

According to the experimental data shown in a proper manner and statistical analysis (linear model Y= A + BX, log-normal fatigue life distribution with constant variance along the entire interval of X used in testing) in accordance with standard ASTM E739-91 [14], the fatigue properties would be determined.

Specimen No	Δσ [MPa]	F_{min} [kN]	F_{max} [kN]	ΔF [kN]	R	A [mm²]	Number of cycles	Place of the failure
		S-N approach for highcycle fatigue						

Specimen No	ε_a [%]	ε_{min} [%]	ε_{max} [%]	σ_a [MPa]	E [MPa]	l [mm]	Number of cycles	Place of the failure
		ε-N approach for lowcycle fatigue						

Fig.4. Table for presentation of Fatigue Test Results for Metallic Materials in accordance to [14]

Experimentally obtained uniaxial tension–compression strain controlled mechanical properties of S355J2+N steel grade strain–life curve (log–log representation), have been determined and shown in Figure 5 [15].

Cyclic stress-strain curve from uniaxial tension–compression strain-controlled fatigue tests and graphical method for obtaining cyclic yield strength are shown in Figure 6 [15].

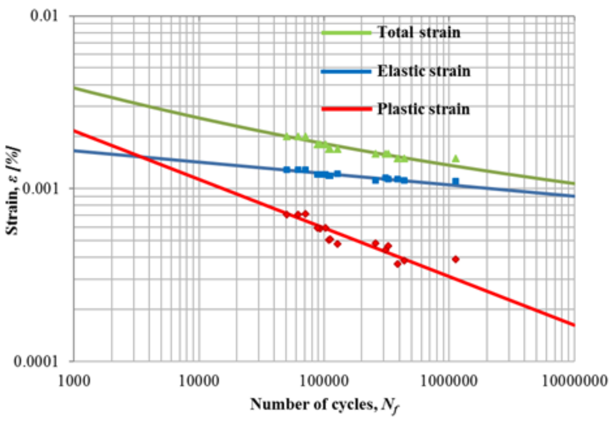

Fig.5. Strain–life curve from uniaxial tension–compression strain-controlled fatigue test of S355J2+N steel grade [15]

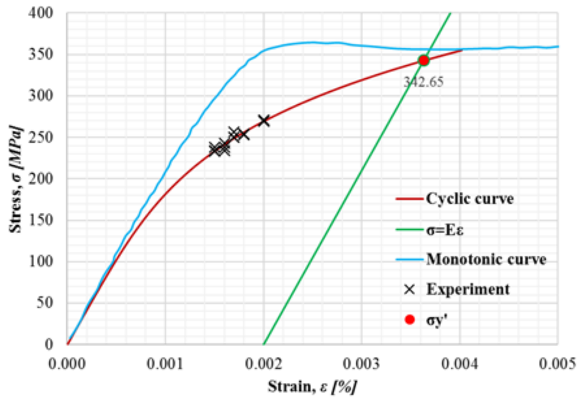

Fig.6. Cyclic stress-strain curve from uniaxial tension–compression strain-controlled fatigue test of S355J2+N steel grade [15]

Based on uniaxial tension–compression stress-controlled experiments, the *S–N* curves (semi-log representation) for S355J2+N, S690QL, and X37CrMoV5-1 steel grades were determined and are shown in Figure 7 [16].

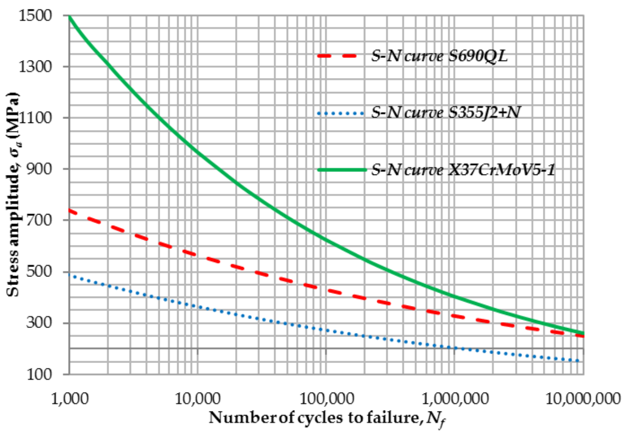

Fig.7. Combined diagram of semi-log S-N curves for S355J2+N, S690QL, and X37CrMoV5-1 steel grades [16]

3. DEVELOPMENT OF AN SOFTWARE APPLICATION

As noted in the previous chapter for each series of fatigue test specimens (strain or stress/force controlled) it is necessary to do statistical analysis according to algorithm and procedure for determination fatigue properties [14]. Because we never have the same number of test specimens in a series, this task is not easy and takes a lot of time.

The main idea is to develop a software solution for post-processing of experimentally obtained fatigue properties of metallic materials [17] in accordance with the appropriate standard for statistical analysis ASTM E739-91 [14], using the Python programming language with appropriate libraries.

3.1. The concept of a software application

The software application for post-processing of experimentally obtained fatigue properties was developed in the Python 3.10.7 programming language [18]. Beside to the standard libraries, additional libraries (NumPy, pandas, matplotlib, tkinter) were used for working with data, drawing graphics, creating a graphical user interface, and Visual Studio Code software [19].

The idea of a general algorithm program for post-processing of experimentally obtained fatigue properties is as follows:

- All obtained results of the experimental tests are collected in an Excel file performed in accordance to ASTM E468-90 standard [9].
- Starting the application is done by running the *.exe file.
- Step 1 is choosing the type of analysis low cycle fatigue or high cycle fatigue.
- Step 2 is to select the appropriate Excel document. For low cycle fatigue, the table contains the following data: modulus of elasticity E, number of the sample, and their values of total strain amplitude ε_a, stress amplitude σ_a and number cycles to failure N. For high cycle fatigue, the table contains the number of samples, stress amplitude σa and and number cycles to failure N.
- Step 3 is the display of the obtained fatigue properties. For low cycle fatigue: fatigue strength coefficient σ_f', fatigue strength exponent b, fatigue ductility coefficient ε_f', fatigue ductility exponent c. For high cycle fatigue: fatigue strength coefficient σ_f', fatigue strength exponent b, Slope of fatigue strength curve m.
- Step 4 is plotting of corresponding ε-N and S-N curves in semi-log or log-log representation with all results of the experimental tests.

3.2. Visualization of a software application

Starting the program (*.exe file) opens the window shown in Figure 8., in which it is necessary to select the type of fatigue properties.

By selecting one type of fatigue assessment, a new file selection window opens. Selecting a file opens a new window, which offers the option to start a program for post-processing the data of the loaded file, prepared in accordance with ASTM E468-90 [9]. By loading the data from the selected file, the calculation procedure of the appropriate fatigue properties of the material is started in accordance with ASTM standard: E739-91 [14]. Results of obtained fatigue properties are shown in Figure 9.

Fig.8. Main window of software application

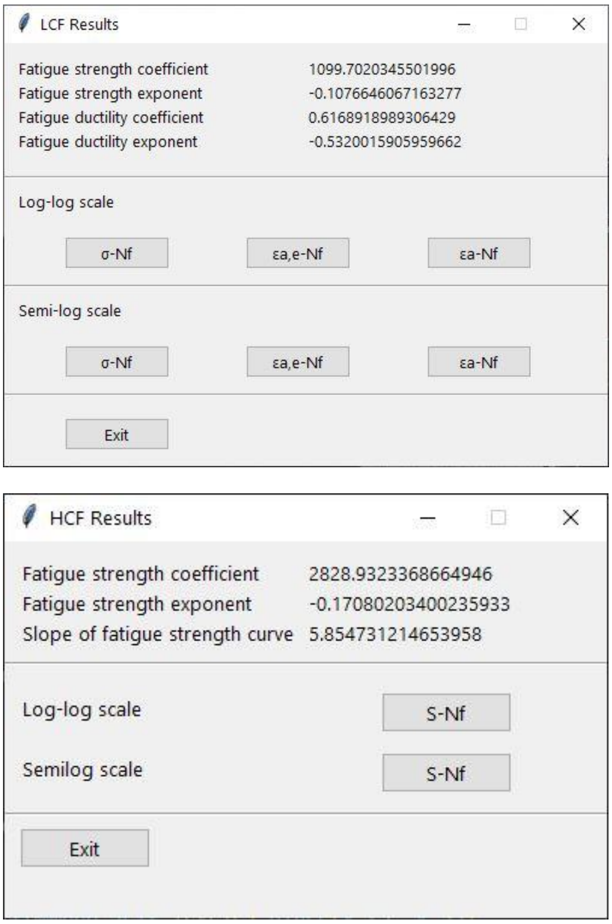

Fig.9. Obtained fatigue properties, window with results

On windows shown in Figure 9 user is enabled to plot different types of ε-N curves and S-N curves. ε-N and S-N curves can be represented in semi-log or log-log form with all results of the experimental tests.

Figure 10. present ε-N curves in log-log representation as results of using the developed software application for the determination of low-cycle fatigue properties of tested metallic material.

Figure 11. present S-N curve in semi-log representation as results of using the developed software application for the determination of high-cycle fatigue properties of tested metallic material.

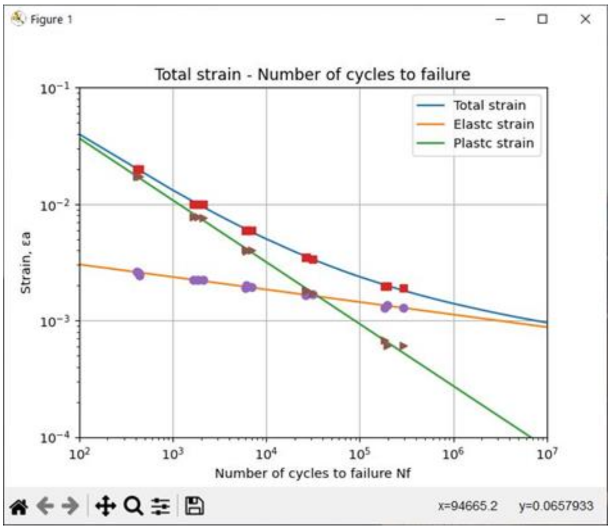

Fig.10. ε-N curves

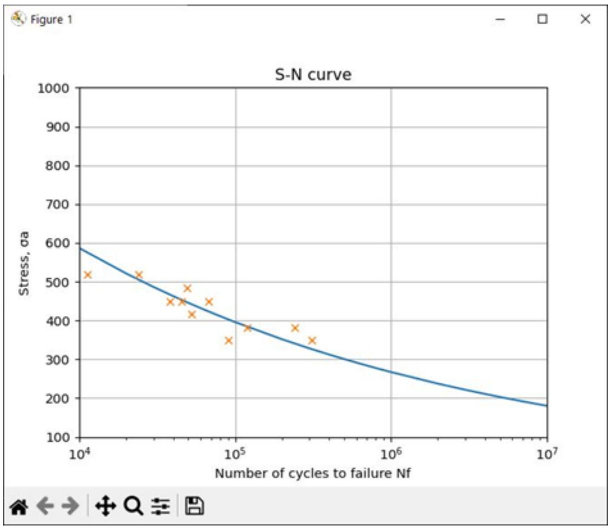

Fig.11. S-N curve

4. APPLICATION IN FINITE ELEMENT ANALYSIS

4.1. Low cycle fatigue application

This example investigates how shape optimisation affects the ultimate fatigue strength of a mechanical part. The mechanical part chosen for this investigation is an axle guard of running gear elements of the Hccrrs 2x2 axle car-carrying wagon.

Material properties were determined experimentally and the necessary numerical calculations were performed by using the finite element method. The observed axle guard is exposed to low cycle fatigue. *ε–N* curves and material properties of the S355J2+N steel grade are obtained by combining theoretical formulae and a mathematical function. According to the obtained experimental and numerical results the number of cycles until failure for both shapes of axle guards is obtained.

According to the scheme of the model loading presented in [20], the strength of the axle guards and analysis of rigidity was done for both shapes of the axle guards when the maximum lateral force is applied to the axle guard. Elastoplastic analysis for both shapes of the axle guards in the case of lateral displacement of 22 mm were done.

The aim of the elastoplastic analysis of the axle guard is the determination of the plastic strain field. Number of cycles before damage can be determined based on the maximum value of the plastic strain.

The plastic strain fields calculated by using the elastoplastic analysis for the old and the new optimized shape of the axle guard are shown in Figure 12 and Figure 13, respectively.

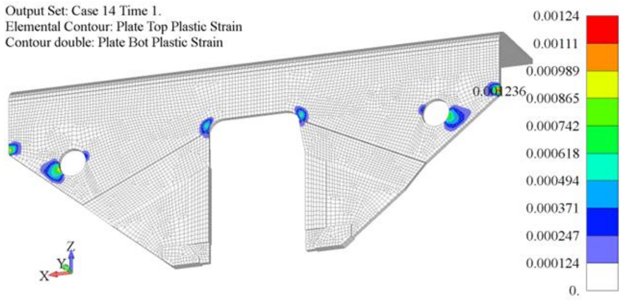

Fig.12. Plastic strain field –old shape of axle guard

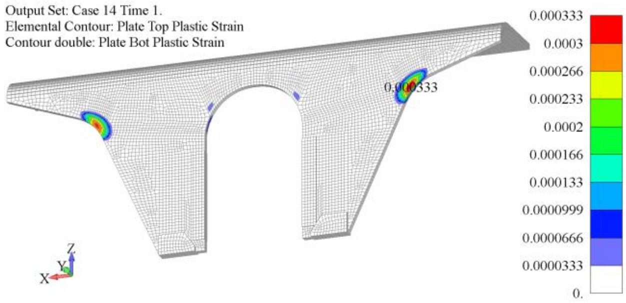

Fig.13. Plastic strain field –new optimized shape of axle guard

The maximum values of the plastic deformation of both shapes of the axle guards are shown in Figure 12 and Figure 13. The results of the elastoplastic analysis are required for the determination of the axle guard's fatigue strength, which is expressed with the number of cycles to failure. This means that the maximum value of the plastic deformation determines the number of cycles that the wagon structure part can withstand.

The strain–life curve, determined experimentally for the S355J2+N steel grade, is shown in Figure 14.

According to the results obtained by the FEM calculation, the maximum value of the plastic deformation of the old shape of the axle guard is 0.00124 (Figure 12), while the maximum value of the plastic deformation of the new optimized shape of the axle guard is 0.000333 (Figure 13).

According to the values of the plastic deformation obtained for both shapes of the axle guards and the fatigue material properties of S355J2+N, the number of cycles to failure is determined. For the old shape of the axle guard the obtained fatigue life reaches 10673 cycles, while the obtained fatigue life of the new optimized shape of axle guard reaches 287937 cycles (Figure 14).

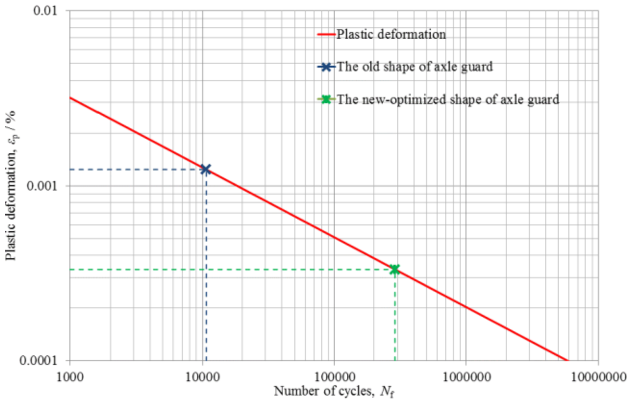

Fig.14. Plastic strain-life curve of S355J2+N material obtained by calculation of old and new optimized shape of axle guard [20]

The example presents the *ε–N* approach or a fatigue analysis based on strain, which assumes that the critical areas of material behaviour depend on the strain. The methodology presented in this section contains an experimental definition of fatigue parameters, shape optimization, a definition of the numerical model, numerical calculation of strength according to standards and estimation of fatigue strength by using experimental and numerical results.

4.2. High cycle fatigue application

This example presents a methodology used to identify causes of cracking nearby the welded joint on the underframe of wagon type Sgmns for the transportation of containers and swap bodies, exposed to high cycle fatigue [21].

Eighty percent of all wagons, which were used in transport, have failure or initial crack. After visual inspection of the wagons type Sgmns, cracks and failure were observed on the bottom side of underframe, on the side of the parking brake, Figure 15.

According to this fact, it was necessary to determine the reason for the appearance of the crack growth on the wagon bottom side of underframe. The observed cracks appear on the welded joint or near the welded joint of two plates which close rolled steel profile of bottom side of underframe, Figure 16.

Fatigue load case is specified by TSI standard [22], Clause 4.2.2.3.3 and British Standard (BS EN 12663:2000) [23], Clause 4.6, 5.2, Table 16.

Limit values for static test to verify fatigue strength, are determined for minimum number of two million constant amplitude cycles, using Eurocode 3, part 1.9 [24] as well as TSI standard [22], Annex N. Limit values for static test to verify fatigue strength for different Detail category (Constructional detail of parent material or welded joint) are shown in Table 1.

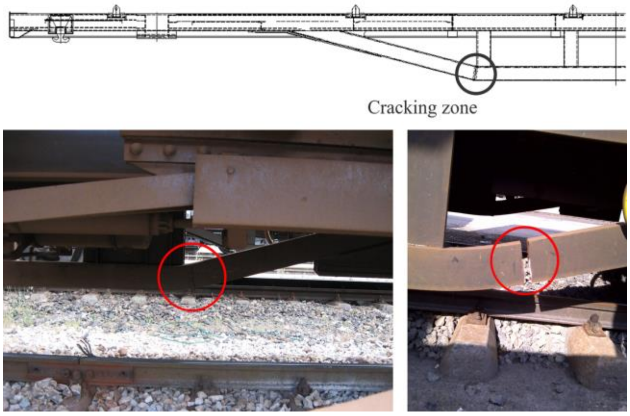

Fig.15. Crack at the bottom side of underframe

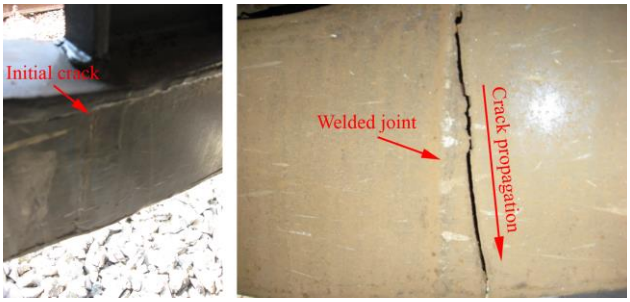

Fig.16. Initial crack and crack propagation nearby welded joint

Table 1. Limit stress values for static test to verify fatigue strength in steel S355J2+N [21]

Detail category	Permissible maximum fatigue stress [MPa]	Limit stress for safe life [MPa]	
		Low consequence (γ_{Mf}=1.15)	High consequence (γ_{Mf}=1.35)
160	347	301	257
100	217	188	160
90	195	170	144
80	173	151	128
71	154	134	114
63	136	119	101
56	121	106	90
50	108	94	80

The fatigue load used in design is in range of ±30% of vertical static load. The Von Mises equivalent stress field is shown in Figure 17. Maximal value of the equivalent stress is 291.6 MPa. The aim of this analysis was to identify cause of cracking in the bottom part of underframe, shown in Figure 15. In Figure 18, Von Mises equivalent stress field at the place of observed cracks is shown. Stress levels used in the legend in Figures 17 and 18 are defined according to Table 1.

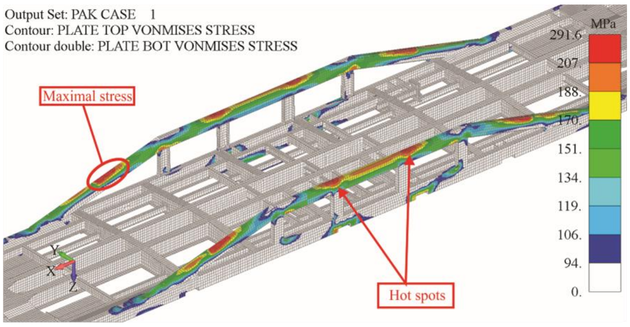

Fig.17. Crack at the bottom side of underframe

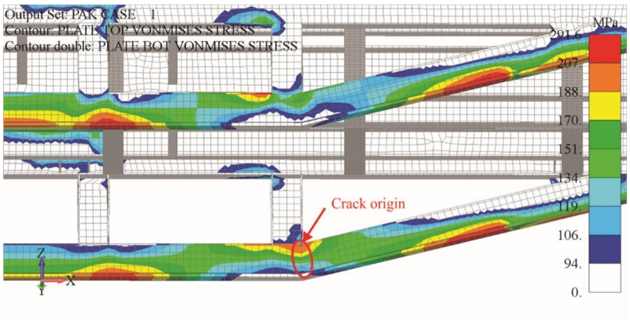

Fig.18. Initial crack and crack propagation nearby welded joint

A review of types of welds in accordance with the Eurocode-3, Section 1.9 [24] and based on the documentation on the technology of welding, observed type of welded joint belongs into the category 71 type of welds. This type of weld is given in the Eurocode-3, Section 1.9 [24] in Table 8.3, constructional detail 13 (butt welds made from one side only).

According to Table 1 for detail category 71 of transverse butt, the welds limit stress for safe life is 134 MPa. According to calculation results at the place of weld, Figure 18, stress is 194 MPa, which is higher than permissible maximum fatigue stress in Table 1. In Table 1 are shown the values of permissible stress for static fatigue testing of welded joints in accordance with Eurocode 3 Part 1.9, Figure 7.1 and Table 3.1 [24].

Maximum value of calculated stress and significant loaded zones are shown in Figure 17. All of these hot spots are in the parent material. The values of calculated stresses in these hot spots are below the limit stress for safe life in parent material (detailed category 160) according to Eurocode 3: Part 1.9 [24], Table 1.

On the basis of these facts, it can be concluded that the cracks on wagon type Sgmns are caused by service (fatigue) load.

The example presents the *S–N* approach or a fatigue analysis based on stress for high cycle fatigue strength assessment of wagon type Sgmns, at a maximal vertical load. This analysis determines that cracks are caused by fatigue in the zone of welded joint (place which connect two closing plates).

5. CONCLUSION

This paper has presented procedures for strain and stress/force-controlled fatigue testing of metallic materials. Procedures are carried out according to the internal procedures of the Centre for engineering software and dynamic testing at Faculty of Engineering University of Kragujevac, based on the relevant standards.

Using prescribed procedures, it is possible to obtain fatigue properties of tested metallic materials, both those that describe the behaviour of materials under high-cycle fatigue and those under low-cycle fatigue.

Experimental tests results have provided the basis for recommendation to use in fatigue life calculations the material cyclic properties determined in controlled conditions which are dominant during operation of structure components.

Developed software application presents useful tool for the determination of fatigue properties of metallic materials in accordance with relevant standard. As a result, the user is enabled to display the corresponding fatigue properties of the tested material as well as the corresponding *ε-N* or *S-N* curves.

For two representative examples, one for low-cycle fatigue and another for high-cycle fatigue, it is shown that the application of this methodology for fatigue assessment of different types of metallic structures.

The developed methodology based on the application of theoretical, experimental and numerical, techniques of fatigue mechanics has proven to be a powerful tool for the assessment of the fatigue life of structures exposed to fatigue loads to estimate the endurance limit and fatigue life.

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