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# The Verification of Fixture for Shear Load with Optical Method ESPI

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**Abstract** This paper describes a proposal of the shape and dimensions of a fixture which allows loading experimental samples by shear. The proposed device and the sample were subjected by a static FEM analysis, for judging the suitability of the given constructional proposal of the fixture for the chosen type of load. The fixture also was subjected to experimental measurement susingnon-contact optical method ESPI.

***Keywords:*** *shear stress, fixture, Arcan test, ESPI, FEM*

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## 1. Introduction

In some analysis it is necessary to simulate shear load of the construction elements in real conditions [1,2,3]. The experimental samples, which we want to load by shear deformation, usually have very complicated shape of the notches for the initiation of the expect shear deformation. For or measurement was selected a sample with a "butterfly" shape. For this sample shape was designed special fixture. Similar methods were used for creation of the fixing device like in the shear tests in Arcan [4,5,6,7]. The fixing device was constructed according to the requirements of particular tension test machine. The fixture proposal has to comply some conditions. One of the conditions is to apply new experimental methods, especially optical methods that use principle of the optical interference.

## 2. Shear Load

In practice, there is a shear stress especially in torsion shaft. Shearing load also occurs on bolts, rivets which connect parts to an assembly, or in use of fillet welding. These connections are also loaded by additional loads, like pull, compressive or bending. In cases of more types of load in the cross-sectional area tangential and normal stress components originate. If the normal components are insignificant compared to the tangential stress, the control is done only for shear load. Then we can propose that in the cross sectional area is only pure shear occurs.

Pure shear is defined only by one component of the tangential stress $\tau_{xy}$. The matrix $[\sigma]$ and $[\varepsilon]$ of the scalar components of the stress tensor and deformation tensor have the following form.

$$[\sigma]=\begin{bmatrix}0 & \tau_{xy} & 0\\ \tau_{yx} & 0 & 0\\ 0 & 0 & 0\end{bmatrix};[\varepsilon]=\begin{bmatrix}0 & \frac{1}{2}\gamma_{xy} & 0\\ \frac{1}{2}\gamma_{yx} & 0 & 0\\ 0 & 0 & 0\end{bmatrix} \quad (1)$$

The dependence between the principal normal stress $\sigma_1, \sigma_3$, and the tangential stress $\tau_{xy}$ are defined by the following relationship.

$$\sigma_{1,3} = \pm\tau_{xy} \quad (2)$$

### 2.1. Experimental Sample

For this experimental measurement was used a flat sample with a symmetric V notch (Figure 1). This shape of the experimental sample is sometimes called butterfly shape.

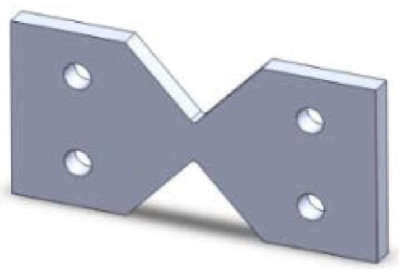


**Figure 1.** The experimental sample with a symmetric V notch

The connection and the stabilization of the experimental sample in the fixture were realized by holes for bolt connections in the extended area of the experimental sample.

### 2.2. Fixture

The experimental sample with the butterfly shape is not possible to clamp in to the tensile test machine directly. Therefore a constructional component was developed for this case. In the development of the component the same construction was used like the one in an Arcan test according to Figure 2.

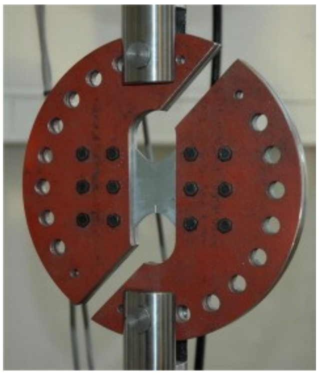


**Figure 2.** Arcan Test

For the Arcan test a special device was made up of two half-circle parts. The experimental sample was connected to the fixture with bolts.

## 3. The Proposal of Shape in Solid Works

The entire assembly of fixture together with screw connections and drawing documentation were created in the program Solid Works (Figure 3). The overlap of the parts of construction system was detected by automatic interference.

**Figure 3.** Fixture with bolt connections in Solid Works

The all fixture are made of four parts and eight bolt connections. Both extended sections of the experimental sample are clenched between two and two parts of the fixture (Figure 3).

The fixture was also developed for other loading conditions. The final shape of the fixture allows loadingof the experimental sample by pure shear (α = 90°), and tension load (α = 0°), see Figure 4. The experimental sample can be loaded with a planestress. This plane stress can be obtained by turning the fixture through angle α.

The angle α can gain values in dependence of the construction from 0° to 90° (Figure 2). We can obtain different states of plane stress. We can only gain one state of plane stress with our fixture, when theloading force is under the angle α = 45° (Figure 4)

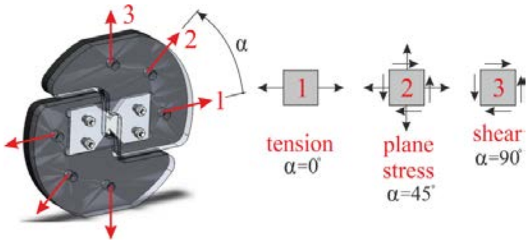
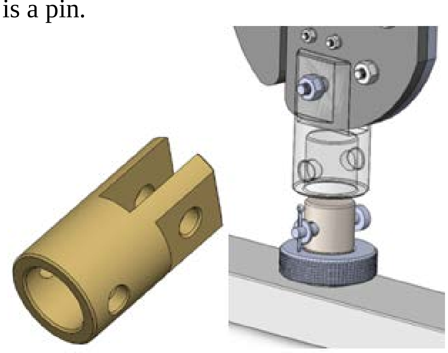



**Figure 4.** State of stress under load in different directions

It is not possible to connect directly device to the tensile machine. Our goal is analyse the sear deformation on a concrete experimental tensile machine Testometric. Therefore two connection elements were proposed (Figure 5 a), for the connection of the fixture to the experimental tensile machine. These elements were designed according to the requirements of the output pin of the experimental tension machine.

The connection of the experimental tension machine with the fixtureis presented on Fig 5 b. The connection element is a pin.



a b

**Figure 5**. Coupling tension machine with fixture

## 4. Verification of the Proposal of Fixture

### 4.1. FEM Analysis

Numerical analysis was made with using finite element method in program Solid Works. The aim of the analysis was to verify the accuracy of the proposal of the entire assembly for the individual types of loading. The bolt connections were eliminated from the simulation. Instead the bolt connections were defined adequate conditions with necessary axial and radial stiffness. Contact areas were defined in the places of contact the experimental sample with the fixture.

The finite elements mesh was compress in the places where the stress was achieved maximal values (Figure 6). Therefore it was possible to use bigger size of the elements on the other parts of the assembly. Complete assembly contains 148 048 elements and 232 855 nodes.

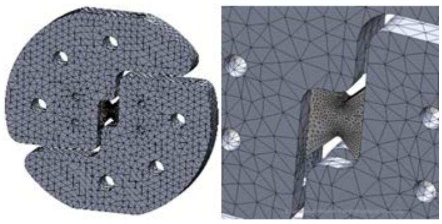


**Figure 6.** Finite element mesh and detail the mesh in the middle areaof the experimental sample with V notch

The accuracy of the solution gives better results if the mesh elements are smaller. This solution converges to the theoretically correct results. However, the smaller mesh elements need longer computation times andmore space on the disc.

## 4.2. Contactless Optical ESPI Method

For the experiment measurement was selected contactless optical method ESPI with a Q 100 device. The fundamental principle of the optical method ESPI is the use of laser light [8,9,10]. Laser beam is divided into object and reference beam (Figure 7).

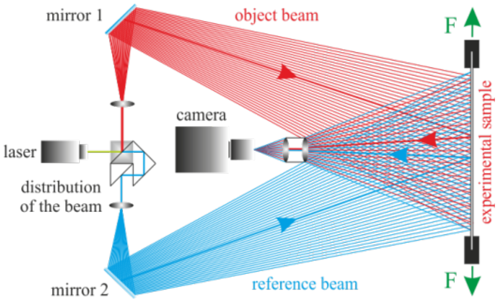



**Figure 7.** Measuring In Plane - ESPI

Laser light illuminates the optically rough surface of experimental sample. Laser light on optical rough surface create characteristic speckle image. Total load is divided on several load steps. The method ESPI compares the speckle image before and after loading step. The result of this interference is the characteristic image with stripes.

Strain of experimental sample were evaluated fromdeformation fields. Using of material elastic constant (Young´s modulus $E$ and Poisson´s ratio $\mu$) also allows evaluate of stresses fields but it is possible only in elastic area.

The fixture and the test sample were constructed based on the results of static analysis. The fixturewith the experimental sampleare presented on Figure 8.

**Figure 8.** One half of Fixture with experimental Sample

The fixture with experimental sample in tension machine and optical sensor of device ESPI are shown on Figure 9.

**Figure 9.** Fixture with the experimental sample and the optical sensor Q 100

The optical sensor is installed directly on the fixture by tensometric adhesive.
The measurement was realized at VŠB in Ostrava at the Department of Mechanics of Materials.

## 4.3. FEM and Experimental Results

Objective of both analyses are not comparison the stress fields from FEM analysis and experimental measurement but it is only verification of proposal of fixture. In numerical FEM analysis it was used random material for fixture and sample. For experimental measurement were used several materials of sample. The results of experimental measurement are for aluminium sample.

The fields of the reduced stress $\sigma_{red}^{HMH}$ of the entire assembly that are result of loading by shear are presented on Figure 10.

From the allocation of the reduced stress it is clear, that on the fixture is affected by the load only lightly, thus the stress can be neglected. The biggest stress occurs in the middle area of the experimental sample as it was wanted.

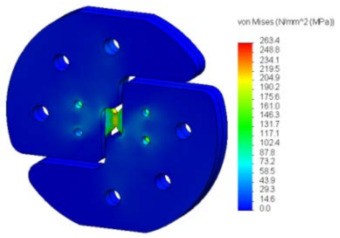


**Figure 10.** The fields of reduced stress $\sigma_{red}^{HMH}$ on the assembly

The details of the reduced stress $\sigma_{red}^{HMH}$ and the tangential stress $\tau_{xy}$ in the middle area of the experimental sample are presented on Figure 11 and Figure 12.

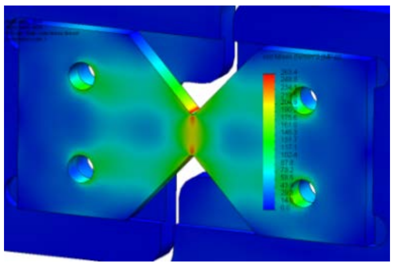


**Figure 11.** Reduced stress fields $\sigma_{red}^{HMH}$

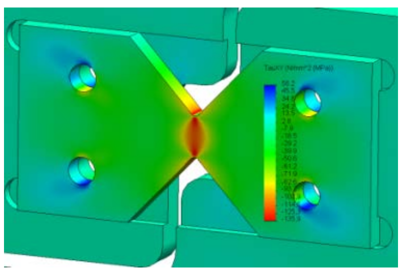


**Figure 12.** Tangential stress fields $\tau_{xy}$

The concentration of reduced stress $\sigma_{red}^{HMH}$ and the tangential $\tau_{xy}$ stress $\sigma_{red}^{HMH}$ are in the middle area of the experimental sample between the notches.

The fields of the principal stress $\sigma_1$ and $\sigma_3$ in the middle area of the experimental sample are shown on Figure 13 and Figure 14.

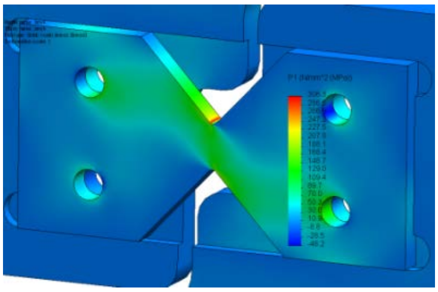


**Figure 13.** The principle stress fields $\sigma_1$

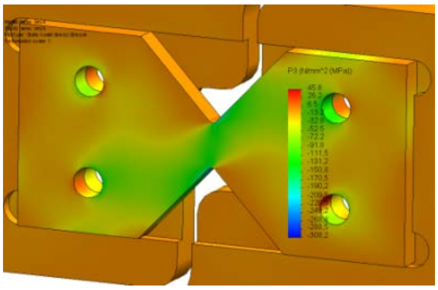


**Figure 14.** The principle stress fields $\sigma_3$

From the results of stress fields, it is clear that at the centre of the experimental sample as pure shear load. In this case, the simulation proved the validity and accuracy of the proposal for the preparation of the sample in the shape of a butterfly.

We can evaluate only small area of experimental sample approximately (25 × 35 mm)with optical method ESPI Q 100 device (Figure 15).

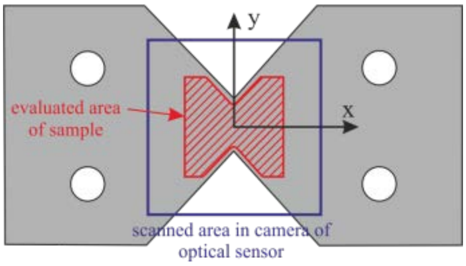



**Figure 15.** Scanned area of experimental sample (ESPI method)

The stress fields calculated experimental optical ESPI method are presented in (Figure 16 - Figure 19). All results are from the middle area of the experimental sample.

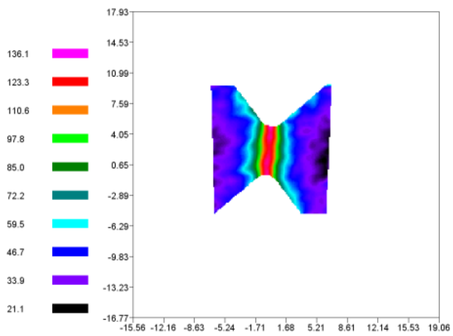



**Figure 16.** Reduced stress fields $\sigma_{red}^{HMH}$

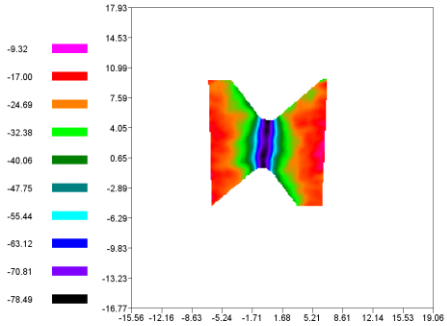



**Figure 17.** Tangential stress fields $\tau_{xy}$

Orientations and magnitude of principal stress under angle 45° in the middle area of the experimental sample are presented on Figure 18 and Figure 19. Stress in the middle area defines the load by pure shear.

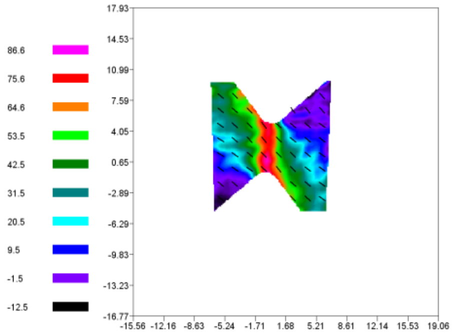



**Figure 18.** The principle stress fields $\sigma_1$ with their direction orientation

The distribution of stress fields of experimental meaurement also confirms the accuracy of the fixture proposal for shear load of the experimental samples.

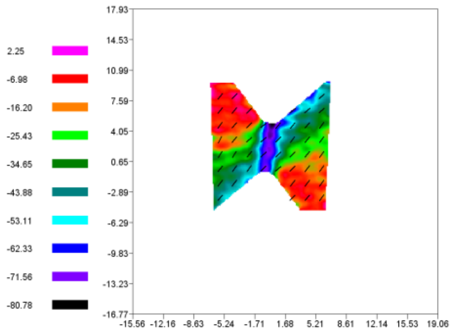



**Figure 19.** The principle stress fields $\sigma_3$ with their direction orientation

## 5. Conclusion

The fixture for loading of experimental samples by shear was proposed by numerical method. The fixture was made based on results of numerical analysis. Experimental measurement was carried out with help of the Department of Mechanics of Materials in Ostrava. Experiment was carried out with optical device ESPI Q 100, which verified the results for pure shear load of the experimental samples. Nowadays this assembly is used for the analysis and identification of the shear deformation and stress on different types of materials.

## Acknowledgement

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for development ofmethodology for identification and prediction of failures in supporting elements of mechanical systems.

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