

STU  
MTF



# TEAM 2016

## 8<sup>th</sup> International Scientific and Expert Conference



# **TEAM 2016**

**Proceedings of the 8<sup>th</sup> International Scientific and  
Expert Conference**

**19<sup>th</sup> – 21<sup>st</sup> October 2016, Trnava, Slovakia**



# **TEAM 2016, Proceedings of the 8<sup>th</sup> International Scientific and Expert Conference**

**19<sup>th</sup> – 21<sup>st</sup> October 2016, Trnava, Slovakia**

**Organizers**      International TEAM Society and Slovak University of Technology, Faculty of Materials Science and Technology in Trnava, Slovakia

All papers are reviewed.

**Place of edition:** Trnava  
**Editor:** AlumniPress  
**Year of edition:** 2016  
**Edition:** 1st  
**Pages:** 360  
**Reviewers:**  
Prof. Ing. Miloš Čambál, CSc.  
Prof. Ing. Milan Marônek, CSc.  
Assoc. prof. Ing. Mária Dománková, PhD.  
Assoc. prof. Krunoslav Mirosavljevič, Dr. Sc.

**ISBN 978 – 80 – 8096 – 237 – 1**  
**EAN 9788080962371**



### Honorary Committee

Prof. dr. sc. Dražan Kozak	Croatia
Prof. dr. sc. Ivan Samardžić	Croatia
Prof. dr. sc. Antun Stoić	Croatia
mr. sc. Josip Jukić	Croatia
Prof. Dr. Lóránt Kovács	Hungary
Prof. Dr. Ing. Jozef Peterka	Slovakia
Prof. Ing. Jozef Zajac, CSc.	Slovakia
Prof. dr. sc. Vlado Guberac	Croatia
Prof. Dr. Radivoje Mitrović	Serbia
Prof. Dr. Aleksandar Sedmak	Serbia

### Scientific Committee

Prof. Zoran Radakovic	Serbia
Dr. Vojislav Simonovic	Serbia
Dr. Zorana Golubovic	Serbia
Prof. Aleksandar Sedmak	Serbia
Dr. Nenad Mitrovic	Serbia
Dr. Milos Milosevic	Serbia
Dr. Sanja Petronic	Serbia
Dr. Katarina Colic	Serbia
Prof. Snezana Kirin	Serbia
Dr. Srdjan Tadic	Serbia
Dr. Zsolt Csaba Johanyák	Hungary
Dr. Lorant Kovács	Hungary
Dr. Erika Török	Hungary
Dr. Judit Pető	Hungary
Dr. Árpád Ferencz	Hungary
Prof. dr. sc. Ivan Samardžić	Croatia
Prof. dr. sc. Dražan Kozak	Croatia
Prof. dr. sc. Antun Stoić	Croatia
Prof. dr. sc. Želiko Ivandić	Croatia
Prof. dr. sc. Goran Šimunović	Croatia
Prof. dr. sc. Vlado Guberac	Croatia
Prof. dr. sc. Sonja Marić	Croatia
Prof. dr. sc. Zvonko Antunović	Croatia
Prof. dr. sc. Darko Kiš	Croatia
Prof. dr. sc. Jasna Šoštarić	Croatia
mr.sc. Josip Jukić	Croatia
Assoc. prof. dr. sc. Krunoslav Mirosavljević	Croatia
dr. sc. Teuta Benković-Lačić	Croatia
dipl. Ing. Ivica Lacković	Croatia
Milan Stanić	Croatia
Prof. Ing. Milan Marônek, CSc.	Slovakia
Assoc. prof. Ing. Mária Dománková, PhD.	Slovakia
Prof. Ing. Miloš Čambál, CSc.	Slovakia
Prof. Ing. Alexander Čaus, DrSc.	Slovakia
Prof. Ing. Maroš Soldán, PhD.	Slovakia



Prof. Ing. Jozef Zajac, CSc.	Slovakia
Assoc prof. Ing. Ján Piteľ, CSc.	Slovakia
Assoc prof. Ing. Peter Monka, PhD.	Slovakia
Prof. RNDr. Dušan Knežo, CSc.	Slovakia
Dr.hc. prof. Ing. Karol Vasilko, DrSc.	Slovakia
Prof. Ailer Piroška	Hungary
Prof. Nicolae Balc	Romania
Dr. Mislav Balković	Croatia
Dr. Jozef Bárta	Slovakia
Prof. Slađana Benković	Serbia
Prof. Pavel Beňo	Slovakia
Prof. Ivana Bilić	Croatia
Prof. Zlatan Čar	Croatia
Prof. Somnath Chattopadhyaya	India
Prof. Robert Čep	Czech Republic
Prof. Ante Čikić	Croatia
Prof. Dražena Gašpar	Bosnia and Herzegovina
Prof. Nenad Gubeljak	Slovenia
Prof. Fuad Hadžikadunić	Bosnia and Herzegovina
Prof. Sergej Hloch	Slovakia
Prof. Grzegorz Królczyk	Poland
Prof. Leon Kukielka	Poland
Prof. Stanislaw Legutko	Poland
Prof. Marin Milković	Croatia
Prof. Mirjana Pejić Bach	Croatia
Prof. Marko Rakin	Serbia
Prof. Pero Raos	Croatia
Prof. Alessandro Ruggiero	Italia
Prof. Bahar Sennaroğlu	Turkey
Prof. Stevan Stankovski	Serbia
Prof. Mladen Šercer	Croatia
Prof. Udo Traussnigg	Austria
Prof. Vlado Tropša	Croatia
Prof. Nicolae Ungureanu	Romania
Prof. Jan Valíček	Czech Republic
Prof. Djordje Vukelić	Serbia

#### **Organising Committee**

Prof. Milan Marônek, PhD.  
 Ing. Jozef Bárta, PhD. (Chairperson)  
 Ing. Ivan Buranský, PhD.  
 Ing. Ingrid Kovaříková, PhD.  
 Ing. Beáta Šimeková, PhD.  
 Ing. Martin Bajčičák, PhD.  
 Assoc. Prof. Erika Hodúlová, PhD.  
 Prof. Koloman Ulrich, PhD.  
 PhDr. Kvetoslava Rešetová, PhD.  
 PaedDr. Dáša Zifčáková



## CONTENT

### TECHNICS SECTION

Using the Ant Colony Optimization method to find an optimal solution in drilling process.....	8
Numerical examination of a system model with a nonlinear component.....	12
Distributed congestion detection and classification method for the analysis of velocity.....	17
Development of the Lower Body of Assistive Humanoid Robot MARKO.....	23
Optimization of Planetary Gear Trains with Spur, Helical and Double Helical Gears.....	29
Optimal Synthesis of the Loader Bucket Mechanism.....	35
Analysis of the Mechanism of Complex Structures with High Class Kinematic Group.....	41
Investigation of Ultrasonic Assisted Milling of Nickel Alloy Monel.....	47
Influence of selected parameters on the machining of sintered carbide by WEDM.....	53
Review of Anomaly-Based IDS Algorithms.....	58
Survey on SDN Programming Languages.....	64
Chip formation mechanism during composite materials machining.....	71
Estimation of statistical parameters of electric appliances based on environmental measurements.....	75
Manufacturing of Twist-Free Surfaces by MAM Technologies.....	79
Coefficient of friction in the design of non-metallic brittle interference fit parts.....	84
Control system design of the parallel kinematics mechatronic press.....	88
Comparison of laser beam cutting and milling of plastics materials made from PMMA focusing on mechanical properties of the material.....	94
Statistical process control in the gear wheel manufacturing.....	99
Cutting analysis of CFRP composites.....	107
Development of On-line monitoring system for monitoring main welding parameters.....	111
Dilatometric testing of maraging steel.....	118
Design and calculation of cylindrical industrial air filter device with use of CFD analysis.....	124
Equalization of stress distribution on threaded connection optimizing pitch geometry.....	134
Influence of the mini - dental implants diameter on stress in the surrounding bone.....	141
The impact of cutting speed and pressure on surface quality during plasma cutting.....	147
Finite Elements Investigation of Laser Welding in a keyhole Mode.....	151
A Study of Laser Sheet Bending with Finite Elements Method.....	155
Structural integrity assessment of a pressure vessel.....	160
Risk based management of pressure equipment safety.....	165
Procedures and evaluation of the stress strain fields on the Locking Compression Plates.....	171
Hardness and metallographic tests of repaired starting vessel used in thermal power plant unit B.....	180



The influence of electron beam welding process on properties of superduplex stainless steel S32507 weld joints .....	185
Wizardry of water – ram pump .....	190
Development and construction of machine for fused deposition modeling .....	195
Numerical simulation of metal cutting using the software DEFORM 2D .....	201
Kerf Variation Analysing After Cutting With Abrasive Water Jet of a Steel Part.....	211
Experimental determination of Tensile Strain-Hardening Exponent and Strength Coefficient of the S355J2+N steel grade.....	218
Specifics of the possible applications of polyester laminates considering mechanical properties .....	224
Design, 3d model and calculation of pelleting machine.....	229
Selecting Image Feature Points Based on the Object Contour Curvature .....	237
Design of polymeric electrolyte membrane reformer.....	241
Initial Sensitivity Analysis of Packed-bed Methanol Steam Reforming Reactor.....	245
Structural Integrity Assessment of a Pressure Vessel .....	251
Flat Die Sliding Model with Variable Contact Pressure in Deep Drawing Process.....	255
Thermal Analysis of Packed-bed Methanol Steam Reforming Reactor.....	259

## EDUCATION SECTION

The difference in somatotype between football and not football players.....	263
Effectiveness indicators and ensuring conditions in dual training .....	268
Functions associated with the weighted mean and median .....	275
Overdetermined systems of linear equations.....	280
Optimal number of clusters provided by K-means and E-M algorithm .....	286

## AGRICULTURE SECTION

Comparative analysis of features in computer vision for apple quality monitoring.....	292
Ambrosia artemisiifolia allelochemicals and relationship to pollen allergy with air pollution.....	297
Weed control of potato with herbicide containing the active substance metribuzin .....	302
Economic evaluation of different technology in the corn growing in Hungary .....	307
Effect of nitrogen on the growth and ingredients of celery .....	312
Familiarity of Honey Products in Slavonski Brod .....	317

## MANAGEMENT SECTION

Financial analysis – indicator of business success .....	322
The impact of the economic crisis on youth leaving Croatia .....	326
Youth Entrepreneurship .....	330



Emotional intelligence in business .....	334
Importance of managing communication process in crisis situations .....	338
Diversification as growth strategy for small enterprises .....	344
Company size and employee training: Case of Vojvodina Manufacturing Industry.....	350
Is Economy of Vojvodina ready for joining EU ?.....	355



# Experimental determination of Tensile Strain-Hardening Exponent and Strength Coefficient of the S355J2+N steel grade

V. Milovanović <sup>a</sup>, A. Dišić <sup>b</sup> G. Jovičić <sup>c</sup>, M. Živković <sup>d</sup>

<sup>a</sup> Faculty of Engineering University of Kragujevac, Sestre janjić 6, 34000 Kragujevac, Serbia, vladicka@kg.ac.rs

<sup>b</sup> Faculty of Engineering University of Kragujevac, Sestre janjić 6, 34000 Kragujevac, Serbia, aleksandardisic@gmail.com

<sup>c</sup> Faculty of Engineering University of Kragujevac, Sestre janjić 6, 34000 Kragujevac, Serbia, gjovicic.kg.ac.rs@gmail.com

<sup>d</sup> Faculty of Engineering University of Kragujevac, Sestre janjić 6, 34000 Kragujevac, Serbia, miroslav.zivkovic@kg.ac.rs

## Abstract

The purpose of this paper is to determine tensile strain-hardening exponent and strength coefficient of the S355J2+N steel grade utilizes stress-strain data obtained in a uniaxial tension test. Tensile data were obtained in continuous and rate-controlled manner via displacement control. Ramberg-Osgood relationship was used to describe the uniaxial tension behaviour of the S355J2+N steel grade. The tensile strain-hardening exponent and strength coefficient are determined from an empirical representation over the relation between the true-stress versus true-strain.

**Keywords:** strain-hardening exponent, strength coefficient, yield stress-strain

## 1. INTRODUCTION

It is well known that both the strain-hardening exponent and the strength coefficient are basic mechanical behaviour performance parameters of metallic materials. When the tensile properties of metallic materials are being evaluated, these two parameters must be known. The value of strain-hardening exponent gives measure of the material's work hardening behaviour and is usually between 0 and 0.5. Values of strength coefficient and strain-hardening exponent for some engineering alloys are given in [1].

There are many methods for determination strength coefficient and strain-hardening exponent. Theoretical calculation of the strain-hardening exponent and the strength coefficient of metallic materials were presented in [2]. Authors were obtained some theoretical results from the deduced expressions and compared with test data. Some authors investigated strain-hardening exponent with a new method named "Double Compression Test". The test was performed experimentally and the results were compared with those obtained by the conventional method [3]. Predicting work hardening exponent of engineering metals using



residual indentation profiles of nano-indentation were presented in [4].

Today steels represent the most used group of mechanical materials. Steels are used in various branches of industry for constructing bridges, buildings, ships, cars, rail vehicles, railways. There are several thousand types of steel obtained by an appropriate combination of carbon and alloying elements of different characteristics.

Because of good mechanical properties, good cutting, forming (forging, rolling, extrusion, pressing), good weldability and low prices, structural steels are widely used in industry. The most commonly used steel for producing carrying parts of structures, exposed to dynamic loads and low temperatures is medium-strength S355J2+N steel grade.

This paper presents determination of tensile strain-hardening exponent and strength coefficient of the S355J2+N steel grade utilizes stress-strain data obtained in a uniaxial tension test according to ASTM E646-00 [5].

## 2. THEORETICAL BASES

The uniaxial tension test is the most common method for determining the mechanical properties of materials, such as strength, ductility, toughness, elastic modulus, stress-strain behaviour and strain hardening capability. Uniaxial tension stress-strain properties are usually reported in handbooks and are used in many specifications. Stress-strain behaviour is obtained from uniaxial tension test where specimen with circular or rectangular cross section with the uniform gage length is subjected to increasing tensile force until it fractures.

When the load (force) is applied, the specimen elongates in proportion to the load, called linear elastic behaviour. If the load is removed, the specimen returns to its original length and shape.

As the load is increased, the specimen begins to undergo nonlinear elastic deformation at a stress called the proportional limit. At that point,

the stress and strain are no longer proportional, as they were in the linear elastic region, but when unloaded, the specimen still returns to its original shape. Permanent (plastic) deformation occurs when the yield stress, of the material is reached.

Property of material that the increase of plastic deformation leads to an increase of yield strength is called work hardening. Knowledge of these property is very important to describe the behaviour of metals in the region of plasticity. In the plastic region, a commonly used relation to define the relation between stress and strain is given by equation:

$$\sigma = K(\varepsilon_p)^n, \quad (1)$$

where  $K$  is strength coefficient and  $n$  strain hardening coefficient.

According to equation (1) and relation that the total strain equals the sum of the elastic and plastic strain and in the region of elasticity Hooke's law is valid, equation for total strain can be derived. Equation (2) represents analytical true stress – true strain relationship, often referred to as the “Ramberg-Osgood relationship” [1], [6], [7], [8]:

$$\varepsilon = \frac{\sigma}{E} + \left( \frac{\sigma}{K} \right)^{\frac{1}{n}}. \quad (2)$$

In equations (1) and (2)  $\sigma$  and  $\varepsilon$  represent true stress and true strain. True strain is the natural logarithm of the ratio of instantaneous length,  $l$ , to the original gage length  $l_0$  that is:

$$\varepsilon = \ln \left( \frac{l}{l_0} \right) = \ln(1+e). \quad (3)$$

True stress is the instantaneous normal stress, calculated on the basis of the instantaneous cross-section area,  $A$ , that is:

$$\sigma = \frac{F}{A} = S(1+e). \quad (4)$$

In equation (3)  $e$  represent engineering strain – dimensionless value that is the change in length  $\Delta l$  per unit length of original linear dimension  $l_0$  along the loading axis of specimen:



$$e = \frac{l-l_0}{l_0} = \frac{\Delta l}{l_0} \quad (5)$$

In equation (4)  $S$  represent engineering stress – the normal stress, expressed in units of applied force,  $F$ , per unit of original cross-section area,  $A_0$ :

$$S = \frac{F}{A_0} \quad (6)$$

### 3. EXPERIMENTAL PROCEDURE

Experimental determination of tensile strain-hardening exponent and strength coefficient of the S355J2+N steel grade, was done on SHIMADZU Servopulser EV101K3-070-0A [9] (Figure 1.).

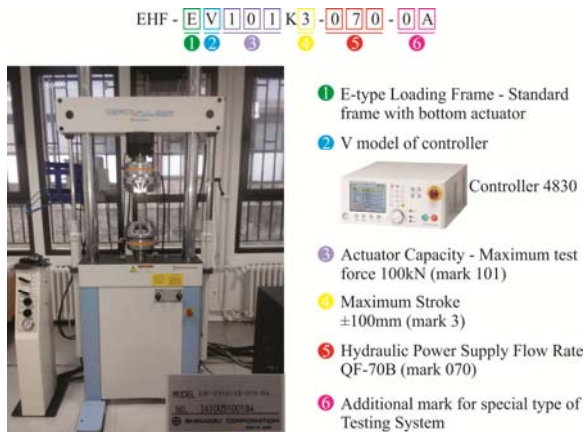


Fig. 1. SHIMADZU Srevopulser EHF-EV101K3-070-0A

Experimental determination of tensile strain-hardening exponent and strength coefficient of the S355J2+N steel grade was done at room temperature ambient ( $23 \pm 5^\circ\text{C}$ ) under static loading conditions.

The shape and dimensions one of tested specimens are shown on Figure 2., in accordance with standard ASTM E646-00 [5].

In preparing the specimens, it is necessary to make a representative specimen, which is flat and the same thickness in all cross sections. Especially attention should be paid to prevent of appearance any possible residual stresses.

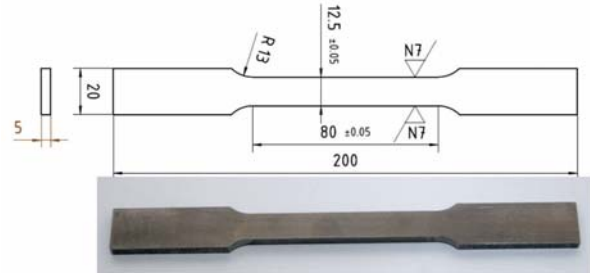


Fig. 2. Specimen for determining Tensile Strain-Hardening Exponent and Strength Coefficient

Testing of specimens for determining tensile strain-hardening exponent and strength coefficient were done at room temperature ambient in stroke control, without change speed of testing, during the strain interval over which  $n$  was determined (region of plasticity). Rate of speed load is 4mm/min.

For the purpose of measurement of elongation, on gage length (50mm), extensometer Mess & Feinwerktechnik GmbH MFA25 was used (Figure 3.).

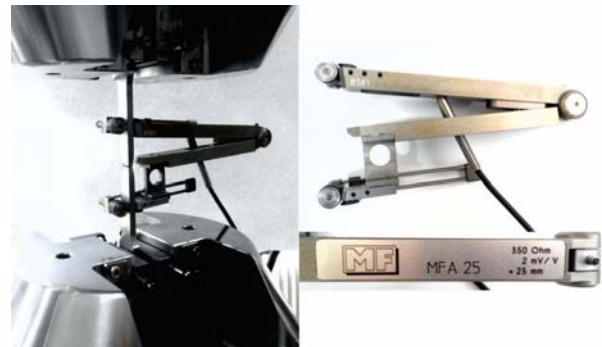


Fig. 3. Extensometer MFA25

### 4. RESULTS AND DISCUSSION

Load-engineering strain diagram, with data-pairs, for determination of tensile strain-hardening exponent and strength coefficient of the S355J2+N steel grade is shown on Figure 4. Measured values of force and corresponding values of engineering strain into nine equal intervals in the plastic region, obtained during the tests procedure are shown in Table 1.

All other parameters necessary for the further determination of tensile strain-hardening exponent and strength coefficient could be obtained based on the values of force and elongation. Values of engineering and true stress



and engineering and true strain can be determined from the equations (6), (4), (5) and (3), respectively.

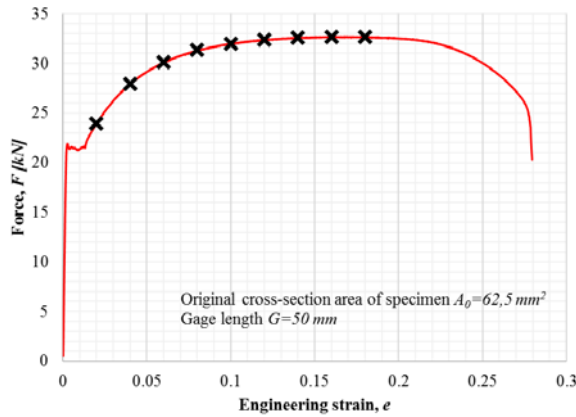


Fig. 4. Load-engineering strain diagram with data-pairs (S355J2+N)

For determination of tensile strain-hardening exponent  $n$  and strength coefficient  $K$  it necessary logarithmic form of the equation (1). Logarithmic form of the power curve representation of the true-stress versus true-strain curve within region of plasticity is given by:

$$\log \sigma = \log K + n \log \varepsilon. \quad (7)$$

According to selected data-pairs and calculated logarithm values of true-stress ( $\log \sigma$ ) and true strain ( $\log \varepsilon$ ), via linear regression analysis, tensile strain-hardening exponent  $n$  can be determined by

$$n = \frac{N \sum_{i=1}^N (\log \varepsilon_i \log \sigma_i) - \left( \sum_{i=1}^N \log \varepsilon_i \sum_{i=1}^N \log \sigma_i \right)}{N (\log \varepsilon_i)^2 - \left( \sum_{i=1}^N \log \varepsilon_i \right)^2}, \quad (8)$$

where  $N$  represents number of data-pairs.

Equation (8) are made convenient by symbolic representation for:  $Y = \log \sigma$ ,  $X = \log \varepsilon$  and  $b = \log K$ , as follows:

$$n = \frac{N \sum XY - \sum X \sum Y}{N \sum X^2 - (\sum X)^2}. \quad (9)$$

Strength coefficient  $K$  can be determined by:

$$K = 10^b, \quad (10)$$

where

$$b = \frac{\sum Y}{N} - n \frac{\sum X}{N}. \quad (11)$$

All test results for experimental determination of tensile strain-hardening exponent and strength coefficient of the S355J2+N steel grade are shown in Table 1. According to previously derived equations, experimentally obtained results of test and via linear regression analysis tensile strain-hardening exponent and strength coefficient were determined. Procedure of their determination were summarized in algorithm and given in Table 2.

Table 1 Determination of the Strain Hardening Exponent and Strength Coefficient – Testing Results

Data pair	Load [kN]	$S$ [MPa]	$\sigma$ [MPa]	$Y$ $\log_{10} \sigma$	$Y^2$	$\Delta l$ [mm]	$e$	$\varepsilon$	$X$ $\log_{10} \varepsilon$	$X^2$	$XY$
1	23.972	383.52	391.22	2.592	6.721	1	0.02	0.012	-1.703	2.901	-4.416
2	27.965	447.44	465.34	2.668	7.117	2	0.04	0.039	-1.407	1.978	-3.752
3	30.121	481.94	510.85	2.708	7.335	3	0.06	0.058	-1.235	1.524	-3.344
4	31.355	501.68	541.81	2.734	7.474	4	0.08	0.077	-1.113	1.240	-3.045
5	31.995	511.92	563.11	2.751	7.566	5	0.10	0.095	-1.021	1.042	-2.808
6	32.434	518.94	581.22	2.764	7.642	6	0.12	0.113	-0.946	0.894	-2.614
7	32.628	522.05	595.13	2.775	7.699	7	0.14	0.131	-0.883	0.779	-2.449
8	32.671	522.74	606.37	2.782	7.744	8	0.16	0.148	-0.829	0.686	-2.306
9	32.694	523.10	617.26	2.791	7.787	9	0.18	0.166	-0.781	0.610	-2.180



Table 2 Algorithm and Worksheet for Calculating the Strain Hardening Exponent and Strength Coefficient of steel S355J2+N grade

Marks:

$$X = \log \varepsilon$$

$$Y = \log \sigma$$

$n$  – strain hardening coefficient

$b$  – log of the strength coefficient

All data were taken from Fig. 4 and evaluated in Table 1. The number of data pairs is  $N=9$ . All logarithms are base10.

A. Ordering data from Table 1.

$$\Sigma X = \Sigma(\log \varepsilon_i) = -9.9169$$

$$\bar{X} = \frac{\Sigma X}{N} = \frac{-9.9169}{9} = -1.1019$$

$$\Sigma X^2 = \Sigma(\log \varepsilon_i)^2 = 11.6560$$

$$\Sigma Y = \Sigma(\log \sigma_i) = 24.5651$$

$$\bar{Y} = \frac{\Sigma Y}{N} = \frac{24.5651}{9} = 2.7295$$

$$\Sigma Y^2 = \Sigma(\log \sigma_i)^2 = 67.0826$$

$$\Sigma(X \cdot Y) = \Sigma((\log \varepsilon_i) \cdot (\log \sigma_i)) = -26.9125$$

B. Determination of strain hardening exponent  $n$

$$\text{Step 1} \quad \frac{\Sigma X \cdot \Sigma Y}{N} = \frac{-9.9169 \cdot 24.5651}{9} = -27.0677$$

$$\text{Step 2} \quad S_{XY} = \Sigma(X \cdot Y) - \text{Step 1} = -26.9125 - (-27.0677) = 0.1552$$

$$\text{Step 3} \quad \frac{(\Sigma X)^2}{N} = \frac{(-9.9169)^2}{9} = 10.9272$$

$$\text{Step 4} \quad S_{XX} = \Sigma X^2 - \text{Step 3} = 11.6560 - 10.9272 = 0.7288$$

$$\text{Step 5} \quad n = \frac{S_{XY}}{S_{XX}} = \frac{\text{Step 2}}{\text{Step 4}} = \frac{0.1552}{0.7288} = 0.2129$$

C. Determination of strength coefficient  $K$

$$\text{Step 6} \quad n\bar{X} = 0.2129 \cdot (-1.1019) = -0.2346$$

$$\text{Step 7} \quad b = \bar{Y} - n\bar{X} = \bar{Y} - \text{Step 6} = 2.7295 - (-0.2346) = 2.9640$$

$$\text{Step 8} \quad K = 10^b = 10^{2.9640} = 920.4955 \text{ MPa}$$



The red line of stress-strain diagram on Figure 5 shows that the power function with determined tensile strain-hardening exponent and strength coefficient is a good approximation of the plastic portion of the curve true-stress versus true-strain obtained by experiment.

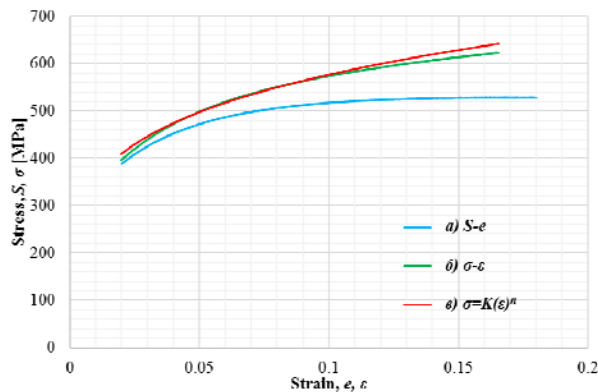


Fig. 5. Stress-strain diagram

## 5. CONCLUSIONS

This paper describes the determination of the tensile strain-hardening exponent and strength coefficient of the S355J2+N steel grade exhibiting a continuous stress-strain curve in the plastic region. The stress-strain data was obtained in a uniaxial tension test. The displacement was applied in a continuous and rate-controlled manner while the normal tensile load and strain are monitored. Based on obtained data and test results, true-stress and true-strain were calculated. According to ASTM E646-00 and calculated logarithm values of true-stress and true strain, via linear regression analysis, tensile strain-hardening exponent and strength coefficient were determined.

Results obtained by power function with determined tensile strain-hardening exponent and strength coefficient show good approximation of the plastic portion of the curve true-stress versus true-strain obtained by experiment. This results and their good matching give a good basis for further research and analysis.

## 6. ACKNOWLEDGEMENTS

The part of this research is supported by Ministry of Education, Science and

Technological Development, Republic of Serbia, Grant TR32036.

## 7. REFERENCES

- [1] R. Stephens, A. Fatemi, R. Stephens and H. Fuchs, *Metal Fatigue in Engineering*, New York: John Wiley & Sons Inc., (2001)
- [2] Z. Zhang, Q. Sun, C. Li, and W. Zhao, Theoretical Calculation of the Strain-Hardening Exponent and the Strength Coefficient of Metallic Materials. *Journal of Materials Engineering and Performance* 15 (2006), pp 19-22
- [3] R. Ebrahimi, N. Pardis, Determination of strain-hardening exponent using double compression test. *Materials Science and Engineering A* 518 (2009), pp. 56–60
- [4] Byung-Min Kim, Chan-Joo Lee, and Jung-Min Lee, Estimations of work hardening exponents of engineering metals using residual indentation profiles of nano-indentation, *Journal of Mechanical Science and Technology* 24 (2010), pp.73-76
- [5] ASTM: E646-00 Standard Test Method for Tensile Strain-Hardening Exponents (n-Values) of Metallic Sheet Materials, 2000.
- [6] G. Jovičić, M. Živković and S. Vulović, *Fracture and Fatigue Mechanics*, Kragujevac: Faculty of Mechanical Engineering, University of Kragujevac, 2011. (in Serbian)
- [7] O. H. Basquin, "The Exponential Law of Endurance Tests," *Proc. ASTM*, vol. 10, no. 11, p. 625, 1910.
- [8] M. Živković, *Nonlinear Analysis of Construction*, Kragujevac: Faculty of Mechanical Engineering, University of Kragujevac, 2006. (in Serbian)
- [9] SHIMADZU Servopulser Fatigue and Endurance Testing Systems