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STRAIN GAUGE ROSETTE FOR TRIAXIAL STRAIN MEASUREMENT

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Abstract–In this paper is presented a way to measure the triaxial state of strain and stress using strain gauge rosette for residual stress measurements and a sensitive pin with a small strain gauge glued on the plane surface of the cylinder. It is proposed an upgraded version of the biaxial state of stress measurement method verified by finite element analysis.

Keywords: measurement, strain gauge rosette, triaxial state of stress

1. INTRODUCTION

Residual stresses are known to be stresses in a solid state of an specimen, at a uniform temperature, in the absence of any external loads (forces, couples or accelerations). This causes the formation of a system of forces in equilibrium, both locally and globally, which is generally difficult to evaluate [1, 2].

A rosette with three grids can determine only plane state (2D) of strain and stress: main strains and stresses (maximum and minimum stress in the rosette plane and their directions). By measuring with actual strain gauges rosettes, we can’t measure strain on the perpendicular to the rosette’s plane direction.

The most used technique for measuring of residual stresses is the hole-drilling strain gauge method [3]. Depending on the type of rosette used, the drilled hole in the center of rosette is typically of 0.9, 1.5 or 3 mm diameter and 1.2 diameters in depth. After residual stress measurement, the part or structure remains with small blind hole(s) in it.

1.1. Residual stress measurement method

The current method has progressed by mounting strain gauge rosettes and milling guide with optical centering [4]. It is often described as semi destructive, because it involves the removal of small amounts of material, but this usually does not affect good performances of the specimen [5].

The main problem with this method is that after the milling takes place the specimen will remain with an important stress concentrator, very unfavorable for fatigue.

1.2. Triaxial measurement

i. Measurement of residual stresses by hole-drilling strain gauge method (ASTM E837), milling a small blind-hole (Fig. 1).

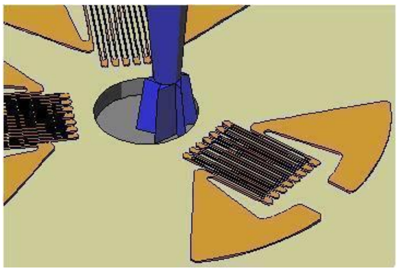

Fig. 1. Milling hole in a plate.

ii. The entire additional sensitive pin is pressed in a cylinder and glued inside the hole (Fig. 2 and Fig. 3).

iii. Free remaining space in the center of the additional device can be eventually filled with adhesive paste and the device’s strain gauge is connected to the measurement bridge.

iv. All the grids of the strain rosette and the strain gauge sensitive pin can be used together for triaxial (3D) state of stress measurement [6].

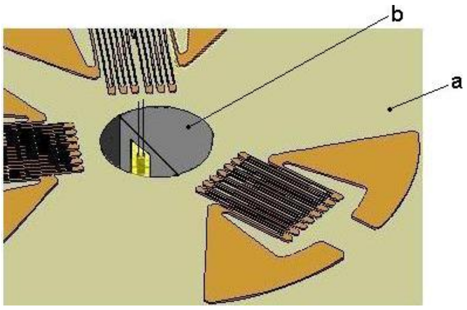

Fig. 2. Strain gauges rosette glued on the plate surface, with sensitive pin mounted in the central hole (a-specimen, b-sensitive pin, adhesive removed).

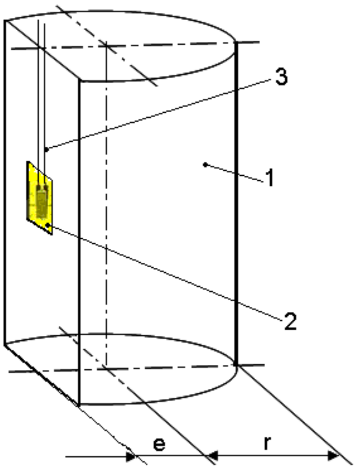

Fig. 3. Sensitive pin (1-pin, 2-electrical strain gauge, 3-conductors, e and r - minimum cross-sectional dimensions).

2. FINITE ELEMENT ANALYSIS

For the finite element analysis we've considered a plate specimen submitted to several cases of measuring state of strain and stress using strain gauge rosette. The plate is square with an edge of 100 mm and 10 mm height. The material chosed was steel with yield strength of 305 MPa and Young modulus of 210 GPa. Simulation was made in ABAQUS 6.14 program, analysis type being elastic for isotropic materials. There are no boundary conditions imposed to the specimen because we used a triaxial state of stress. The loading is uniform, type positive pressure of a 1 MPa magnitude for following simulations (blind hole plate, plate with sensitive pin and partial blind hole, plate with sensitive pin and adhesive pill).

Depending on actual characteristics of the geometry there are two types of mesh used: structured with hexagonal element shape or hybrid structured with hexagonal dominated element shape.

2.1. Blind hole plate

The classical strain gauge method means the specimen will have a blind hole drilled in order to measure the residual stresses with strain rosette. The mesh is structured with hexagonal elements and we have a more detailed mesh around the stress concentrator that is the blind hole (Fig. 4).

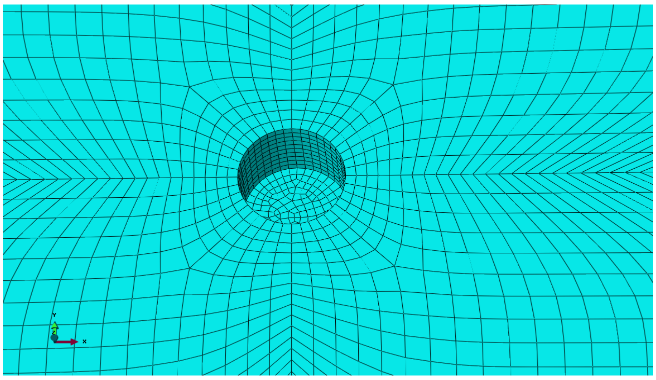

Fig. 4. Mesh distribution for the blind hole plate.

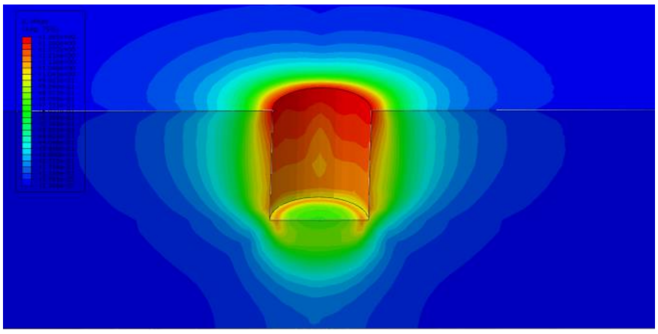

Fig. 5. von Mises stress in cross section of the blind hole plate.

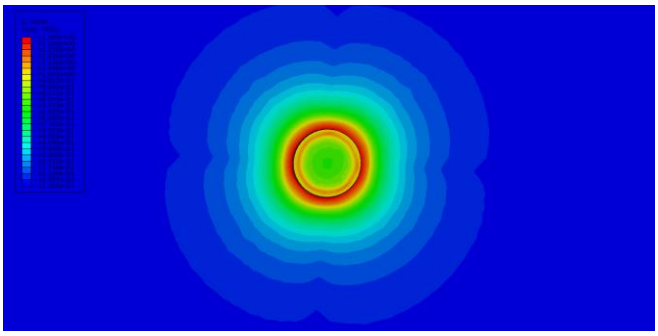

Fig. 6. von Mises stress of the blind hole plate (top view).

Fig. 5 and Fig. 6 are the representations of von Mises stress that appear in the specimen after simulation and we can observe the importance of the stress concentrator that remains in the plate after the drilling took place in form of the blind hole.

2.2. Plate with sensitive pin and partial blind hole

The second situation that it is analysed contains a plane plate with a blind hole in which is glued a cylindrical shaped sensitive pin. The pin itself is made from same material as the plate and it has a flat edge where the resistive sensor is glued.

This new situation has a structured mesh with hexagonal dominated element shape (Fig. 7).

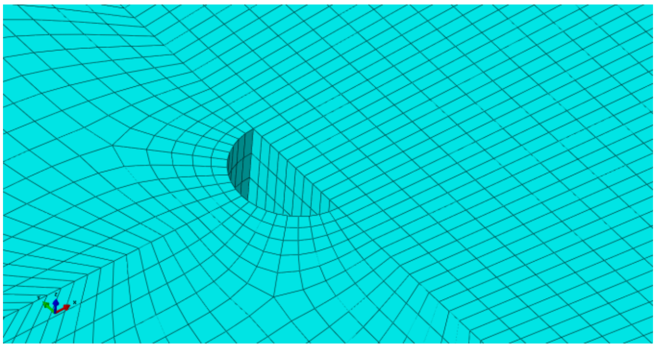

Fig. 7 Mesh distribution for partial blind hole.

The stress distribution is different than our first case and the higher values are to be observed at the exterior of the pin where the surfaces are glued.

Fig. 8 and Fig. 9 show the von Mises distribution of stresses, presenting a significant decrease of the stress on the circular surface of the pin.

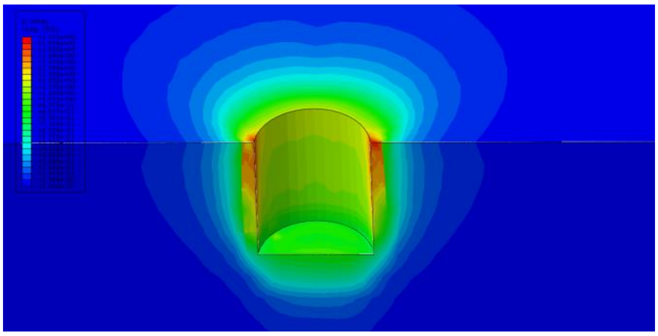

Fig. 8. von Mises stress in cross section of the milling hole.

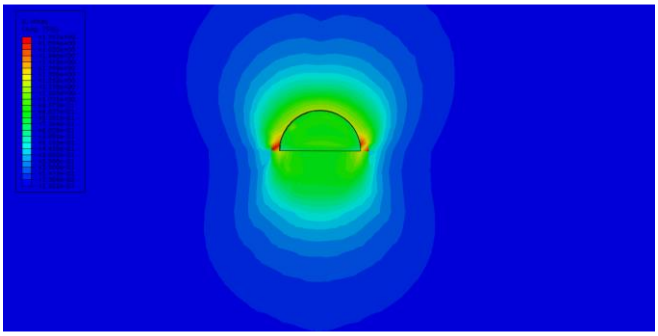

Fig. 9. von Mises stress - specimen with pin and partial blind hole.

2.3. Plate with sensitive pin and adhesive pill

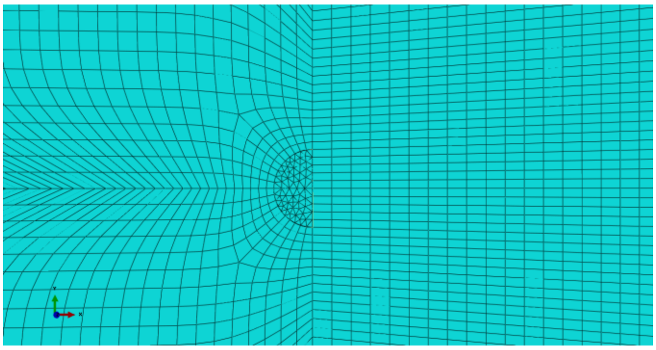

Fig. 10. Mesh distribution for plate with adhesive pill.

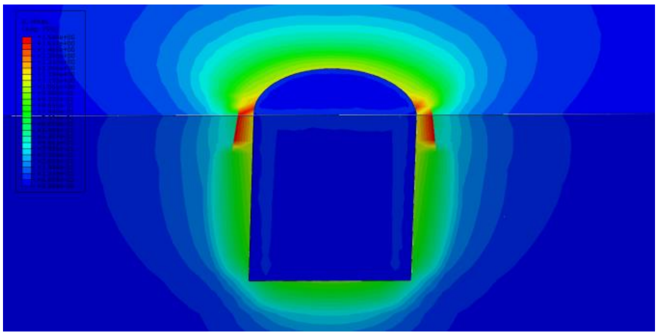

Fig. 11. von Mises stress for plate with pin and adhesive pill.

Our last case consists in studying the plain plate where the drill hole was made, but in the end that initial stress concentrator is minimized because we first insert the sensitive pin and in the remained hole a mass adhesive is used to fill it. The adhesive is also an isotropic material and has a Young modulus of 3.1 GPa.

There is a hybrid type of mesh with pyramids and prisms elements, but the important characteristic is that the nodes of the adhesive's mesh concur with the plate and pin's mesh (Fig. 10).

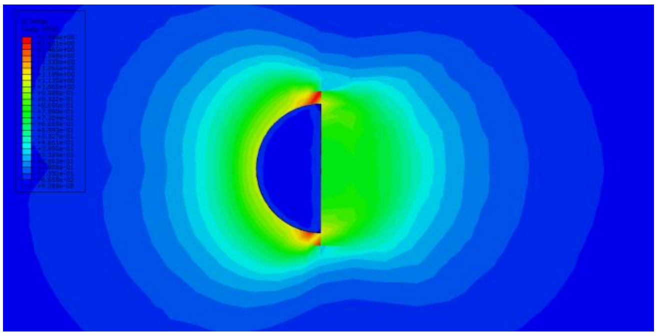

Fig. 12. von Mises stress for plate with pin and adhesive pill (top view).

The loadings of all three types of plates are identical so we could see the differences given by the sensitive pin and the state of the hole, either full, half full or empty (Fig. 13).

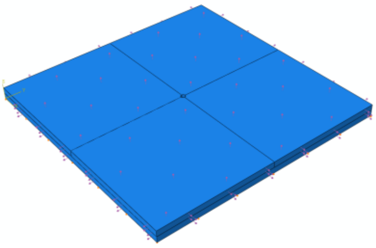

Fig. 13. Loading conditions for all three cases.

3. RESULTS AND DISCUSSION

We can observe that the state of stress was reduced by using the last method and the obtained values are slightly lower, as we can see in the bellow diagrams (Figures 14, 16, and 18).

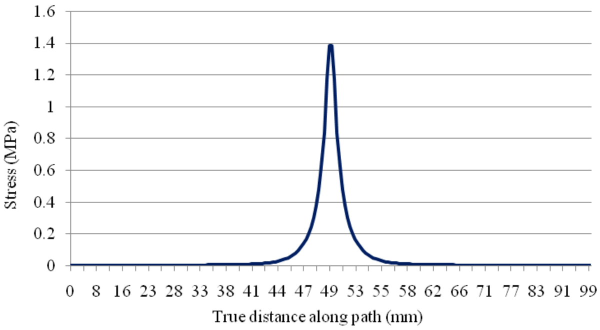

Fig. 14. von Mises stress for blind hole plate.

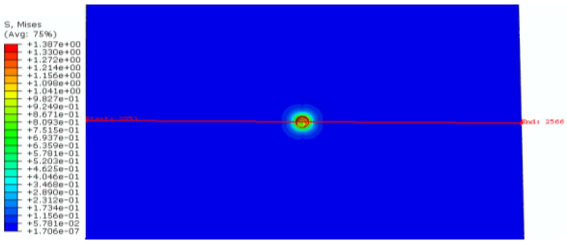

Fig. 15. Data recording line for the blind hole plate.

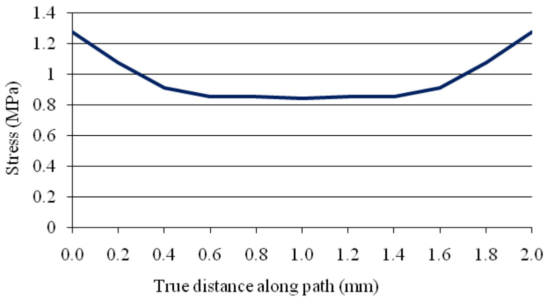

Fig. 16. von Mises stress for Plate with sensitive pin and partial blind hole.

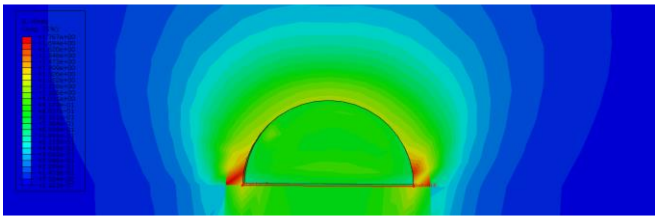

Fig. 17. Line data recording for the second case.

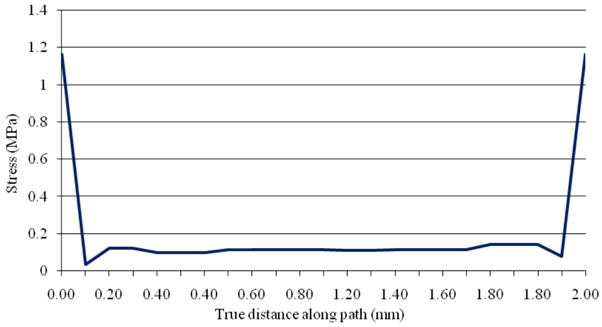

Fig. 18. von Mises stress for plate with sensitive pin and adhesive pill.

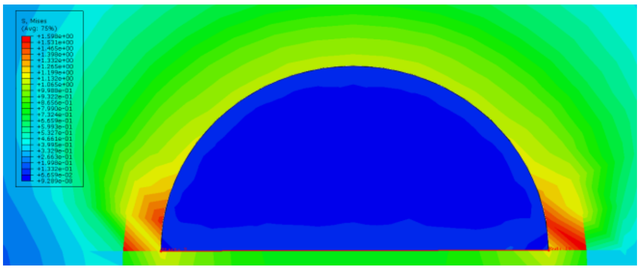

Fig. 19. Data recording line for third case.

From the finite element analysis results we could make the following observations for the blind hole plate in comparison with the plate with sensitive pin and partial blind hole:

i. The maximum stresses are lower as value in our second case;

ii. The material volume where there are developed important stresses is smaller on the plate with sensitive pin and partial blind hole;

iii. In the first case, the maximum stresses are developed in the vicinity of a so called concave corner as it is here the bottom of the hole, while on the second case they appear at a convex corner which is actually the hole's edge. It is known that micro cracks are formed easier on the proximity of a concave corner.

The above observations entitle us to say that the plate with sensitive pin and adhesive pill will behave better at fatigue then the blind hole plate.

4. CONCLUSIONS

The method that it is presented and for which the finite element analysis was made proves that the goal was achieved and so the triaxial state of stress can be measured using a strain gauge rosette and a sensitive pin. Endurance of the plaque with hole and pin will be better.

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