

## ON THE CRUCIFORM SPECIMENS FOR MATERIALS TESTING

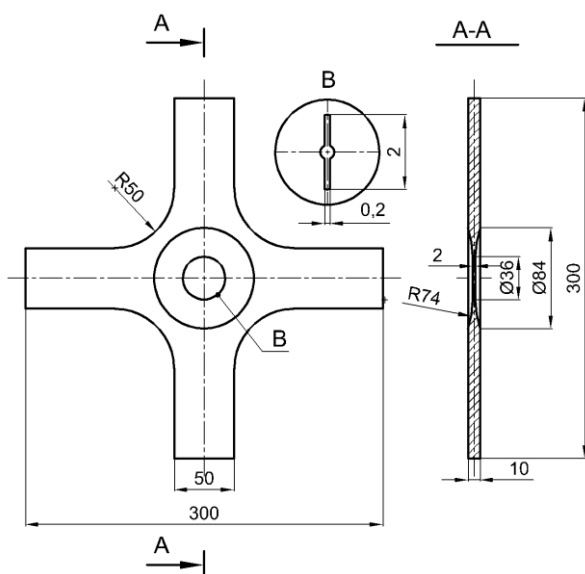
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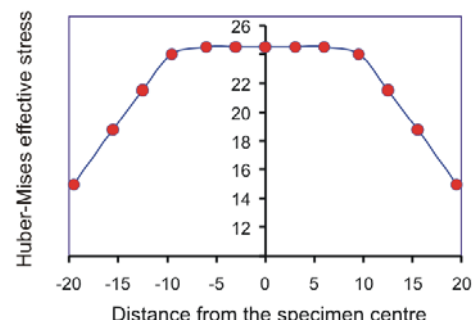
### 1. Introduction

Examination of material behaviour is conducted by the use of various kinds of specimens. Among them one can distinguish: cylindrical, tubular or cruciform. Each specimen type is attributed to selected kind of experiment. For determination of typical mechanical properties such as: Young's modulus, yield point and ultimate tensile strength, which are necessary for analytical or numerical calculations, cylindrical specimens are mostly used. In the case of material examination under complex stress state being combination of axial force and twisting moment the thin-walled tubular specimens are most suitable. The cruciform specimens are usually applied for tests being performed at two axial stress components acting in two mutually perpendicular directions. Such specimens may be applied to investigate plastic flow [1], determination of material resistance on brittle fracture (Fig. 1) [2], and fatigue [3]. Plastic flow is usually tested by means of cruciform specimens having measurement sections in a shape of square, Fig. 3.



**Fig. 1.** Cruciform specimen for fracture mechanics [2].

Fracture mechanics requires specimens possessing notch located in the centre of measurement zone, while fatigue process can be investigated using specimens of circular section [3]. A condition of high stress distribution uniformity in the measurement part of specimen is not trivial task. Therefore, many research groups use analytical, statistical and numerical (FEA) methods to optimize a geometry of the measurement section and specimen's dimensions [3, 4, 5].



**Fig. 2.** Huber-Mises stress at circular measurement zone of cruciform specimen for fatigue tests [3].

Application of various calculating methods enables to obtain even 80% increase of stress distribution uniformity. Final results can be in a form of stress state components isolines [4] or simple equations [5]. The Huber-Mises effective stress values after optimization are shown in Fig. 2 [3].

Material characterisation on cruciform specimens is usually performed on biaxial testing machines. This type of equipment is typically designed to have four servomotors, which act by means of two digital feedback close loops [3]. With respect to servomotors configuration, two variants of the testing machines are usually produced: the loading frame is a vertical configuration with the actuators mounted at 45° [7] or 90° from the vertical, [6]

In the case of a typical configuration of the cruciform testing machine (90°) an influence of specimen weight on the collected results occurs. If the servomotors arrangement is determined by the angle of 45° from the vertical then the effect disappears. The problems mentioned above indicate that investigations on cruciform specimens are quite difficult and not sufficiently recognized yet. Therefore, further studies are necessary in order to get more thorough knowledge related to cruciform specimens testing. The paper is an attempt in this area. Certain progress can be achieved by means of investigations supported by Finite Element Analysis.

## 2. Numerical procedure

To extend the knowledge of experiments conducting on the cruciform specimens, the Kelly's specimen design was selected [1]. Application of this type specimen for plastic flow and creep analysis was the main motivation of this paper.

The Kelly's specimen was modelled using Patran/Nastran software. 3D Hex 8 elements were applied. Data representing linear stress-strain relationship of material and Young's modulus of 2.1 GPa were implemented to the software. MultiPoint Constrain (MPC) was used to simulate tension in both perpendicular directions.

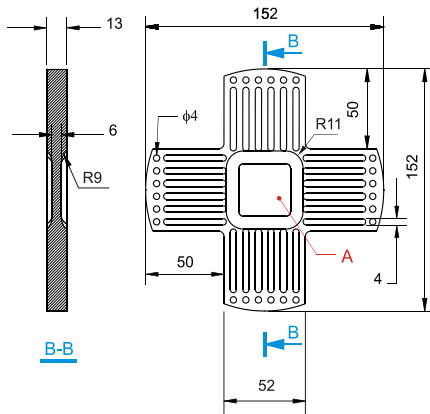


Fig. 4. Kelly's cruciform specimen [1].

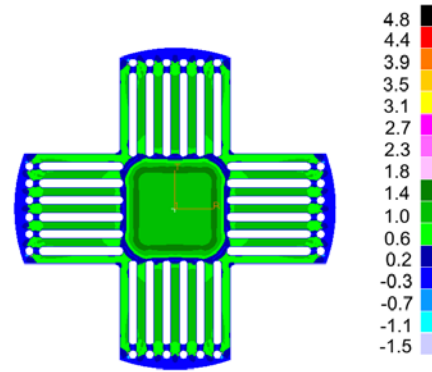


Fig. 5. Radial stress distribution.

FEA results show the uniform distribution of radial stress in almost 90% area of the measurement zone, Fig. 5. For tangential stress even better uniformity was obtained (97%). Stress distribution in 0z direction on 0xy plane was similar to the radial stress distribution map, while in a perpendicular cross section the stress gradient was observed due to the radius between measuring and gripping sections, Fig. 6.

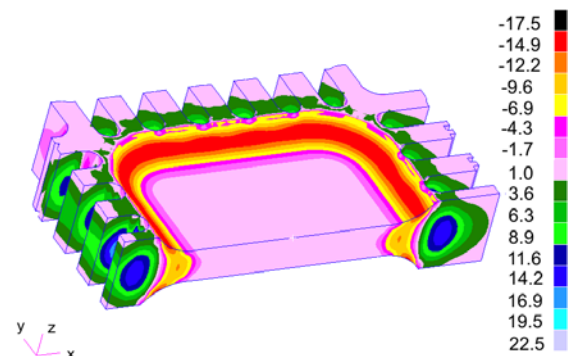


Fig. 6. Distribution of  $\sigma_{zz}$  stress.

## 3. Summary

Determination of stress distribution in 3D coordinate system enables to reach differences in distribution of stress state components important for strain measuring.

## References

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