EAN 2019
57th conference on experimental stress analysis

Influence of loading speed on yield strength value of S235 and C45 steels

FUSEK Martin[1,a], PORUBA Zdeněk[1,b], HALAMA Radim[1,c], FRANTIŠEK Ondřej[2,d], SCHNEIDER Markus[2,e], BIAGINI Veronica[2,f] and SADÍLEK Marek[1,g]

[1]Department of Applied Mechanics; Faculty of Mechanical Engineering; VSB – Technical University of Ostrava; 17. listopadu 15, 708 00 Ostrava, Czech Republic

[2]ABB Corporate Research Center; Wallstadter Strasse 59, 685 26 Ladenburg, Germany

[a]martin.fusek@vsb.cz, [b]zdenek.poruba@vsb.cz, [c]radim.halama@vsb.cz, [d]ondrej.frantisek@de.abb.com, [e]markus.schneider@de.abb.com [f]veronica.biagini@de.abb.com, [g]marek.sadilek@vsb.cz

Keywords: Yield strength, Loading speed, Static loading, Dynamical loading, Digital image correlation

Abstract. The aim of the paper is to evaluate the dependency of the yield strength of steels S235 and C45 on loading speed. In order to quantify this phenomenon, static and dynamical tension tests of both steels were realized and evaluated. Static tension tests realized on flat specimen confirmed values of yield strength under static loading given my material sheets of both steels. Dynamical testing has shown different behavior of steels under increased loading speeds. While the steel S235 has shown a significant growth of yield strength with the increased loading speed in the interval from 0 m/s till 3 m/s, the steel C45 has shown this ability in the interval from 0 m/s till 1 m/s only and the subsequent growth of yield strength has been very slow. In order to quantify the strain distribution in the specimen during dynamical tests using digital image correlation method, experiments were recorded using high-speed camera as well. Unfortunately, none of the results could be used since the colour applied on the surface of the specimen was eroded from the surface due to its fast deformation.

Introduction

During different types of experiments, the dependency of yield strength value on loading speeds was observed [1]. In order to quantify this phenomenon, static and dynamical tension tests of S235 and C45 steels were performed and evaluated.

Values of the yield strength of S235 steel were measured and evaluated under four different loading speeds – static loading, 1 m/s, 2 m/s and 3 m/s.

Values of the yield strength of C45 steel were measured and evaluated under ten different loading speeds – static loading, 1 m/s, 1.5 m/s, 2 m/s, 2.5 m/s, 3 m/s, 4 m/s, 6 m/s, 10 m/s and 20 m/s.

Results measured can be subsequently used for design of devices working under higher speeds, such as electric contactors, switches, etc.

Laboratory Equipment

The measurement of yield strengths under static loading was realized using tension testing machine Testometric M500-50CT (50 kN), dynamical tests were realized on the high-speed tensile testing machine Instron VHS 65 (available testing speeds from 1 m/s till 20 m/s, maximal dynamical loading force 80 kN). The testing machine Instron VHS 65 and detail view on fixed specimen are depicted in Fig. 1 and Fig. 2 respectively.

In addition, the dynamical experiment was recorded using high-speed camera (max. 30 kHz) with the intention of its evaluation using digital image correlation method [2], see Fig. 3.

Fig. 1: High-speed tensile testing machine Instron VHS 65

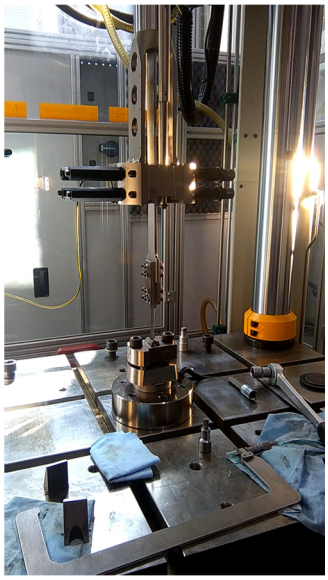


Fig. 2: Jaws with installed specimen

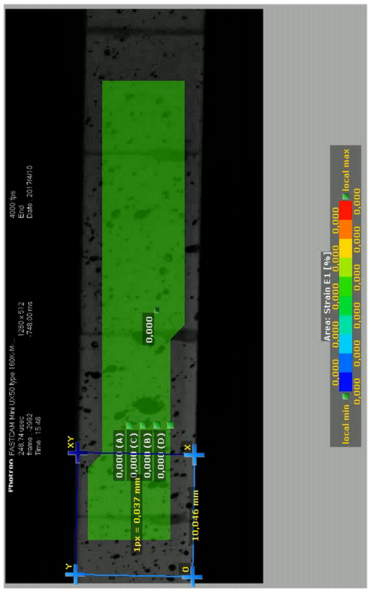


Fig. 3: Measurement of strain distribution using optical correlation method

Results Measured

Results measured for steel S235 and C45 are depicted in the form of stress vs. strain and yield strength vs. loading speed relations in Fig. 4 and Fig. 5 respectively. The course of yield strength vs. loading speed was extrapolated using linear Eq. (1) and exponential Eq. (2) for steel S235 and C45 respectively.

$$f_y = 84.172v + 349.7 \tag{1}$$

$$f_y = 508.56v^{0.0384} \tag{2}$$

where f_y [MPa] is the yield strength and v [m/s] is the loading speed.

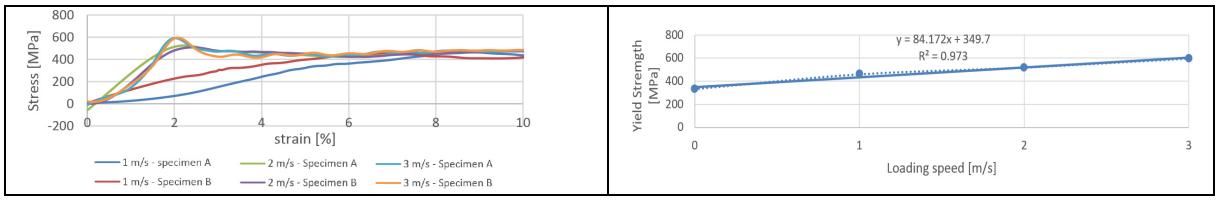


Fig. 4: Results of tension test of steel S235 under dynamical loading

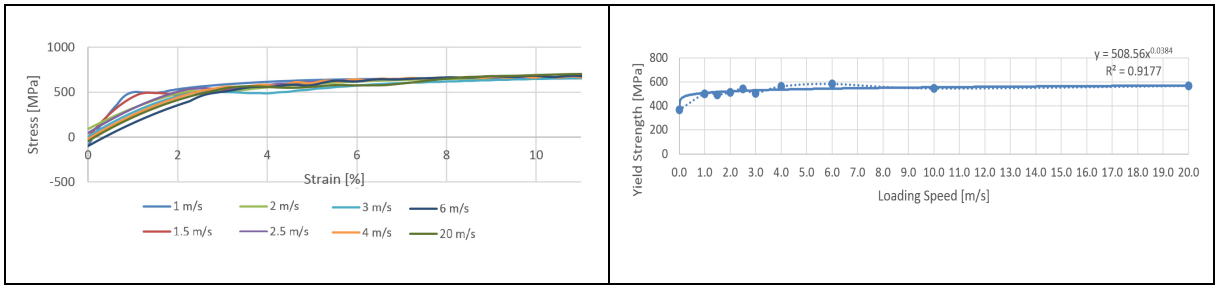
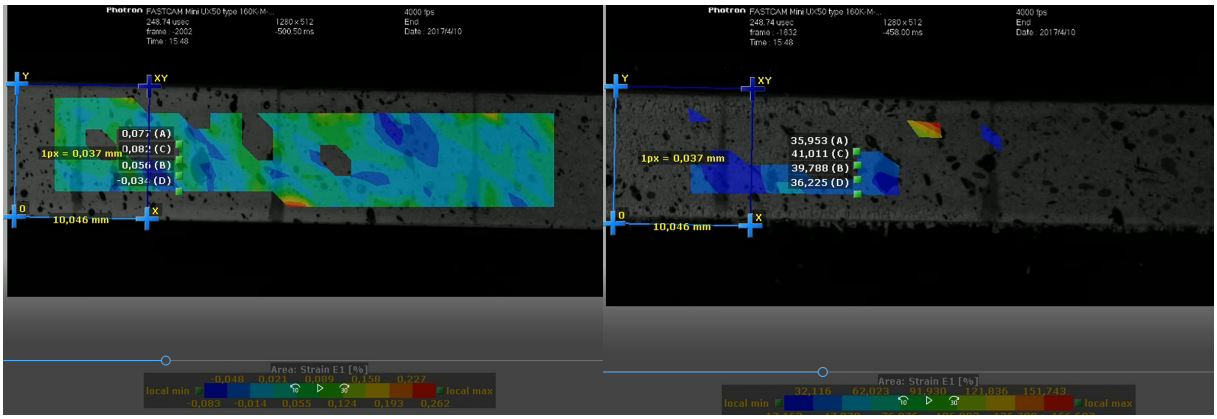
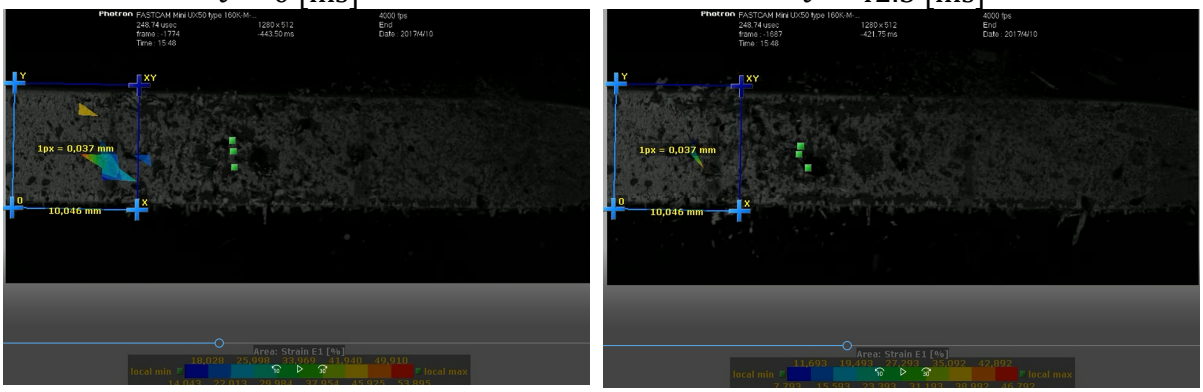


Fig. 5: Results of tension test of steel C45 under dynamical loading

As mentioned above already, the intention of authors was to measure the strain distribution on the surface of the specimen during the dynamical testing using digital image correlation method. To do so, the surface of the specimen was provided by spotted spraying and subsequently recorded by high-speed camera during the loading. Unfortunately, the fast loading caused the peeling-off the color sprayed on the specimen surface and made so the measurement impossible. The peeling-off process can be seen in series of images depicted in Fig. 6.



$t = 0$ [ms] $t = 42.5$ [ms]



$t = 57$ [ms] $t = 78.75$ [ms]

Fig. 6: Digital image correlation: peeling-off process of sprayed color

Conclusions

According to the results measured, following conclusions can be stated:

- Values of yield strengths of S235 and C45 steels under static loading correspond to the values defined in material sheets – min. 235 MPa and 340 MPa respectively,
- Steel S235 shows a significant growth of yield strength with the increasing loading speed in the interval from 0 m/s till 3 m/s,
- Steel C45 shows the growth of yield strength with the increasing loading speed in the interval from 0 m/s to 1 m/s, the growth of yield strength above 1 m/s is very slow,
- Results from high-speed camera could not be used since the colour applied on the surface of the specimen was eroded from the surface due to its fast deformation.

Acknowledgement

This work was supported by the Czech projects of Ministry of Education, Youth and Sports under No. SP2019/100.
Article has been done in connection with project Innovative and additive manufacturing technology - new technological solutions for 3D printing of metals and composite materials, reg. no. CZ.02.1.01/0.0/0.0/17_049/0008407 financed by Structural Founds of Europe Union.
This article has been elaborated under support of the project Research Centre of Advanced Mechatronic Systems, reg. no. CZ.02.1.01/0.0/0.0/16_019/0000867 in the frame of the Operational Program Research, Development and Education.
This article has been created under the state support of Technological Agency of the Czech Republic under the project TN1000071 National Competence Centre of Mechatronics and Smart Technologies for Mechanical Engineering of the program National Centers of Competence 1.

References

[1] MAINSTONE, R. J. Properties of materials at high rates of straining or loading. Matériaux et Constructions. 1975, 8(2), 102-116 ISSN 0025-5432.

[2] KUBIAK, M., DOMAŃSKI, T., DEKÝŠ, V. and SAPIETOVÁ, A. Measurement of Strain During Tension Test of Welded Joint Using Multi-camera 3D Correlation System. Procedia Engineering. 177(2017), 107-113. ISSN 18777058.