36th Danubia-Adria Symposium on Advances in Experimental Mechanics
24–27 September 2019, Plzeň, Czech Republic

INFLUENCE OF STRAIN RATE ON THE MECHANICAL PROPERTIES OF STEEL

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1. Introduction

In order to measure strength, elastic constants and other material properties of steel, a number of mechanical tests were developed initially for research purposes and then have been refined and compared to establish if they meet the strict requirements of standardization. A basic and universal engineering test is the tensile test.

Tensile testing procedures have evolved to cover strain rates ranging from static to very high speed. Current tests of tensile properties of various metallic materials may take place in the strain rate range 10^{-6} s^{-1} to 10^{6} s^{-1} on specimens with various gauge length dimensions [1].

While studies of high speed impact situations such as car crashes require high strain rate tests, low strain rate measurements of tensile properties are still widely used for selecting metallic materials for other engineering applications [2].

The purpose of this study was to determine the effect of the strain rates on the mechanical properties and elastic constants of a mild steel under tensile loading.

2. Materials and methodology

The tensile testing methodology fulfills requirements specified in standards ASTM E8-16/ISO 6892-1. Testing was carried out using the universal fatigue testing machine INSTRON 8801 equipped with hydraulic wedge grips and an extensometer (Fig.1).

Five identical sets, each having four identical samples, were cut and machined from a PC52 (0.22%C) steel bar. Specimens had the gauge length of 50 mm and 12.5 mm diameter. Each of the five sets was tested in traction at room temperature and at a specific crosshead speed: 0.1 mm/min; 0.5 mm/min; 1 mm/min; 1.5 mm/min; 2 mm/min. The corresponding strain rates are in the range $3 \cdot 10^{-5}$ s^{-1} – $6 \cdot 10^{-4}$ s^{-1}.

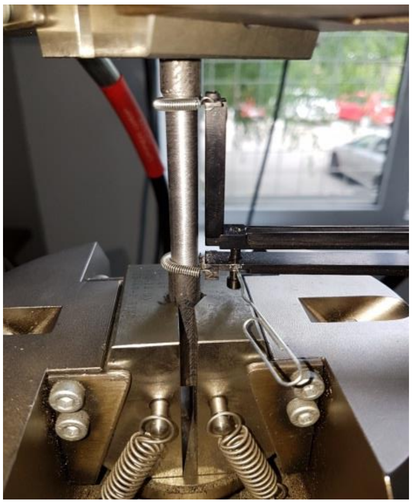

Fig. 1. Fastening of specimen with hydraulic wedge grips.

3. Results

The stress-strain diagrams obtained for the five sets of samples, each tested at a different strain rate, are plotted in Figure 2. Each curve represents the average values obtained from the testing results of the four samples of the set.

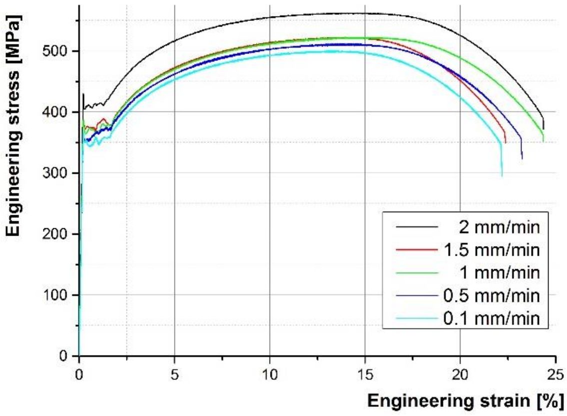

Fig. 2. Stress-strain diagrams for different crosshead speeds.

Figure 3 represents the stress-strain diagrams corresponding to the four specimens tested at a crosshead speed of 1.5 mm/min. The individual values are very close to the average of the set, in comparison to the rest of the sets.

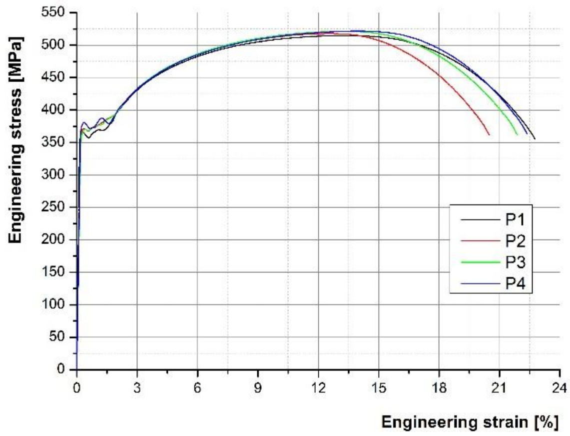

Fig. 3. Stress-strain diagrams for crosshead speed 1.5 mm/min.

Some of the tensile properties measured for the steel specimens at the loading speed of 1.5 mm/min are presented in Table 1.

Table 1. Test results for crosshead speed 1.5 mm/min.

Sample	Yield Strength [MPa]	Tensile Strength [MPa]	Fracture strain (%)	Fracture strength [MPa]
1	355.6	514.8	22.77	354.5
2	368.4	519.2	20.47	360.1
3	366.0	521.2	21.85	361.3
4	368.7	521.3	22.34	363.1

In order to estimate the effect of the loading speed on the statistical distribution of the values of tensile properties measured during testing, the coefficient of variation was calculated according to formula:

$$CV(\%) = \frac{\sigma}{\mu} \cdot 100 \qquad (1)$$

where σ is the standard deviation value and μ represents the mean value. Figures 4 and 5 present the coefficient of variation as a function of the crosshead speed for two of the measured properties, namely yield strength and tensile strength.

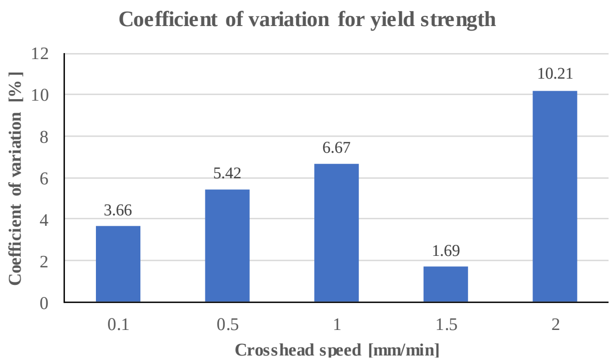

Fig. 4. Coefficient of variation of yield strength.

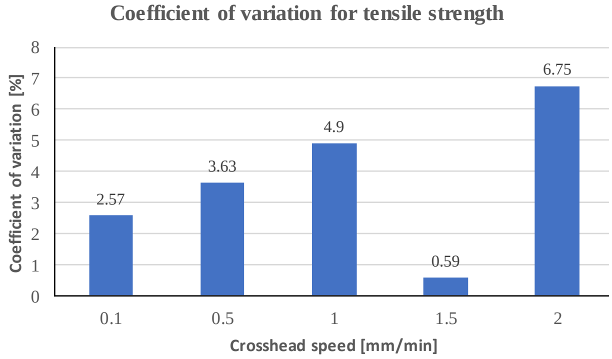

Fig. 5. Coefficient of variation of tensile strength.

4. Conclusions

Tensile properties of steel PC52 have been studied at different loading rates. The results obtained led to the following conclusions:

- Although the strain rates are low, it was noticed that the values of yield strength and tensile strength increase with crosshead speed (Fig.2) in agreement with reference literature [2,3].

- The spread of data of the four stress-strain diagrams (Fig. 3) obtained at loading speed of 1.5 mm/min is the lowest of all rates tested. Therefore, the corresponding values of the coefficients of variation are also the lowest for all tensile properties e.g. 1.69 for yield strength (Fig.4) and 0.59 for tensile strength (Fig. 5), values which are in good agreement with standard ASTM E8/E8M-16. This loading rate should be recommended for tensile test of mild steel PC52.

- The values of the coefficients of variation of tensile properties for other load speeds are higher as a result of a higher spread of measured values.

- The range of these specific low strain rates applied in the study is typical for testing steel used for engineering components in applications such as storage tanks and pressure vessels [1].

References

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