



Dynamic compressive behavior and fracture modeling of Titanium alloy IMI 834



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ABSTRACT

A comprehensive study has been performed for understanding the constitutive behavior of titanium alloy IMI 834 under different strain rates, stress triaxialities and temperatures. Results confirmed an improvement in its strength with increase in strain rate and stress triaxiality. Experimental results obtained from the specimens of materials were employed to calibrate the material parameters of Johnson–Cook (J–C) strength and fracture model. The microstructure study has been undertaken to discuss the shear band and grain growth mechanisms. Three constitutive models: Johnson–Cook (J–C), Zerilli–Armstrong (Z–A) and Cowper–Symonds (C–S) models are established to determine the flow stress using dynamic compression data. The ballistic tests were performed in which 8 mm thick target plates were impacted by 7.62 AP projectiles with a velocity of 830 m/s. The ballistic test results were replicated through numerical simulations carried out using ABAQUS finite element code. It is observed that the residual velocities generated by simulations were in good agreement with the experimental results.

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1. Introduction

Titanium alloy IMI 834 has found numerous aerospace and other applications for its outstanding properties of low density, high strength, good stiffness and better formability [1]. The aero engine parts operate at elevated temperatures under complex loading conditions and extremely hostile environments. Knowledge on dynamic material behavior of this alloy at elevated strain rates and high temperatures is essential for applications such as plastic deformation (forging and machining) and foreign object damage (FOD). It is indispensable to understand the high strain rate behavior of Titanium alloy IMI 834 at different stress triaxialities and temperatures. The present literature mainly focused on the compressive behavior of various titanium alloys under dynamic loading conditions [2–6]. In general, the literature data available on the high strain rate behavior of titanium alloys at high temperatures is not sufficient. Therefore, it is crucial to investigate the high strain rate behavior of titanium alloy IMI 834 under various stress triaxialities and temperatures.

The Johnson–cook (J–C) constitutive and fracture models [7–12] have been successfully developed for various metals. J–C model

constants have been generated and calibrated for different materials [13–15]. Weldox 460 E steel, OFHC Copper, Armco Iron, 4340 steel and AA5083–H116 aluminum alloy [7–15] have been investigated to calculate the J–C constitutive and fracture parameters. Constitutive models represent the relationship among strain, strain rate, temperature and flow stress for modeling the high strain rate phenomena of materials. The accuracy of predicted results is fully dependent on the correctness of developed constitutive equation. Enough amount of research has been carried out on steels, aluminum alloys and some other metals using empirical, semi-empirical and physically based constitutive models. However, few attempts have been made on titanium alloys, such as IMI 834.

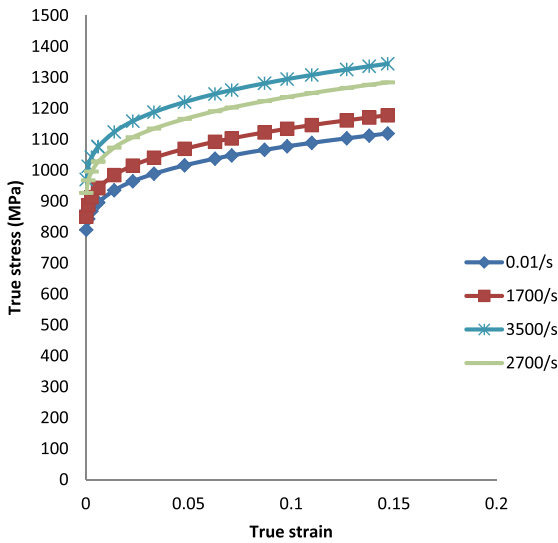
In this paper, the effect of strain rate, temperature and stress triaxiality of titanium alloy IMI 834 is investigated by uniaxial quasi-static and dynamic tensile tests. The ballistic tests were performed in which 8 mm thick target plates were impacted by 7.62 AP projectiles with a velocity of 830 m/s. The ballistic test results were replicated through numerical simulations carried out using ABAQUS finite element code.

2. Materials and experiments

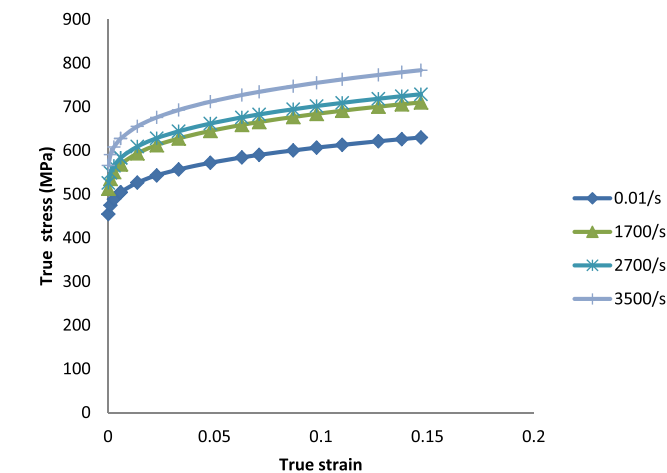
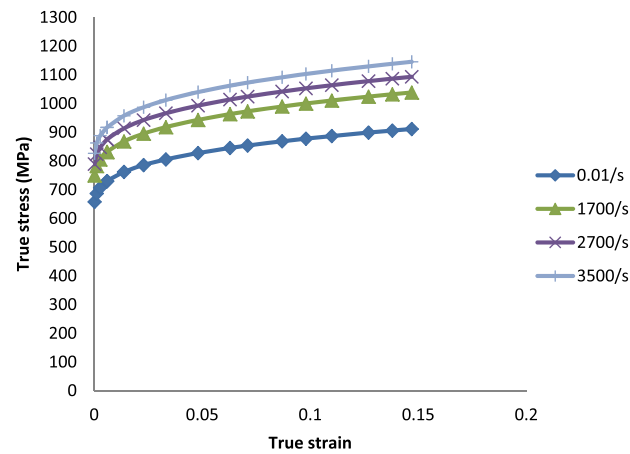
The titanium IMI-834 alloy, with the composition, Ti-5.8Al-3.0Sn-3.33Zr-0.38Nb-0.32Mo-0.33Si, was used in the present study. High strain rate compression experiments were carried out

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(a) 25 °C



(c) 600 °C

Fig. 1. The true stress strain curves of Titanium alloy IMI 834 at various temperatures of (a) 25 °C (b) 200 °C (c) 600 °C.

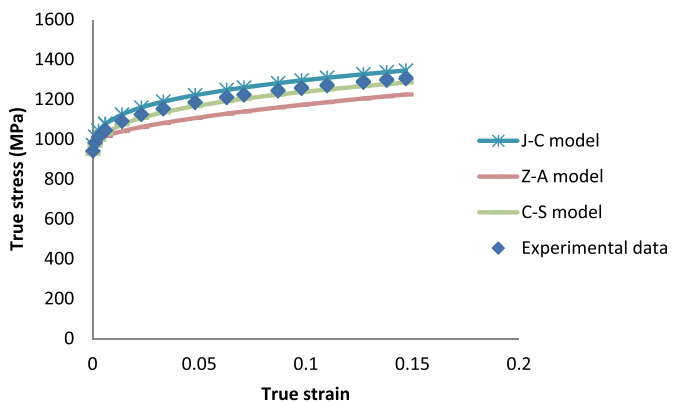
Table 1
Johnson-Cook constants.

A (MPa)	B (MPa)	n	C	m
840	712	0.3	0.011	0.81

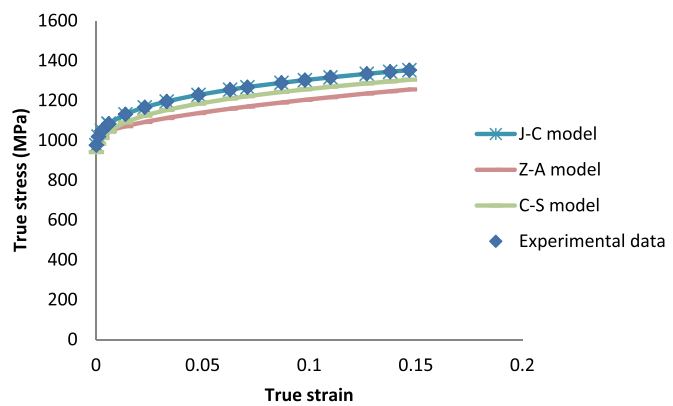
using Split-Hopkinson Pressure Bar (SHPB). Cylindrical specimens of 10 mm in diameter and 5 mm in thickness were according to ASTM: E209 standard. The quasi-static tensile testing was performed according to ASTM E8/E8M-11. The quasi-static tension experiments (at a constant strain rate of 4 mm/min) were done on INSTRON machine. A Split-Hopkinson Tension Bar (SHTB) setup was used for the high strain rate tensile tests [14,15]. Tensile tests were carried out at the temperatures of 25 °C, 200 °C, 400 °C and 600 °C under the different high strain rates of 1700, 2700/s and 3500/s. The ballistic experiments were carried out by firing the 7.62 AP projectiles on 8 mm thick titanium plate at a constant incidence velocity of about 830 m/s at normal incidence.

3. Results and discussion

The true stress-true strain curves produced under uniaxial compression at quasi-static and high strain rates are shown in Fig. 1.



(a) 2000/s



(b) 3000/s

Fig. 2. Comparison between various constitutive models and experimental results of Titanium alloy IMI 834 at room temperature and strain rates of (a) 2000/s (b) 3000/s.

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