UNIVERSITY OF EAST SARAJEVO

FACULTY OF MECHANICAL ENGINEERING

4th INTERNATIONAL SCIENTIFIC CONFERENCE

COMETa2018

„Conference on Mechanical Engineering Technologies and Applications“

PROCEEDINGS

27th-30th November

East Sarajevo-Jahorina, RS, B&H

COMETa 2018
4th INTERNATIONAL SCIENTIFIC CONFERENCE

27th - 30th November 2018
Jahorina, Republic of Srpska, B&H

University of East Sarajevo
Faculty of Mechanical Engineering
Conference on Mechanical Engineering Technologies and Applications

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27 - 30. Novembar 2018.

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PREFACE

Faculty of Mechanical Engineering East Sarajevo is organizing the 4th International Scientific Conference COMETa 2018 - "Conference on Mechanical Engineering Technologies and Applications“. The aim of the conference is to contribute to the implementation of new technologies in production processes by achieving better cooperation between scientific research institutions and companies, and to enable practical application of research results presented in the proceedings.

The main objective of the conference is to bring together eminent domestic and international experts in the field of engineering and the application of new technologies and the development of mechanical systems, and to contribute increasing the competitiveness of the domestic economy through the exchange of experience and knowledge, public presentations of current research and new construction solutions.

The organization of previous conferences COMETa2012, COMETa2014 and COMETa2016, according to the assessments of participants, especially foreign colleagues, were successful.

The efforts were recognized by the Ministry of Science and Technology of the Republic of Srpska, since in May 2018 the COMETa conference was ranked among international scientific conferences of the first category.

The COMETa 2018 conference program consists of the following thematic areas:

- *Manufacturing technologies and advanced materials,*
- *Applied mechanics and mechatronics,*
- *Machine design and product development,*
- *Energy and environmental protection,*
- *Maintenance and technical diagnostic,*
- *Quality, management and organization.*

At this year's COMETa2018 conference, a record number of papers from the country and abroad have been submitted. In total 277 authors from 13 countries participates in the international conference COMETa2018, 112 papers were accepted, including 4 plenary papers. Within the COMETa2018 conference, it is planned to organize two working meetings that will focus on the current topics of the Conference.

With the desire to improve the organizational as well as the scientific effect of the Conferences, and appreciating the contributions made by the scientific community in this way, we want to emphasize that each of your suggestions is more than welcome and will be appreciated in connection with the above.

On behalf of the Organizing and Scientific Committee of the COMETa2018 conference, we would like to express our gratitude to all authors, reviewers, institutions, companies and individuals who contributed to the Conference.

Hoping that the results of our joint work will meet expectations, the organizer of the Conference, Faculty of Mechanical Engineering East Sarajevo, wants you active participation that will contribute to the development of modern ideas and solutions, in the spirit of technical and technological development of the modern world.

We wish you a pleasant stay in Jahorina. Welcome to the COMETa2018 conference.

East Sarajevo, November 21st, 2018.

President of the Scientific Committee	*President of the Organizing Committee*
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DETERMINATION OF TENSILE STRAIN-HARDENING EXPONENT AND STRENGTH COEFFICIENT FOR HIGH STRENGTH STEEL AT ELEVATED TEMPERATURE

Vladimir Milovanović [1], Aleksandar Dišić[2], Vukašin Slavković[3], Miroslav Živković[4]

Abstract: The purpose of this paper is to determine tensile strain-hardening exponent and strength coefficient of the STRENX 700 steel utilizes stress-strain data obtained in a uniaxial tension test at elevated temperature. 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 STRENX 700 steel. The tensile strain-hardening exponent and strength coefficient at elevated temperature are determined from an empirical representation over the relation between the true-stress versus true-strain.

Key words: Tensile properties, elevated temperature, high strength steel, strength hardening coeficient, strength hardening exponent

1 INTRODUCTION

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. The development of steel has created an opportunity for manufacturers to produce a wide range of steels with different characteristics to suit the intended use, by combining the small percentage quantity of carbon with other alloying elements. During certain technological processes of production of parts and exploitation in extreme conditions like high temperatures, knowing the behavior of the material and its mechanical characteristics in these conditions is necessary. For ductile materials, reduction in strength and additional increases ductility are coming with increasing temperature. This behavior of the materials is the result of the influence of the temperature on its deformation. In order to determine the characteristics of the material

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in this case, it is necessary to perform material testing at elevated temperature.

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. 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 [1]. Many authors investigated strain-hardening exponent with some new methods where the tests were performed experimentally and the results were compared with those obtained by the conventional method [2]. Values of strength coefficient and strain-hardening exponent for some engineering alloys at room temperature are given in [3].

This paper presents determination of tensile strain-hardening exponent and strength coefficient of the STRENX 700 steel at elavated temperature utilizes stress-strain data obtained in a uniaxial tension test according to ISO 6892-2 [4], ASTM E21-17 [5].

2 TESTING AT ELEVATED TEMPERATURE

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.

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:

$$\sigma = K(\varepsilon_p)^n \,, \tag{1}$$

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” [3], [7], [8], [9].

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

The tests at elevated temperature consist in assessing the behavior and determining the mechanical properties of the material under load. Three basic test methods are distinguished [6]:

- Short-term heating (tensile testing, compressing, bending, impact strength, etc.),
- Long-term heating (creeping, relaxation, etc.),
- Short-term and long-term heating after long-term heating at elevated temperatures.

Tensile testing at elevated temperatures over 35 °C is carried out in accordance with a procedure that basically coincides with the test procedure standard for tensile at room temperature. The methodology for testing of metallic materials at elevated temperatures is defined by the standards ISO 6892-2 [4], ASTM E21-17 [5] and ASTM E646-00 [10].

3 EXPERIMENTAL PROCEDURE OF TENSILE TESTING AT ELEVATED TEMPERATURES

Uniaxial tension at elevated temperature was carried out at the Center for Engineering Software and Dynamic Testing at the Faculty of Engineering Sciences, University of Kragujevac, according to standards ISO 6892-2 [4], ASTM E21-17 [5] and ASTM E646-00 [10]. The testing program includes the testing of mechanical characteristics at five temperatures from 100 °C to 500 °C, including room temperature.

Experimental determination of tensile strain-hardening exponent and strength coefficient of the STRENX 700 steel at room temperature, was done on SHIMADZU Servopulser EV101K3-070-0A (Figure 1.). The shape and dimensions one of tested specimens are shown on Figure 2., in accordance with mentioned standards.

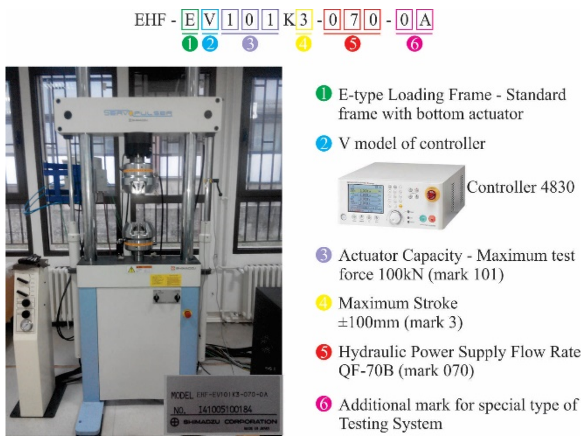

Figure 1. *SHIMADZU Srevopulser EHF-EV101K3-070-0A*

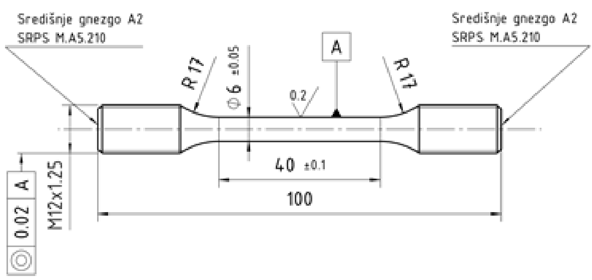

Figure 2. *Specimen for determining Tensile Strain-Hardening Exponent and Strength Coefficient at Elevated Temperature*

For the purpose of measurement of elongation, on gage length (*25 mm*) at high temperature, extensometer EPSILON 3548-025M-050-ST (Figure 3) was used which was installed in the furnace in a horizontal position. The selected strain rate is $5\ 10^{-4}\ s^{-1}$, which corresponds to the velocity of the cross head of *0.02 mm/s*.

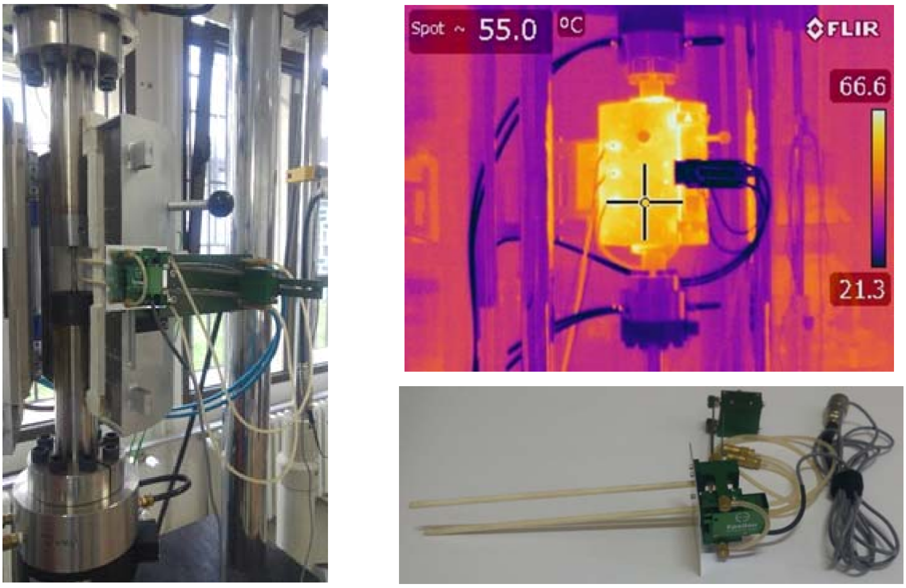

Figure 3. *Extensometer EPSILON 3548-025M-050-ST*

Load-engineering strain diagram, with data-pairs, for determination of tensile strain-hardening exponent and strength coefficient, according to ASTM E646-00 [10] is shown in Figure 4.

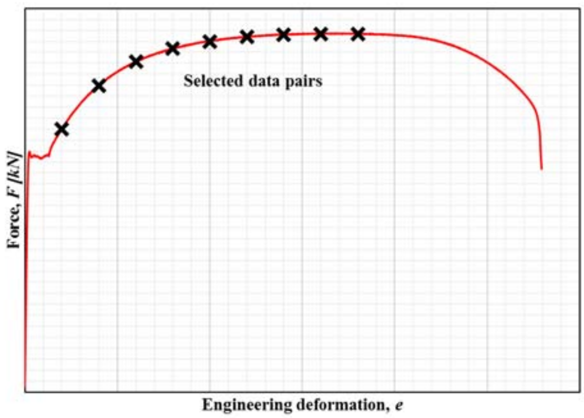

Figure 4. *Load-engineering strain diagram with data-pairs*

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. 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:

$$\log \sigma = \log K + n \log \varepsilon \,, \tag{3}$$

According to selected data-pairs and calculated logarithm values of true-stress *(logσ)* and true strain *(logε)*, tensile strain-hardening exponent *n and* and strength coefficient *K* can be determined via linear regression analysis in accordance with procedure shown in [10].

4 RESULTS AND DISCUSSION

Specimens after testing and coresponding stress-strain curves from uniaxial tension tests of STRENX 700 steel at room and elevated temperature are shown in Figure 5.

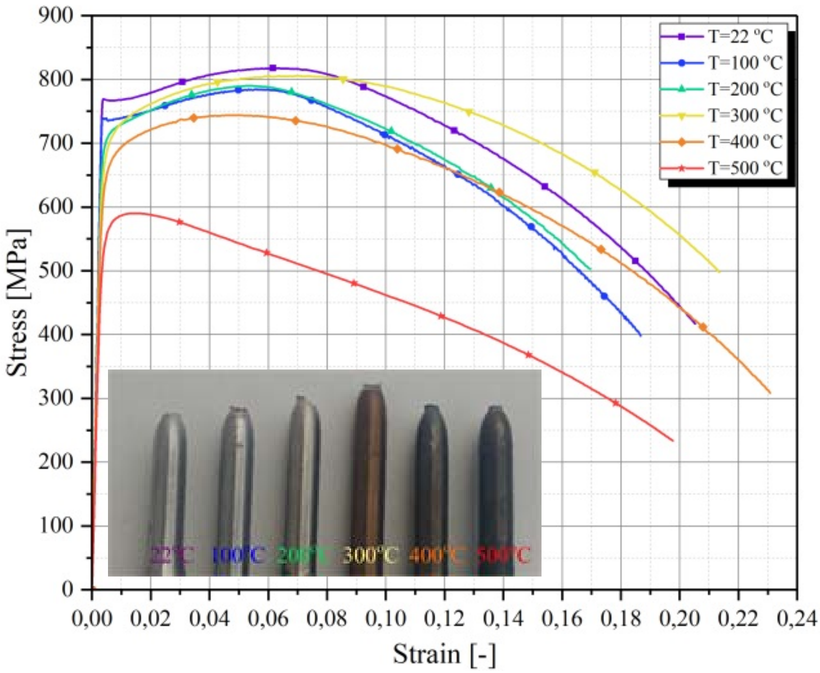

Figure 5. *Specimens after testing and comparative overview of stress-strain curves from uniaxial tension tests of STRENX 700 steel*

It is concluded that at temperatures exceeding *400 °C* there is a sudden drop in the strength of materials for tested specimens. Also, it is noticeable that at temperatures of *200 °C* and *300 °C* the values of the stress are greater than the value corresponding to the room temperature. The temperature range in which this phenomenon occurs is known as the *blue brittle* region.

According to previously derived equations, experimentally obtained results of tests at five temperatures from 100 °C to 500 °C, including room temperature and via linear regression analysis tensile strain-hardening exponent and strength coefficient were determined and shown in Table 1

Table 1. *Experimental determined hardening parameters for STREN X700*

T [°C]	*n*	*K [MPa]*
22	*0.05094*	*992.67*
100	*0.04616*	*936.61*
200	*0.05600*	*975.84*
300	*0.06277*	*1015.74*
400	*0.05008*	*908.64*
500	*0.01893*	*652.04*

5 CONCLUSION

This paper has presented the determination an experimental determination tensile strain-hardening exponent and strength coefficient of the high strength steel STRENX 700 at elevated temperatures 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 for various levels of temperature. Obtained results show changing of material properties (strength and elongation) of the high strength steel STRENX 700 at temperature higher than *400 °C*.

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