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ARTENS

ASOCIAȚIA ROMÂNĂ DE TENSOMETRIE ȘI ÎNCERCAREA MATERIALELOR

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in cooperation with *Central Travel*

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FOREWORD

Each year since 1984, the Danubia-Adria Symposium on Advances in Experimental Mechanics brings together internationally recognized experts and young researchers in an effort to exchange ideas in different topics having as common link Experimental Mechanics. Since the beginning, this Symposium was a platform for establishing connections between different research groups trying to establish future scientific collaboration and an agora where faculty members, students, scientists, researchers, engineers and industrial experts present and discuss the status and impact of modern technology and development in the field of experimental mechanics.

In 2018, the 35th Danubia Adria Symposium on Advances in Experimental Mechanics is to be held between September 25 – 28 in the wonderful mountain resort Sinaia, Romania.

The Book of Abstracts of the proceedings includes 97 papers, which have been selected and accepted after peer-review by the Scientific Committee, formed by the delegates of the eleven DAS member countries – Austria, Croatia, Czech Republic, Germany, Hungary, Italy, Poland, Romania, Serbia, Slovakia, and Slovenia.

The papers are organized in five sections:

- Structural analysis
- Materials characterization and testing
- Biomechanics
- Practical applications/case-studies/instrumentation
- Numerical methods

The present volume emphasizes the actual trends which are given to the development of methods and models that account for and integrate physical phenomena taking place on multiple scales. These include complex processes such as the evolution of the meso- and micro-structure of the material during loading, and if these phenomena could be accounted for, then their influence on the macroscopic constitutive behavior of materials could be also predicted, thus being able to create new, exceptional materials. While this perspective is fascinating, the current state-of-the-art falls short from attaining this goal. The better understanding of phenomena where large populations of defects - such as dislocations - interact in highly non-linear ways and the consideration of large deformations can lead to the creation of improved constitutive models of the materials' behavior to be observed macroscopically.

Finally, it is important to underline that, with the 2018 Romanian edition of the Symposium, the Danubia Adria Society on Experimental Methods proudly announces its 35th anniversary!

We wish all the participants to have a high level of scientific discussions and to enjoy the beauty of the Romanian mountains.

The Editors,

Professor Ştefan Dan Pastramă

Professor Dan Mihai Constantinescu

EXPERIMENTAL DETERMINATION OF STRAIN HARDENING EXPONENT FOR STRENX 700

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1. Introduction

The most common material today in all aspects of daily life is steel. Its history is very rich, but it can be said and the future, although we are witnessing of increasing usage of new materials in the present. Many world grooving economies, as well as those of the future, owe their progress to a large part of the development and consumption of steel and its products. 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. The choice of adequate material for projected part depends on its ability to respond to the established requirements regarding the functional durability to the load it is exposed to, as well as the possibility of making them according to the given dimensions.

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

In this paper, material characteristic of high strength steel STRENX 700 was studied experimentally at elevated temperature.

2. Testing at elevated temperature

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 [1]:

• 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 ^{o}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 [2], ASTM E21-17 [3]. The simplest form of the equation of the hardening curve in the case of uniaxial tension, without influence of temperature and strain rate, can be written in the form [4]

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

where *n is* the strain hardening exponent and *K* is coefficient of proportionality. A much more adequate form of equation for strain hardening is variation of Ramberg-Osgood equation in form [5]

$$\sigma = \sigma_{uy} + C_y(\varepsilon_p)^{n_y} \tag{2}$$

in which C_y and n_y represent material constant. σ_{uy} is yield stress. These material constants can be determined from the expressions

$$C_y = \frac{R_m e^n - R_p}{n^{\frac{R_m e^n}{R_m e^n - R_p} n}} \tag{3}$$

$$n_y = \frac{R_m e^n}{R_m e^n - R_p} n.$$

in which R_p is yield stress and R_m is ultimate strength.

3. Methodology 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 standard ISO 6892-2 [2]. The testing program includes the testing of mechanical characteristics at five temperatures from 100 °C to 500 °C, including room temperature. By optical scanning of the samples after fracture and by placing separate parts in contact by matching the fractures surfaces, a digital reconstruction of the specimen geometry was performed during the test at the time of the breakage. On that way, the actual fracture deformations were determined.

All tests were performed on universal servo-hydraulic machine SHIMADZU servopulser EV101K3-070-0A. For measuring of strain at high temperature, extensometer EPSILON 3548-025M-050-ST was used which was installed in the furnace in a horizontal position. The selected strain rate is $5 \cdot 10^{-4}\ s^{-1}$, which corresponds to the velocity of the cross head of 0.02 mm/s. Optical measurements were realized using the optical measuring device ATOS COMPACT SCAN 5M, which basically represents a contactless measuring system for digitizing the complete geometry of visible surfaces on objects of different sizes and complexities. Measuring volume of optical device was 300/MV300.

4. Results and discussion

The summarized results are shown in the diagram in Figure 1.

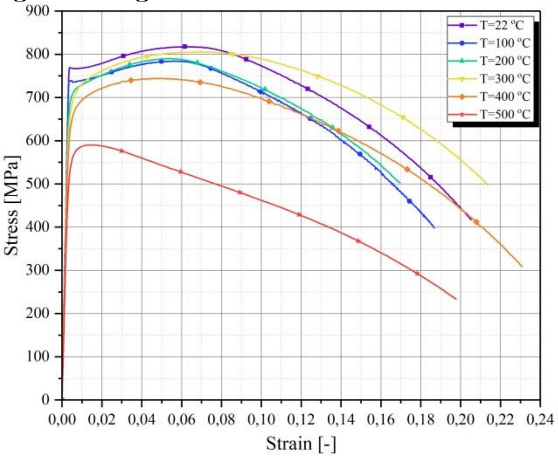

Fig. 1. Comparative overview of test results for each temperature

It is concluded that at temperatures exceeding 400 °C there is a sudden drop in the strength of materials for both types of test tube. 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. Table 1 shows experimental determined hardening parameters.

Table 1. Experimental determined hardening parameters for both form of equation for STREN X700

	$\sigma = K\varepsilon^n$		$\sigma = \sigma_{yy} + C_y\varepsilon^{n_y}$		
T [°C]	n	K [MPa]	$\sigma_{yy} = R_e$ [MPa]	C_y [MPa]	n_y
22	0,05094	992,67	767,38	378,1	0,4708
100	0,04616	936,61	735,68	333,7	0,4401
200	0,05600	975,84	710,53	367,6	0,3742
300	0,06277	1015,74	692,84	407,3	0,3259
400	0,05008	908,64	657,15	319,4	0,3132
500	0,01893	652,04	559,30	123,0	0,2699

5. Conclusions

This paper has presented an experimental determination of strain hardening parameters for high strength steel STRENX 700 at elevated temperatures. By increasing the temperature, the material characteristics like strength and elongation are changed, especially at 400 °C and higher temperatures. The testing procedure was performed using of special measurement device, servo-hydraulic SHIMADZU servopulser.

Acknowledgements

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