Dynamic Properties of 316L Identified by Split Hopkinson Pressure Bar

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Keywords: Stainless steel, A316L, SHPB, Johnson-Cook, Dynamic testing, Regression

Abstract. This work presents a dynamic testing of conventional rolled stainless steel A316L on self-constructed Split Hopkinson Pressure Bar (SHPB) apparatus with three different impact speed of striker. The ten cylindrical samples with slenderness ratio equalled to one were tested. Acquired signal of pressure wave propagation were separated into three different waves and stress-strain dependence were evaluated. The coefficients of simplified Johnson-Cook material model were estimated by Power law regression.

Introduction

In modern age of computer aided engineering and finite element analysis solutions is mandatory to know proper mechanical properties of used materials include dynamic response. Dynamic response of material can be tested by lot of different techniques. One of them is Split Hopkinson Pressure Bar (SHPB) invented by Bertram Hopkinson [1] and modified by Herbert Kolsky [2]. In this article self-constructed SHPB is used for identifying of dynamic properties of rolled stainless steel A316L at various strain rate.

Fig. 1: Self-constructed Split Hopkinson Pressure Bar apparatus

SHPB testing. Cylindrical samples of A316L with diameter d = 10 mm and slenderness ratio d/l = 1 was tested at three different speed of 200mm long striker. Sample is compressed between two prismatic bars equipped by resistance strain gauge. Main goal of test is record pressure wave propagation in prismatic bars caused by accelerated striker to incident bar. The dynamic response of material is evaluated from strain gauge signal. Acquired signals from incident and transmitted prismatic bar are depicted on Fig. 2.

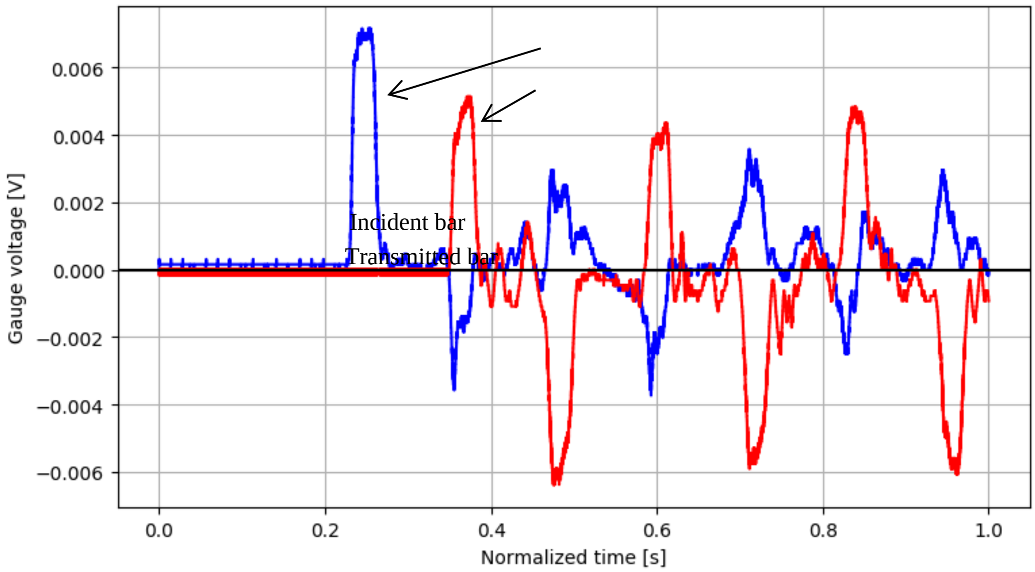

Fig. 2: SHPB test record of sample

Three types of wave are identified in signals - incident wave, reflected wave from first prismatic bar and transmitted wave through sample to second prismatic bar - Fig. 3.

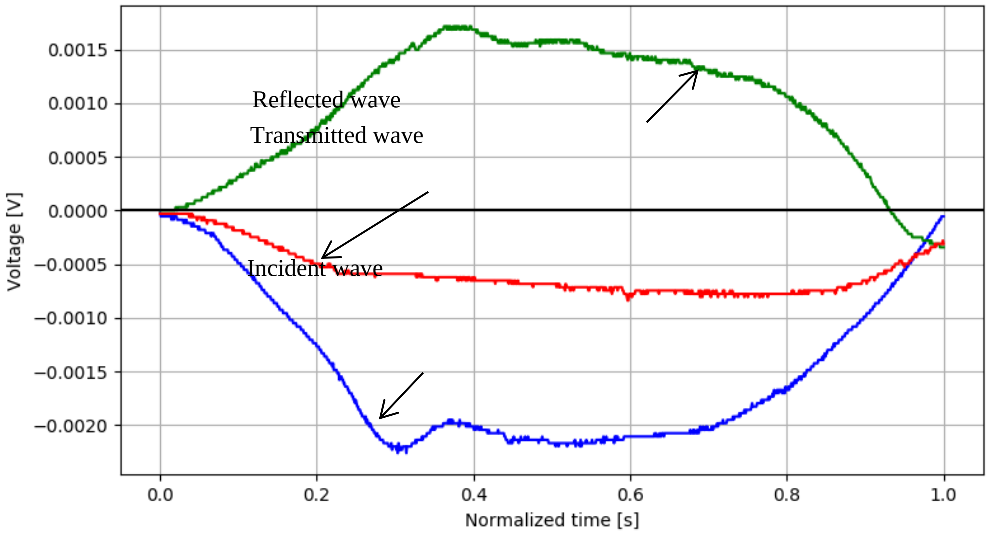

Fig. 2: SHPB test record of sample

Separated waves are used for evaluation of stress, strain and strain rate by Eq. (1 - 3).

$$\sigma(t) = \frac{A_{bar} \cdot E_{bar}}{A_{sample}} \cdot \varepsilon_{trans}(t) \tag{1}$$

$$\dot{\varepsilon}(t) = \frac{2 \cdot C_{bar}}{L_{sample}} \cdot \varepsilon_{ref}(t) \tag{2}$$

$$\varepsilon(t) = \frac{2 \cdot C_{bar}}{L_{sample}} \cdot \int_0^t \varepsilon_{ref}(t)\, dt \tag{3}$$

where A_{bar} and A_{sample} is the cross-section area, E_{bar} is Young modulus of prismatic bars, L_{sample} is length of sample, C_{bar} is speed of sound in prismatic bars and ε_{trans}, ε_{ref} are identified waves in signal.

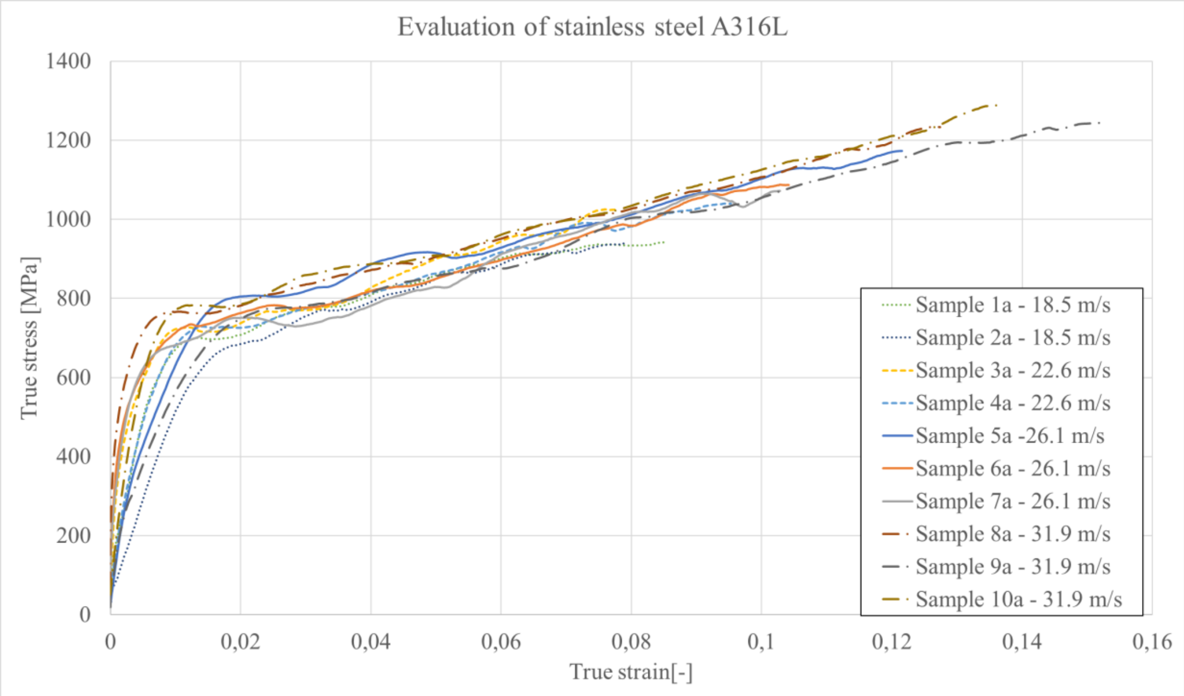

Fig. 3: Stress-strain dependence of tested samples

Stress–strain dependences of tested samples are depicted on Figure 3. The curves of dependences lie close to each other, which shows the stable material behaviour thought different strain rate.

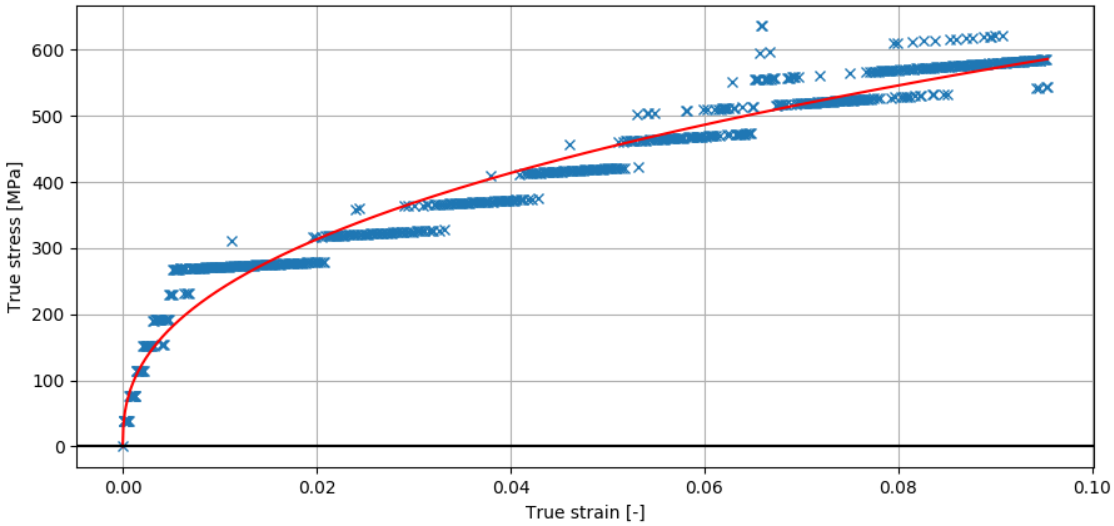

Fig. 4: Power law regression of sample data

Evaluated stress-strain curves are fitted by power law regression (Fig. 4) on the simplified Johnson-Cook material model [3], described by Eq. (4).

$$\sigma = (A + B \cdot \varepsilon^n)(1 + C \cdot \ln \dot{\varepsilon}) \tag{4}$$

where A, B, C, ε, n are material constants. Estimated coefficients of Johnson-Cook material model are summarized in Table 1.

Table 1: Estimated coefficient of Johnson-Cook material model

	A [MPa]	B [MPa]	n [-]
Stainless steel A316L	453	1536	0,593

Conclusions

The aim of the work was to determine the dynamic compressive response of conventional stainless steel of A316L on self-constructed Split Hopkinson Pressure Bar apparatus. Tests with three different strain rates were performed and evaluated to stress-strain curves. Stainless steel A316L shows insensitivity to different load speeds. Finally evaluated stress-strain curves were fitted to the simplified Johnson-Cook material model for purposes of finite element analysis.

Acknowledgement

This work was supported by The Ministry of Education, Youth and Sports from the Specific Research Project (SP2020/23) and has been done in connection with the DMS project reg. no. CZ.02.1.01/0.0/17_049/0008407 financed by Structural Funds of Europe Union.

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