

Dynamic shear deformation and failure of Ti6Al4V

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I. INTRODUCTION

Ti6Al4V (TA6V) is sometimes called the “workhorse” of the titanium industry because it is by far the most used titanium alloy. The material offers an excellent combination of high strength, light weight, formability and corrosion resistance. Some of the many applications where this alloy is used include aircraft turbine engine components, aircraft structural components, aerospace fasteners, high-performance automotive parts, marine applications, medical devices, parts for the chemical industry, sports equipment...

In these typical applications, the loading speed can be very high. In this case, the material becomes very sensitive to strain localization and adiabatic shear banding. Since strain localization is a precursor to failure, it is very important to understand the conditions and mechanisms of this deformation process.

II. EXPERIMENTS

A. Hat-shaped specimen testing technique

The high-strain-rate behaviour of titanium can be studied by compressing hat-shaped specimens very fast. The top of the specimen is indented into the brim (Figure 1). The occurring shear deformation is concentrated in a narrow region due to the special specimen geometry [1]. This forces the strain to localize and adiabatic shear bands are formed. Thanks to the Hopkinson technique used here, the total force and the deformation

of the specimen can be measured during the experiment.

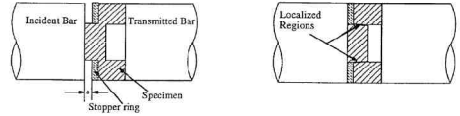


Figure 1: Principle of a hat-shaped specimen compressed between two Hopkinson bars

The experiment can be interrupted at any time by placing a stopper ring on top of the specimen (Figure 1). In this way, the deformed material can be studied at different levels of strain.

B. Measurements

The total force as a function of the displacement on a titanium specimen during both a quasi-static and a dynamic experiment is plotted in Figure 2.

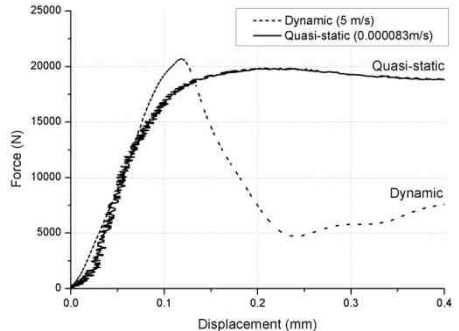


Figure 2: Force-displacement curve for quasi-static and dynamic deformation

The dynamic force-displacement curve shows a sharp peak while in the quasi-static case the force stays on a constant level. This

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clearly shows that the load carrying capacity of dynamically loaded Ti6Al4V decreases spectacular! The physical explanation of this strain rate dependent behaviour can be found in thermal softening of the material by the high temperatures that are reached during dynamic experiments.

C. Microscopic analysis

The shear region of the hat-shaped specimen can only be observed visually after cutting it along the transverse direction. With microscopic techniques it is possible to gain further insights into the material behaviour (example in Figure 3).

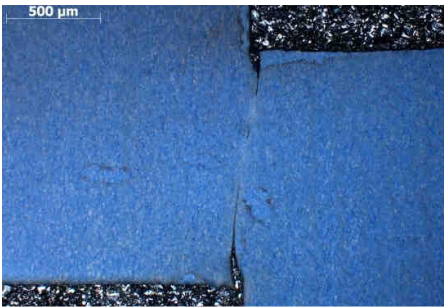


Figure 3: Microscopic view of the shear region of a hat-shaped specimen. Three different cracks can be distinguished in the severely deformed shear band.

III. NUMERICAL SIMULATIONS

The local stress, strain and temperature distribution and evolution cannot be measured experimentally with hat-shaped specimens. To obtain more information on these parameters, numerical simulations are a useful tool. Therefore, a 2D axis-symmetric finite element model has been created in ABAQUS/Explicit. The simulation results are qualitatively in good agreement with the experimental observations (Figure 4).

This model has been used to see the effects of the specimen dimensions on the results of the experiment. Small variations in specimen dimensions can already cause very diverging force-displacement measurements [2].

The simulations also show that it is not possible to fulfil the two conditions of a homogeneous stress distribution and a pure shear stress state simultaneously during the whole experiment.

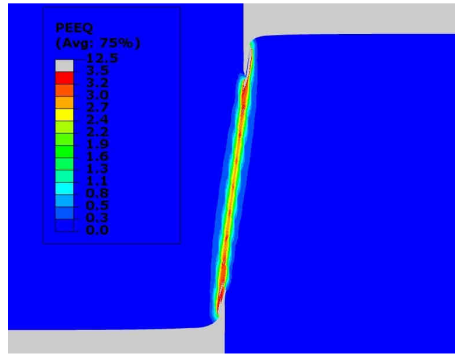


Figure 4: Simulated plastic deformation (PEEQ) in the shear region

IV. CONCLUSIONS

Ti6Al4V is sensitive to strain localization which can cause accelerated failure of the material. To study this phenomenon, dynamic experiments on hat-shaped specimens are carried out. Afterwards, the specimens are investigated microscopically. In addition, numerical simulations are used to extend our insights into the used experimental technique.

V. PERSPECTIVES

The next step in the research is to apply other experimental techniques for dynamic material characterization.

ACKNOWLEDGMENTS

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REFERENCES

- [1] Bronkhorst C.A., et. al., Int. J. of Pl, 22, 2006
- [2] Peirs J, Verleysen P., Degrieck J. *The use of hat-shaped specimens for dynamic shear testing*. To be published in FCEE, 2008