A comparison of ductility measurement approaches for Ti alloy sheet

W. Heatman, 117 Blackburn Street, Salford, M3 6AS, UK, wayne.heatman@manchester.ac.uk, J. Fonseca, P. Shanthraj (both University of Manchester, Oxford Rd, Manchester M13 9PL, UK and K. Fox, Rolls Royce, Elton Rd, Allenton, Derby DE24 8ED, UK

Introduction

Titanium (Ti) alloys are used extensively in the manufacture of aeroengines. [1–3] The most commonly used alloy is Ti-6Al-4V (Ti64), due to its excellent mechanical properties and flexible microstructure. [1–3] There is a drive to replace Ti64 with alloys with improved formability, to help save cost and improve material usage. To take advantage of these potential improvements, a better understanding is required of how manufacturing processes affect the microstructure and texture in these alloys, and their effect on ductility.

The aim of this work is to investigate different ways of measuring the onset of necking in Ti alloys. Three methods were identified.

1. The Considère Criterion. This method uses the work hardening curve given by the change in stress over the change in strain. Where this curve meets that of the flow stress curve is where the onset of necking is deemed to occur.

2. The derivative method. This is determined by looking at the strain rate around the fracture point and comparing it to the strain rate elsewhere on the sample and when the difference between the two strain rates reaches a certain threshold, in this case ten times, the necking is deemed to have started.

3. The spacio-temporal method. This obtained by drawing boxes around the fracture, with one smaller box inside a larger box and comparing the thickness strain rates in the areas in the two boxes.

Results

Tensile tests were performed on samples of both materials in three loading directions; in the rolling direction (RD), at 90° to the loading direction ie the transverse direction (TD) and at 45° to the RD. Digital image correlation (DIC) was used to map the deformation on the surface of the specimen during testing

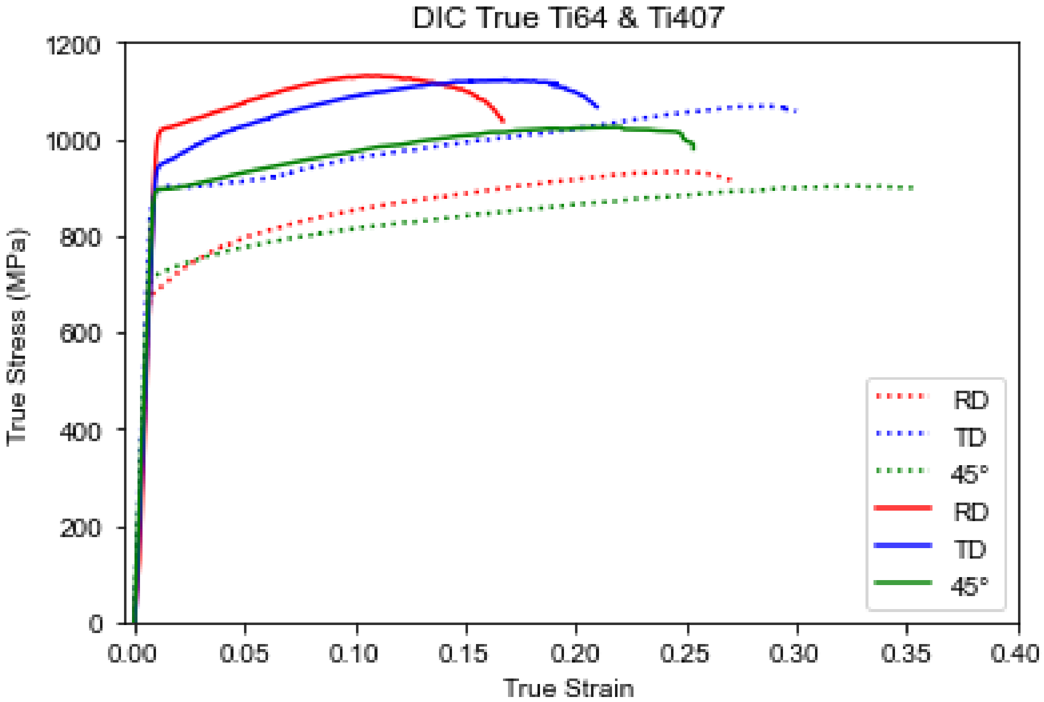
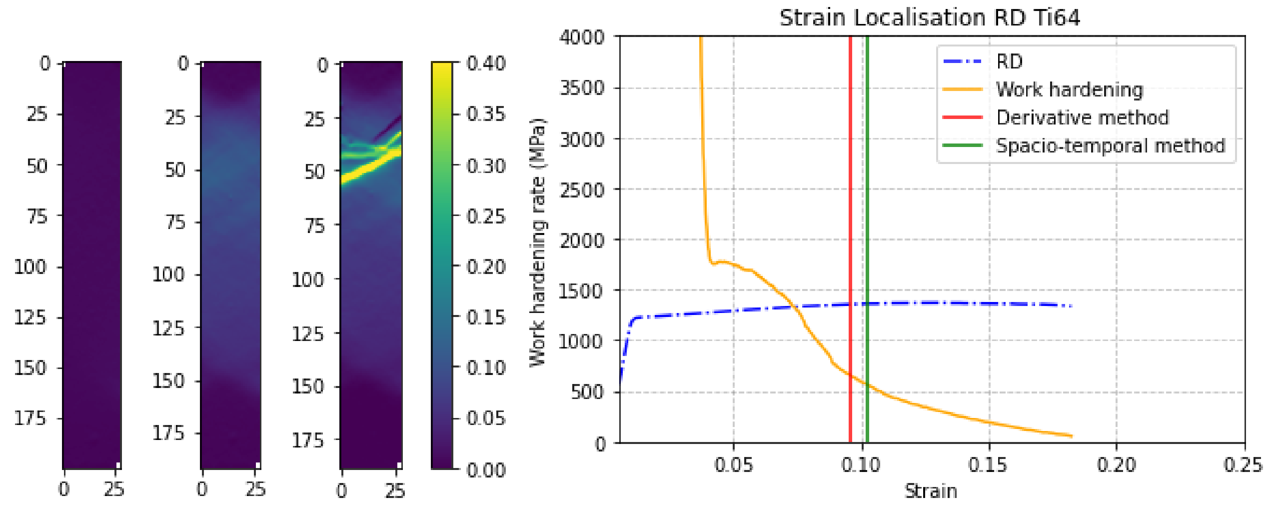


Figure 1-Stress/strain curves for Ti64 (solid lines) and Ti 407 (dotted lines) in three loading directions

Figure 1 gives the results of the tensile tests. Determination of the necking points is a way to measure the ductility of a material. Figure 2 gives the strain maps obtained from DIC for the Ti64 sample strained in the rolling direction along with a plot demonstrating the necking points derived by three different methods. The strain map at (a) is the yield point where the strain is still homogeneous throughout the sample. At the necking point (b), although still diffuse it can be seen that strain is beginning to localize culminating in high localisation at the fracture point in (c).



(a) (b) (c) (d)

Figure 2-Strain maps for Ti64 sample strained in the rolling direction (a) at yield, (b) at necking and (c) at fracture. Plot (d) gives the necking points for the same sample using the 3 methods.

The results of using the three methods of determining the necking point are given in (d). The Considère Criterion gives the necking point at the lowest strain of 0.0737. The derivative method shown by the red line gives the necking point at a strain of 0.0961. The spacio-temporal method given by the green line gives a necking point of 0.1022 which is close to that given by the derivative method.

Conclusions

- There is a difference in behaviour depending on loading direction. RD and TD are strongest in Ti64 and Ti407 respectively. For both alloys, 45° direction has longest strain to fracture.
- The longest post necking elongation for both alloys occurs in the 45° direction.
- Different methods of determining necking point can give this occurring at different strains.. Although the derivative and spacio-temporal methods give the onset of necking at similar strains, the Considère Criterion gives the onset of necking at a far lower strain.
- Texture plays a role in this behaviour.

References

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