Thermomechanical Constitutive Response of a Near α Titanium Alloy Over a Wide Range of Strain Rates

Longhui Zhang[1a], Antonio Pellegrino[1], David Townsend[1], Nik Petrinic[1]

[1]Department of Engineering Science, University of Oxford, Oxford, OX1 3PJ, United Kingdom

[a]email:longhui.zhang@eng.ox.ac.uk & lhzhang.mechanics@gmail.com

Abstract. The constitutive behaviour of a near α Ti3Al2.5V alloy is characterized at quasi-static, medium and high strain rates ranging from 10^{-3} s^{-1} to 10^{6} s^{-1} by using the cylindrical compression specimen and Shear Compression Specimen (SCS). The adiabatic heating effect from medium to high strain rates is evaluated experimentally. The experimental results are used to determine a simple constitutive model for numerical simulations of the Taylor impact tests. The constitutive model predicts the deformed shapes with good agreement.

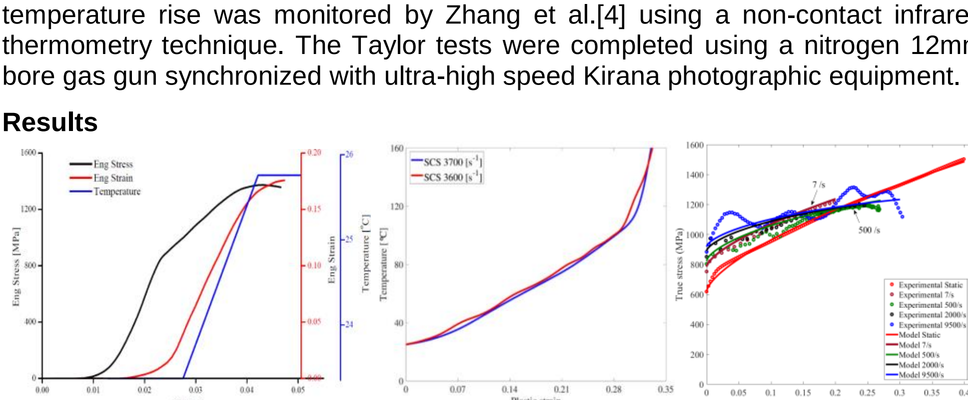
Introduction

Titanium alloys with excellent high strength to weight ratio have been used widely in aerospace engineering which would be subjected to impact loading. Itis important to understand the mechanical response over a wide range of strain rates particularly high strain rates, at which the adiabatic temperature rise is likely to affect the overall mechanical response [1, 2].

Experimental Techniques

The quasi-static and medium rate compressive experiments were conducted using a Zwick machine and an Instron machine respectively. A K-type thermocouple was spot wielded on the centre surface of cylinder specimen for temperature measurement. The SCS specimen [3] was employed to investigate the high strain rate behavior at the level of 10^{4} s^{-1} using the Hopkinson bar system. The adiabatic temperature rise was monitored by Zhang et al.[4] using a non-contact infrared thermometry technique. The Taylor tests were completed using a nitrogen 12mm bore gas gun synchronized with ultra-high speed Kirana photographic equipment.

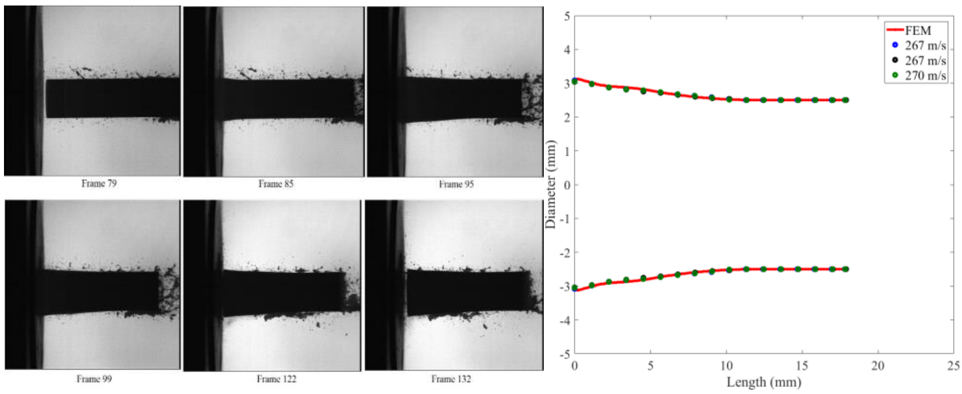
Results



(a) (b) (c)

Fig.1 (a) Temperature monitoring at medium rate 7 s^{-1}. (b) Temperature rise vs. plastic strain at high strain rate 3600 s^{-1} [4]. (c) Comparison between the constitutive model and experimental data

The typical temperature recording (Fig.1a) shows the temperature is less than 26 °C and consequently cannot cause any thermal softening effects at medium rate 7 s^{-1}. Fig.1b presents typical plots of the temperature vs plastic strain at strain rate of ~3600 s^{-1} [4]. The temperature rise increases to around 100 °C and ultimately soars up to several hundred degrees due to the strain localization. Fig.1c presents the stress-strain curves at various strain rates.



(a) (b)

Fig.2 (a) A montage of experimental images of the impact at 270 m/s with frame rate $1x10^6$ fps (b) Comparison bwtween the experimental and numeriacal residual shape of the specimen impacted at 267 m/s.

Fig.2a shows high-speed photographs during a Taylor test at 270 m/s. The deformation results in a high radial deformation at the impact end and the mushroom head. A thermal viscoplastic model [5] is designed to describe the mechanical behaviour of Ti3Al2.5V. A comparison between the experimental stress–strain curves and the calibrated model descriptions is given in Fig.1c. Fig.2b shows a comparison of the observed residual shape with that predicted by the simulation of the impacted rods. The simulation accurately predicts the overall geometry, including the final shortened length and the diameter along the length and the residual plastic deformation.

Conclusion

A wide range of strain rates is conveniently explored by using cylindrical and SCS specimens on different loading platforms. The temperature rise at medium rate 7 s^{-1} is small while the temperature rise at strain high rate is significant. A simple constitutive model is proposed for the simulation of Taylor impact tests; good agreement is found between predictions and measured deformed shapes.

References

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