MEASUREMENT OF MATERIALS PROPRIETIES BY ELECTRONIC SPECKLE PATTERN INTERFEROMETRY

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1. Introduction

Knowledge of real material parameters and its behaviour is nowadays a condition for numerical simulations, widely used in industry to design quality components in very short time. The paper presents the method of **E**lectronic **S**peckle **P**attern **I**nterferometry (ESPI) to get the coefficient of thermal expansion of carbon fibres laminates and behaviour of the high strength steel sheets during the unloading process after large plastic deformations.

ESPI is an optical measuring technique that allows highly accurate measurement of deformations. In comparison with other techniques for strain measurement the ESPI enjoys the advantages of being non-contact, full-field, has a high spatial resolution, high sensitivity, delivers accurate displacement data and does not require any calibration or costly surface preparation. It can be applied to any material provided that the surface is sufficiently rough and the laser light is diffusely reflected.

In the following the in-plane speckle interferometer principle [1,2], also called double illumination principle, will be explained (Fig.1). The laser beam is split in two beams at an angle of 2θ using a beam splitter (e.g. diffraction grating). These two object beams generate their own speckle patterns which are added coherently and form a resulting subjective speckle at the detector of a CCD camera. Correlation fringes which occur by subtracting the speckle pattern of the object in two stages (unloaded & loaded) represent contours of equal in-plane displacement component parallel to the plane containing the two illumination beams. The displacement can be calculated when the phase change $\Delta\phi(x,y)$ is known according to the formula

$$u_x(x,y) = \Delta\phi(x,y)\cdot\frac{\lambda}{4\pi\sin\theta}. \quad (1)$$

The phase determination relies on temporal phase shifting technique (i.e. a four phase algorithm [1,2]).

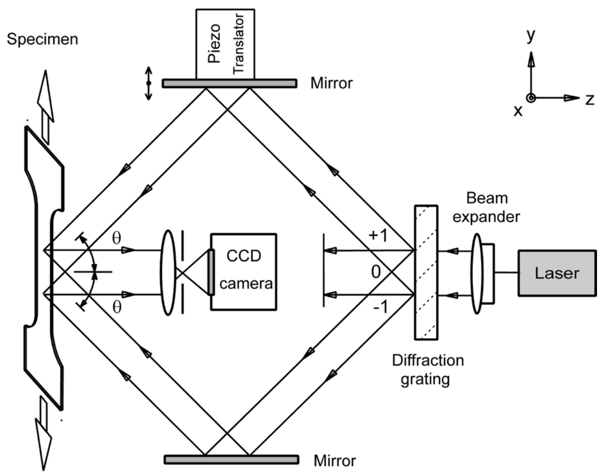

Fig. 1: Optical arrangement for in-plane ESPI

As beam splitter a diffraction grating (1600 lines/mm) was used. The “+1” and “-1” diffraction orders are used as illumination beams and the “0” order is absorbed. A piezo-translator mounted on a mirror produce the phase shifting effect. For a Nd:YAG laser with a wavelength of 523 nm the in-plane measuring sensitivity of the set-up is 0,417nm.

2. Experimental Results

First presented application of the ESPI measuring system is determination of the coefficient of thermal expansion (CTE) for some carbon fibres laminates [3]. Carbon fibre laminated sheets have multiple industrial applications, products with low thickness being particularly required for lightweight structures.

Measurement of the CTE for anisotropic materials such as carbon fibre composites using ESPI offers not only a final value but also full-field information about the deformation of the material under thermal stress, especially if the mismatch between CTE of matrix and fibres are taken into account. Examples of phase maps in dependence with fibre directions for the unidirectional laminate are presented in Fig. 2.

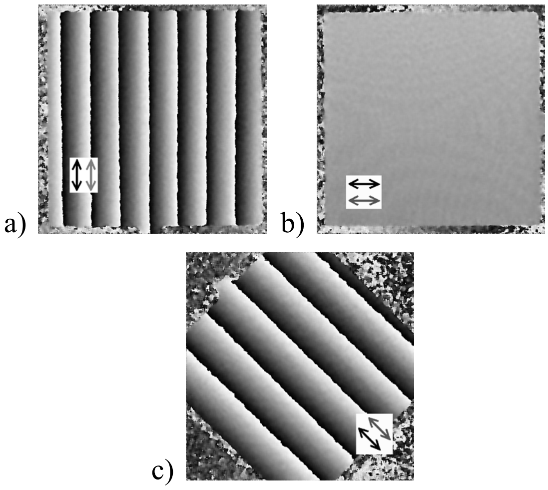

Fig. 2: Phase maps of unidirectional laminate for fibres direction: (a) perpendicular to measuring direction, (b) parallel with measuring direction, (c) rotated -45° from measuring direction.

It could be proved that the optical method of ESPI has special advantages for the investigation of thin (< 1 mm) and small (< 10 mm) specimens, for which other methods cannot be applied. Another advantage is that the fringe or phase maps give important information about the uniformity or non-uniformity of the strain field in the specimen as for example in composites. The overall accuracy of the CTE measurement by the suggested method was estimated at ≈ 0.1×10^{-6} [1/K].

Another application of ESPI technique refers to investigation of non-linear springback for high strength steel sheets [4]. The springback prediction in deep drawing is an important issue for the production of car bodies in the automotive industry. The springback of the sheet metals after large deformations during deep drawing is not a strongly linear process with a constant Young's modulus but, the stress-strain behaviour during the unloading phases, shows considerably non-linear and inelastic effects. Unloading of two types of steel sheets for cold forming, a cold-rolled high strength micro-alloyed steel and a low carbon steel sheet, have been analysed by ESPI. The specimens were investigated by uniaxial tension tests, and the influences of different testing parameters upon springback were analyzed.

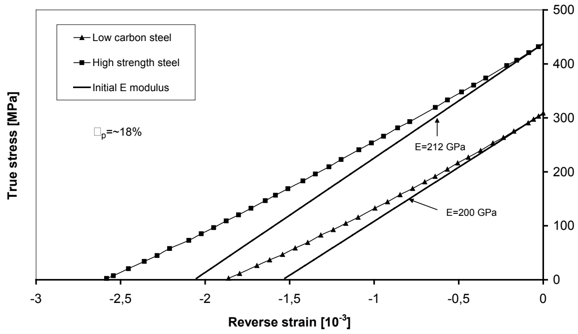

Fig. 3: Inelastic recovery for the high strength steel in comparison with the low carbon steel measured by ESPI

The experimental measurements showed that the stress-strain curve during unloading is non-linear, the influence of the prestrain path upon unloading is minor and the secant moduli of unloading curves decrease with increasing of prestrain. When the prestrain value becomes high enough, a saturated value for the secant modulus is approached.

Acknowledgements: This research was supported by the Department of Experimental Mechanics from Chemnitz University of Technology, Germany and the Alexander von Humboldt Stiftung/Foundation.

References

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