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STRESS AND STRAIN FIELDS ANALYSIS BY METHOD ESPI WITH USE OF FIXTURE FOR SHEAR EXAMINATION ARCAN

NAPÄŤOVÁ A DEFORMAČNÁ ANALÝZA METÓDOU ESPI S VYUŽITÍM UPÍNACIEHO PRÍPRAVKU PRE ŠMYKOVÉ SKÚŠKY ARCAN

Abstract

This article describes the possibilities of utilizing of ESPI - Electronic Speckle Pattern Interferometry for system Q-100 application for strain and stress analysis on surface of flat specimens predominantly loaded by shear deformation. The fixture standardly used for shear tests – Arcan test was designated for such stress state excitation. Tested specimens were made with respect to their geometry by water ray from two materials - dural and stainless steel. There were determined stress fields in elastic area from measured strain fields which were consequently verified by finite element method.

Abstrakt

Článok popisuje možnosti využitia metódy ESPI - Electronic Speckle Pattern Interferometry so systémom Q-100 pre napäťovú a deformačnú analýzu na povrchu plochých vzoriek namáhaných prevažne šmykovou deformáciou. Pre dosiahnutie tohto napäťového stavu bol využitý upínací prípravok štandardne používaný pre šmykové skúšky Arcan. Skúšobné vzorky vzhľadom na svoju geometriu boli vyrezané vodným lúčom z dvoch materiálov - dural a nerezová oceľ. Z nameraných polí elastických deformácií boli determinované napäťové polia, ktoré boli následne verifikované metódou konečných prvkov.

Keywords

ESPI, shear stress, Arcan test, FEM, elastic deformation

1 INTRODUCTION

The present is characterized by the development of non-conventional methods of deformation measurement. One of these methods is the optical method ESPI - Electronic Speckle Pattern Interferometry. ESPI method is an analogy of the holographic method. The great advantage of this method is mainly the possibility of non-contact deformation measurement. There is not necessary to interfere in the investigation of element. The fields of strains are evaluated on the basis of the measured displacement. Active tension in the elastic deformation can be evaluated using Hooke's law. Other optical methods (Photoelasticimetry, DIC - Digital Image Correlation) do not. The aim of the article is presenting ESPI optical system with a device Q 100 for reader. The possibility of use

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this optical method have been demonstrated in the proposed test samples. The fixture was designed to sample loading in tensile machine. The accuracy of optical method ESPI was verified by numerical calculations FEM in program ANSYS.

2 TEST SPECIMENS AND LOADING FIXTURE

To obtain the shear deformation has been proposed several types of flat specimens. The experimental measurements were used „butterfly´s shape" of test sample (Fig. 1 a)). We used two types of material – dural AlMg3 (EN AW 5754) H 22 and stainless steel 1.4301 (ASI 304) (Fig. 1 b)). This shape of test specimen has the advantage of simple production and also to minimize the possible occurrence of notches that affect the overall stress on the specimen.

Fig. 1 a) Geometry of the test specimen - „butterfly´s shape"; b) Dural ; c) Stainless steel

Presented shape of the test specimen was clamped by the fixture with the geometry used in the shear tests Arcan (Fig. 2 a)). The test specimen has two holes to secure position of the fixture (in the case of tensile loading respectively load that causes planar stress (Fig. 2 b)).

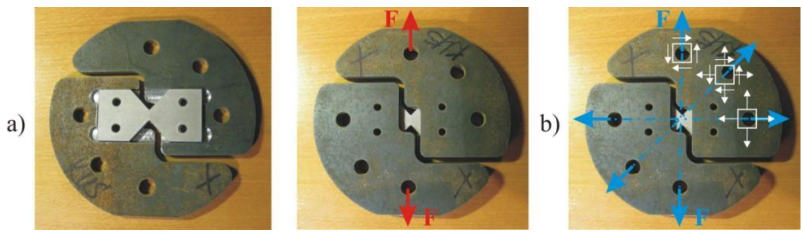

Fig. 2 a) Fixture to ensure the shear deformation of the specimen at application load F
b) The possibilities of load test of specimen in fixture (tensile, shear, plane stress)

Prescribed mechanical properties and material constants of the specimens are shown in Tab. 1

Tab. 1 Prescribed mechanical properties and material constants of the test specimens.

	$R_{e\,min}$ [MPa]	R_m [MPa]	E [MPa]	G [MPa]	μ [-]
Dural AlMg3	130	220-270	$7.25.10^4$	$2.5.10^4$	0.34
Stainless steel 1.4301	210	520-720	$2.1.10^5$	$7.7.10^4$	0.3-0.31

3 THE PRINCIPLE OF ELECTRONIC SPECKLE PATTERN INTERFEROMETRY

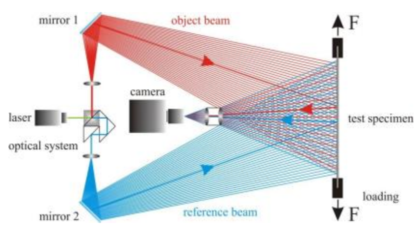

Fig. 3 The principle of measurement deformations in plane ESPI

ESPI is contactless, two-steps optical method based on coherent light (Fig. 3). The principle of this method is in distribution of coherent light on object bond beam and reference bond beam. Necessary condition of this method is application coherent light on a optical rough surface.

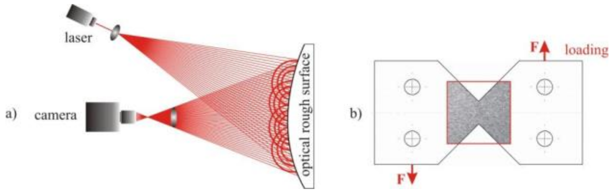

Fig. 4 a) The interference of speckle pattern; b) Resultant speckle pattern

The speckle pattern occur on surface of test specimen by mutual interference of reflexive wavefront from scanned surface (Fig. 4 b)). This speckle pattern is characteristic for each load condition. The ESPI compares two load condition - after and before loading of examined object. Resultant speckle patterns are mutual compare.

3 THE RESULTS AND THEIR VERIFICATION BY FINITE ELEMENT METHOD

Due to the possibilities of an optical head, the coordinate system used in the experiment is rotated 90 ° counterclockwise to the coordinate axes in the numerical analysis (Fig. 5).

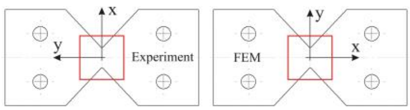

Fig. 5 Orientation of the coordinate axes - Experiment/FEM

All the strain and stress fields were plotted in a central area of the specimen between notches (Fig. 5), where as a result of shear-induced deformations were expected maximum stress and strain.

Fields of normal relative strains ε_x, ε_y and shear strains field γ_{xy} that obtained by experimental measurements on a specimen of stainless steel are shown in Fig. 6 and Fig. 7.

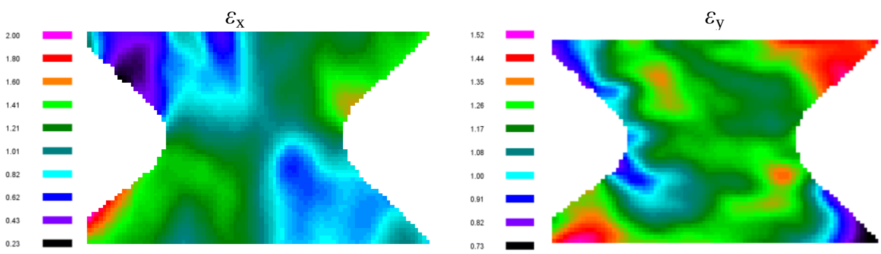

Fig. 6 Fields of normal relative strains ε_x, ε_y (stainless steel) [µm/mm]

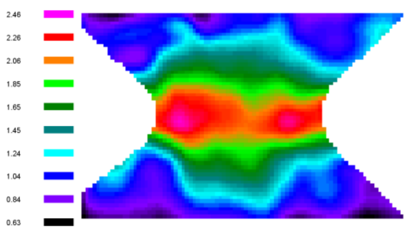

Fig. 7 Field of shear strains γ_{xy} (stainless steel) [µm/mm]

Fig. 8 shows the fields of shear stress τ_{xy} for a specimen of stainless steel obtained by experiment and numerical calculation in ANSYS.

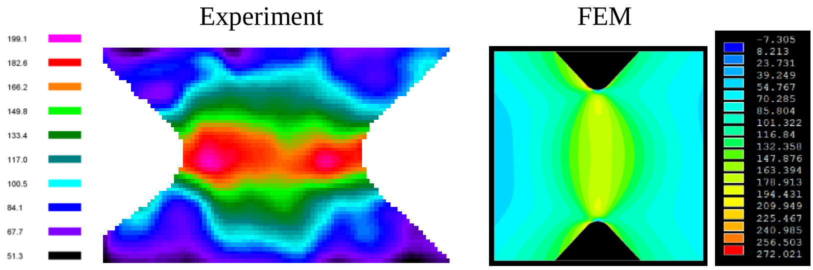

Fig. 8 Shear stress fields τ_{xy} (stainless steel) [MPa]

Fields of principal stresses σ_1 and σ_3 with showing their directions are presented in Fig. 9 and Fig. 10.

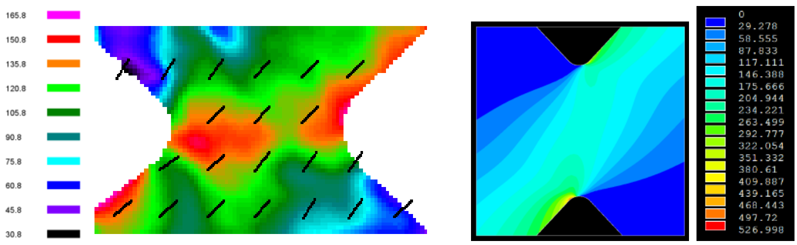

Fig. 9 Fields of principal stresses σ_1 with showing their directions (stainless steel) [MPa]

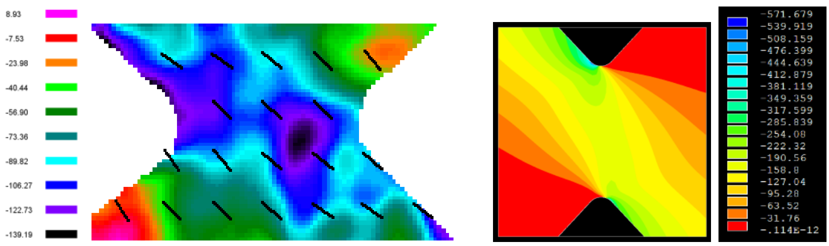

Fig. 10 Fields of principal stresses σ_3 with showing their directions (stainless steel) [MPa]

Fig. 11 and Fig. 12 show fields of relative normal strains ε_x and ε_y and shear strains γ_{xy} on the dural specimen.

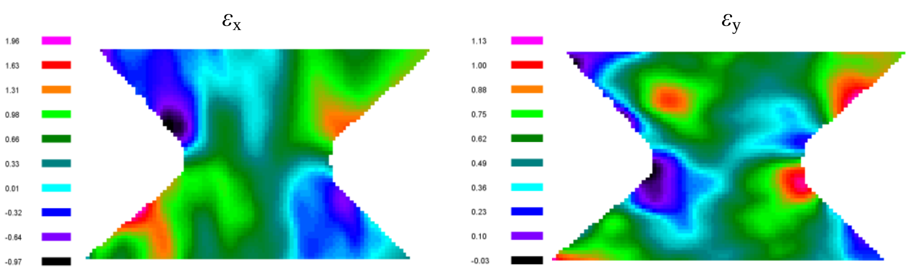

Fig. 11 Fields of relative normal strains ε_x, ε_y (dural) [μm/mm]

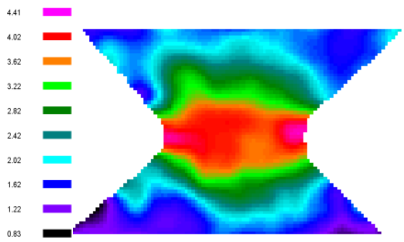

Fig. 12 Fields of shear strains (dural) γ_{xy} [μm/mm]

Fields of shear stress τ_{xy} for a dural specimen in middle area are shown in Fig. 13.

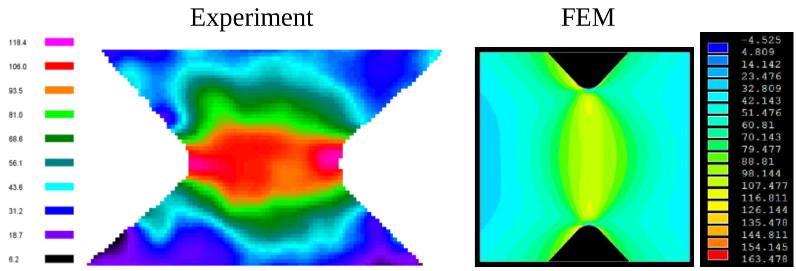

Fig. 13 Shear stress field τ_{xy} (dural) [MPa]

Fields of principal stresses σ_1 and σ_3 with showing their directions are presented in Fig. 14 and Fig. 15.

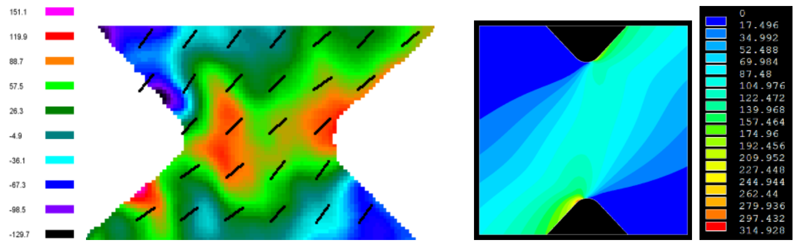

Fig. 14 Fields of principal stresses σ_1 with showing their directions (dural) [MPa]

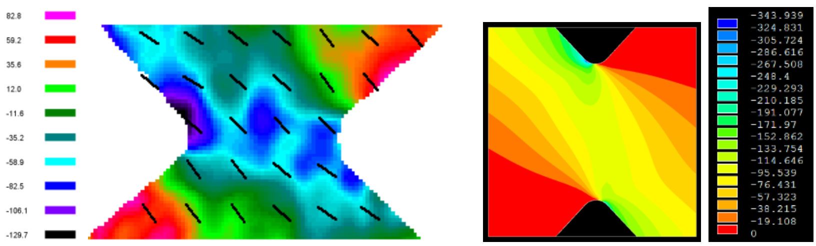

Fig. 15 Fields of principal stresses σ_3 with showing their directions (dural) [MPa]

Based on fields of shear stress τ_{xy}, can be seen that the maximum values of elastic deformation are in the central area of the test specimen between notches. Also, the maximum values of the principal stresses are concentrated in the central area between the notches. The directions of these principal stresses are inclined at an angle of approximately 45 degrees. The values of principal stresses are the same size and have the opposite sign. It is evident achievement of shear deformation.

Small but insignificant effect on stress fields induced additional bending stress. This effect might be caused by small shifts due to factory inaccuracy of the measurement chain. Trembling of loading device has also some negative impact to evaluation of stress and strain fields during the experiment.

5 CONCLUSION

This paper describes experimental measurements using modern contactless optical method ESPI with system Q-100. In this method are compared occur interference stripes during progressive loading. To obtain the shear deformation was chosen "butterflies" shaped specimen with two opposing notchces with top angle 90 degrees. Since it is not possible to directly clamped the specimen in jaws of ripper, it was designed loading fixture for mounting of test specimens with possibility of shear stress. It were chosen two types of specimen with different mechanical properties to verification using of method ESPI. Aluminum alloy - dural AlMg3 in comparison with stainless steel 1.4301 has a significantly lower yield strength R_e and tensile strength R_m. The results obtained by measurement on stainless steel specimen are more complex and avoid leaving the area with local extremes of operating stress. The results of the distribution of the maximum stresses and the deformations show that the required stress status can be obtained at a specimen stress test. Verification of the stress field by finite element method showed the possibility of application of the optical system for measuring flat specimens witch notches, that are loaded by shear deformation. The comparison with experimental results clearly shows a relatively good agreement in the distribution of stress fields. The differences of the values obtained by numerical calculation and experiment are in the range 10 to 20 MPa.

ACKNOWLEDGEMENT

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