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DESIGN AND DEVELOPMENT OF A DEVICE USED IN BIAXIAL TESTING OF MATERIALS

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Abstract. Biaxial testing of cruciform specimens is one of the most used experimental methods for the assessment of plane stress and strain state. The main advantage of this technique it is his versatility. The device conceived, designed and developed represents an alternative to complex testing machines. Cruciform specimen size and shape were established after conducting a series of finite element analysis in elasto-plastic domain. Experimental results obtained by biaxial tensile testing of cruciform specimens using devices attached to the universal testing machine are accurate.

Keywords: material characterization; biaxial tensile tests; plane stress states; cruciform specimens, FEA.

1. Introduction

Objectives of biaxial experiments are: to predict material failure, to evaluate materials mechanical behaviour, to calibrate constitutive models, to validate limit state theories, etc. Also this tests are used for fracture

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characterization of glass fiber composite laminate (Rashedi *et al.*, 2016), anisotropy characterization (Zhang *et al.*, 2015) etc. Loading an in-plane cruciform specimen in two orthogonal directions simultaneously, with attachable devices, is a big challenge.

Zouani *et al*. have realized a brief review of the existing multiaxial testing methods through which can be obtained a biaxial tensile stress state (Zouani *et al.*, 1999). Brieu *et al*. have proposed and validate a new biaxial tension mechanism for testing hyperelastic behavior of rubber-like materials (Brieu *et al.*, 2007).

Biaxial experiments are limited by a set of factors such as:

– cruciform specimen shape and size;

– material nature;

– cruciform specimen processing methods;

– testing system set-up;

– costs, etc.

Through biaxial tensile loadings can be tested a wide range of materials: warm rolled 316 L stainless steel (Petegem *et al.*, 2016), DC04 sheet steel (Schmaltz and Willner, 2014), dual phase steel - JSC590Y (Hanabusa *et al*., 2013), cell seeded collagen gels (Hu *et al*., 2014), rubber (Fujikawa *et al.*, 2014), elastomers (Promma *et al.*, 2009) etc.

Attachable devices to universal testing machines used in biaxial tensile tests can be based on various mechanisms:

– mechanisms with sliding elements (Andrușcă *et al.*, 2014);

– mechanisms with articulated connecting rods (pantograph) (Andrușcă *et al.*, 2014);

– mechanisms with inclined planes (Andrușcă *et al.*, 2015) etc.

2. Design, Development and Testing of Attachable Device

After the analysis and design of different versions for attachable devices the alternative selected to be built was the one with sliding elements on inclined planes.

Drawing of custom apparatus is showed in Fig. 1. Main parts of the assembly are listed in Table 1.

The operating principle of the device is based on the sliding of the four main elements (driving and median). One of the two driving elements is fixed in universal testing machine. The other is driven by traction force and is controlled by the load cell of testing machine. The contact between the four elements is made over the entire length of sliding cylinders, but not on the entire circumference.

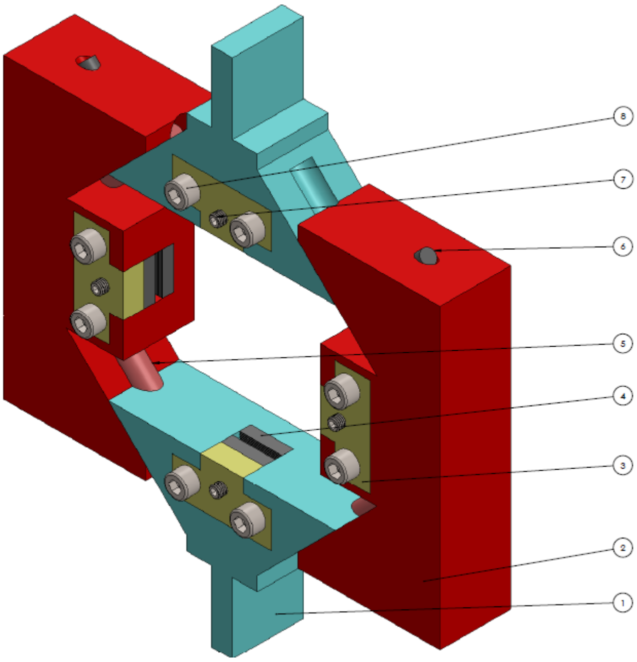

Fig. 1 – Component elements of the custom-built attachable device.

Table 1
Main Components of the Mechanism

Item No.	Description	Qty.
1	Driving element	2
2	Median element	2
3	Fixing element for grippers	4
4	Gripper	8
5	Sliding cylinder	4
6	Fixing element for sliding cylinder	4
7	Set screw	4
8	Hexagon socket head cap screw	8

For a median element (Fig. 2) can be written the condition that the resultant force projection in the horizontal direction to be null like in Eq. (1).

$$N - 2P\cos 45° + 2F\cos 45° = 0 \quad (1)$$

where: N, P, F represents forces acting on device elements.

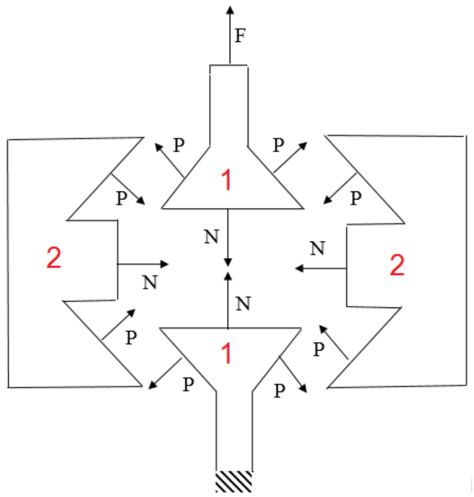

Fig. 2 – Forces acting on device elements.

Cruciform specimen model used in FEA analysis, with areas of interest, is presented in Fig. 3. Equivalent stress is calculated with von Mises limit state theory, frequently used for failure prediction of materials with predominantly ductile behavior.

$$\sigma_{VM} = \frac{1}{\sqrt{2}}\sqrt{\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + \left(\sigma_z - \sigma_x\right)^2 + 6\left(\tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2\right)} \quad (2)$$

where: σ_i represents normal stresses and τ_{ij} represents shear stresses, [MPa].

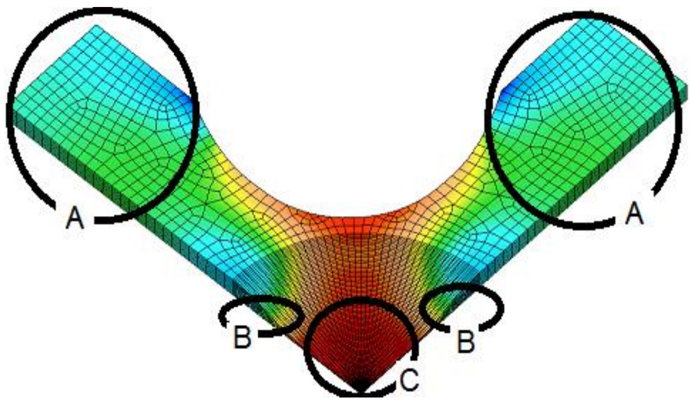

Fig. 3 – FEA analysis of 1/8 cruciform specimen (von Mises stresses)
A – arms region; B – Transition region; C – Gauge area.

After the device and cruciform specimen were designed and realized, they have been used in biaxial testing of metallic materials (Fig. 4). Cruciform specimens manufactured from Al 6082 T6 aluminum alloy were tested up to breaking.

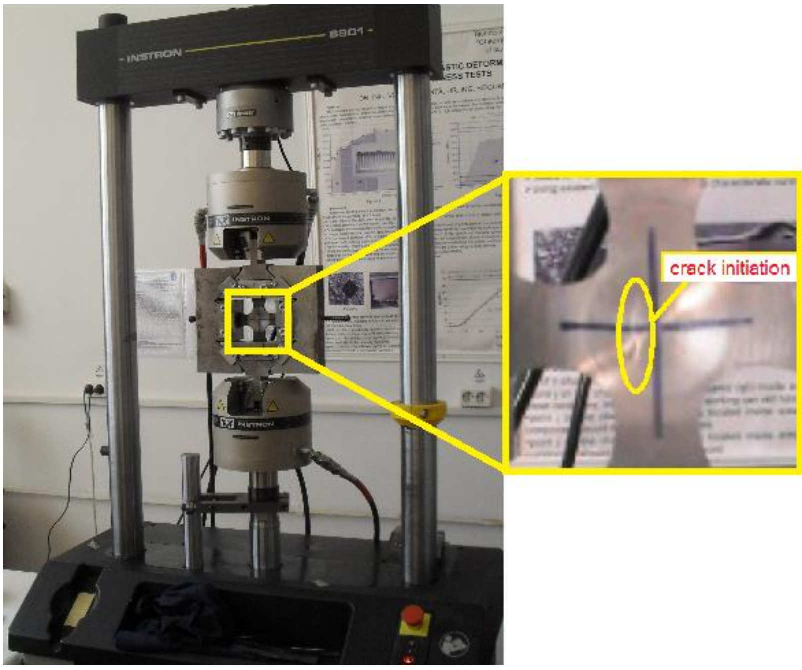

Fig. 4 – Attachable device used in biaxial tensile tests installed on Instron 8801 universal testing machine.

3. Conclusions

A new concept of an attachable device and cruciform specimen is used to asses biaxial stress state in metallic materials. Inclined planes device is the solution proposed to perform biaxial tensile tests using cruciform specimens. The experimental set-up was validated for metallic materials (S 235 JR, Al 6082 T6).

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PROIECTAREA ȘI DEZVOLTAREA UNUI DISPOZITIV FOLOSIT ÎN TESTAREA BIAXIALĂ A MATERIALELOR

(Rezumat)

Testarea la tracțiune biaxială a epruvetelor cruciforme reprezintă o tehnică experimentală foarte versatilă. Prin intermediul ei se poate obține o stare plană de tensiuni pentru o gamă variată de materiale. În contextul raționalizării și minimizării configurației experimentale este necesară găsirea unor noi soluții constructive privind mașinile, dispozitivele și epruvetele utilizate în testarea multiaxială a materialelor. Dispozitivele atașabile la mașinile de încercat universale reprezintă varianta economică la sistemele de testat complexe și scumpe. Rezultatele experimentale obținute în urma încercării la tracțiune biaxială a epruvetelor cruciforme folosind sistemele atașabile sunt precise. În această lucrare este prezentat un nou model de dispozitiv care a fost proiectat, realizat și validat pentru testarea biaxială a materialelor metalice.