The Characterization of Metallic Alloys during Tensile Tests

Introduction

Speckle interferometry offers the possibility of full field and non contact measurement of displacements and strains. The development of a miniaturized and easy to use laser optical strain sensor based on this principle offers a new range of applications. The analysis of notched titanium alloy specimen can determine the strain distribution around the notches. Strain concentrations as well not uniaxial loads are visualized.

Fig. 1: 3D-ESPI sensor attached to a tensile testing machine.

The increasing demand for better characterization of materials and components in many cases requires full field information for the analysis of the mechanical behaviour. Speckle interferometry is known as non contact and full field measuring technique for displacement and strain analysis. New designs of miniaturized and easy to use speckle interferometric measuring systems enable new applications in tensile testing machines. In this paper some examples of application in the field of material testing will be demonstrated.

Measuring principle

Speckle interferometry uses a high resolution CCD-camera to take the image of the object under investigation while it is illuminated with laser light. The resulting speckle pattern is stored as reference image on a personal computer. When the object is deforming e.g. under tensile load the speckle pattern will change and the comparison with the reference pattern will show correlation fringes representing the displacement of the object, [1]. The obtained fringes then correspond to in-plane displacements. The derivation of the displacement values leads to the strain distribution at each position of the measuring area. Figure 1 shows the compact 3D ESPI sensor adapted to a tensile testing machine.

Notched titanium alloy specimen

Three sets of notched titanium alloy TA6V specimen with three different notch radiuses have been tested in a tensile test machine. During the test the full field deformation has been recorded with the 3D-ESPI system. Figure 2 shows the strain distribution of the notched sample with the smallest radius. The strain intensification in the notch ground is clear indicated. In Figure 3 the strain distribution of the longitudinal and transverse strain fields just before fracture is shown. The differences in the strain concentrations at different radius of the notches are clearly visible. The parallel sample (radius =) and the sample

with the larger radius are showing ductile behaviour. Before fracture, the formation of shear bands becomes visible. The sample with the smaller radius showed brittle behaviour, no shear band formation across the sample occurred. *Table 1* shows the variation of the maximum strains in longitudinal
and transverse directions for the different samples. The variation of the maximum longitudinal strain is about 300%, the variation of the maximum transverse strain is much more less.

	S1	S2	S3
Maximum longitudinal strain	12.8%	15.5%	34%
Maximum transverse strain	6%	7%	9%

Table 1: Variance of maximum strain. S1: parallel length sample, S2: Sample with larger radius of notch, S3: Sample with smaller radius of notch.

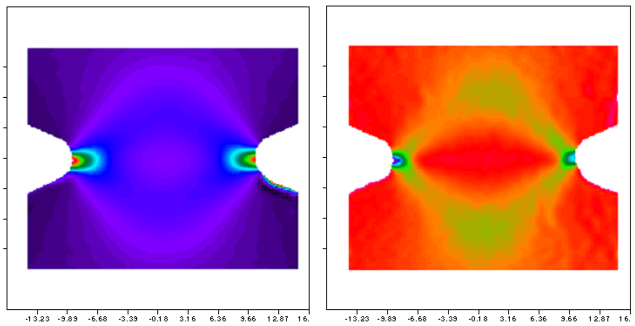

Fig 2: Strain distribution of a notched titanium sample, load 18000N, thickness of 1.5 mm, width in notch ground 20 mm. Left: longitudinal strain field, right: transverse strain field

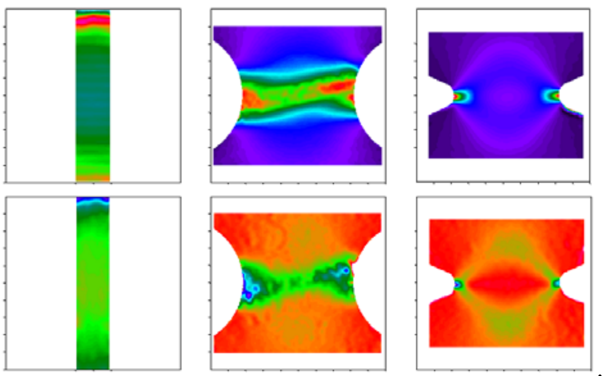

Fig. 3: Strain distribution of three different samples of titanium. Upper row is the longitudinal strain field, the lower is the transverse strain field.

True stress and true strain

During the measurement the transverse as well the longitudinal strain distribution is monitored. Therefore it is possible to calculate true stress and true strain curves. This is shown for the parallel sample in *Figure 4*. The values are calculated as average values for two different regions of the length sample. The large area reflects the mean values over the whole sample. The values from the small area are taken out just of the shear band formation zone. The maximum longitudinal and transverse strains are much higher then the strains derived as mean values from the whole sample.

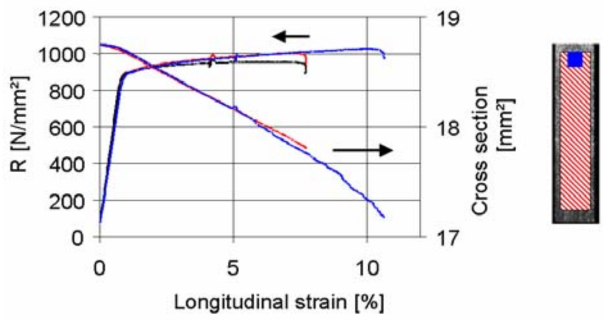

Fig 4: True stress-/true strain diagram for the parallel sample. The shorter curves are the average values over the sample.

Strain concentration at notch

For the notched samples there is a variation of the transverse strain across the width of the sample. *Figure 5* shows the dependence of the strain from the position between the notches as a function of the measurement steps. The strain concentration is located near the notch ground.

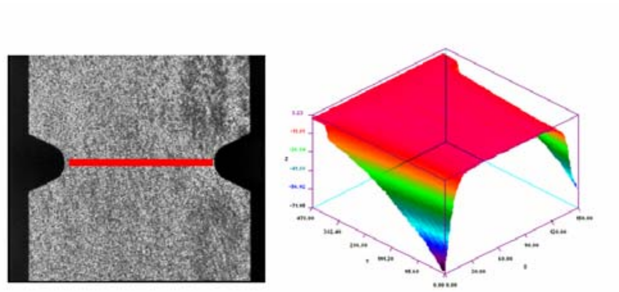

Fig. 5: Variation of the transverse strain as a function of the position across the notch and the measurement steps. The red line indicates the line where the values for the diagram have been taken.

Change of width

The full field measurement can also be used to measure the change of width of the specimen during the tensile test. As example, *figure 5* shows the variation of the width of the samples in the notch ground in correspondence with the applied force. Due to the multiaxial load the width becomes larger at the start of the test. Only at higher load level, the notch width is reduced below the start value. The influence of the different notch diameters is again seen in the diagrams. The mechanics of the expansion of the width of the notched area is explained in the in-plane display of the movement of the specimen, *Fig. 7*. At elastic load level, the material is pulled to the sides in the notch area, while at higher load levels the effect of pulling the outer edges of the specimen is much bigger.

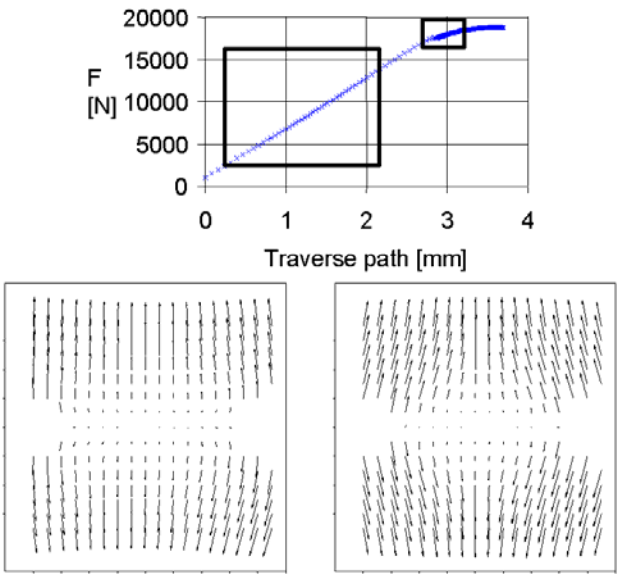

Fig 6: Variation of the width at notch ground for the two notched titanium samples.

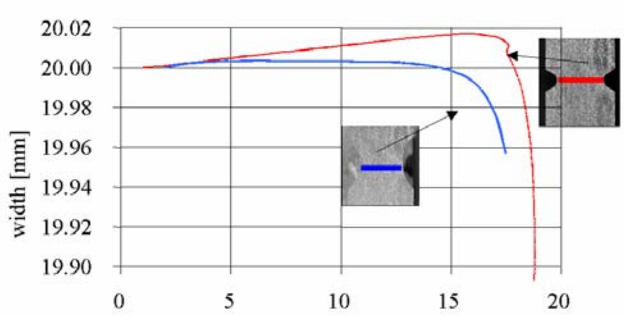

Fig. 7: In-plane movement of the notched specimen at elastic (left) and plastic (right) behavior.

Summary

Electronic speckle interferometry is a powerful tool for the characterization of behaviour of materials under loads. Inhomogeneous deformation is easily detected. Due to high accuracy true stress and strain curves can be determined, the discrimination of different part of the sample is possible. Strain concentration due to notches can quantatily detected. The application of speckle interferometry in restricted to a special kind of material, nearly every material can be characterized using this technique.

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References

[1] A. Ettemeyer, *Non contact and whole field strain analysis with a laseroptical strain sensor*, VIII International Congress on Experimental Mechanics, June, 10-13, 1996, Nashville, Tennessee.

For more information, please contact:

Dantec Dynamics GmbH
Kaessbohrerstraße 18
D-89077 Ulm

Tel.: +49-731-9332200
Fax: +49-731-9332299

E-mail: product.support@dantecdynamics.com
Internet: http://www.dantecdynamics.com