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STRAIN GAUGE APPLICATION IN SOFT MATERIAL TESTING

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ABSTRACT

Strain gauges are commonly used for strain measurements; however, their performance depends on several physical and mechanical effects [1-2]. Some of these limitations are associated to the stiffness of the material tested, since larger elastic modulus of the strain gauge causes strain reduction in the softer test sample [3]. Attachment of the strain gauge also includes strain distortions around edges, where the strains are transmitted from the test sample to the gauge [3]. These phenomena are attributed to the effect known as "reinforcement effect" [1]. As a result of the reinforcement effect, strain gauges measure lower strains than the strains experienced by the test sample in the absence of the strain gauge. In figure 1, contour plots of the 3D model show both strain reduction below the gauge and strain distortions around the edges.

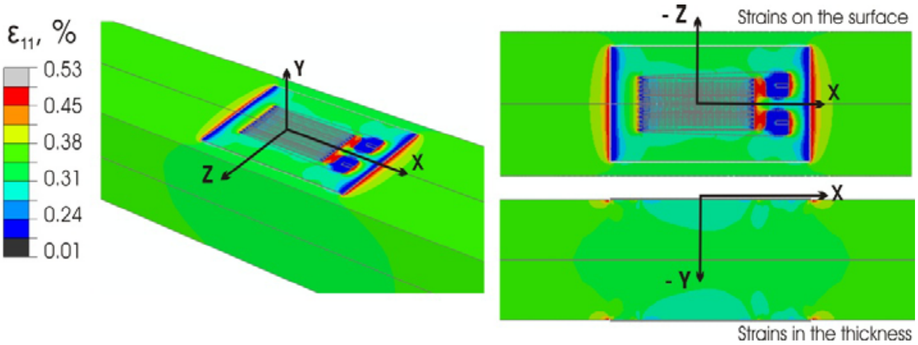

Figure 1: Strain fields obtained by the 3D model at ε = 0.35 % (specimen dimensions 85 x 12 x 10 mm^3)

In the present study, correction methods of the gauge factor for a strain gauge are proposed. Gauge factor shows the relation between the relative electrical resistance change of the strain gauge and the strain of the underlying material. It is common that gauge factor is found from a calibration on a relatively stiff material. Nevertheless, the gauge factor will depend on the stiffness of the underlying material, thus ideally the calibration should be done on a similar material as tested. Experimental and numerical methods are used to determine the correction coefficient, *C*, for test sample with material stiffness ranging from 1 to 200 GPa. In addition, a parameter study of specimen and strain gauge geometrical dimensions is included. Based on a full 3D finite element simulation the design of significantly less stiffness dependent strain gauge for use on thick test samples is proposed. Digital image correlation method was used to observe experimentally strain field distortions in the test samples.

Main conclusions of the study suggest that the correction coefficient of the gauge factor is greatly influenced by the test sample stiffness and thickness, as well as the length of the strain gauge. In figure 2, the 2D model predicted dependency of the correction coefficient on the test sample thickness and stiffness is shown, where *C* represents the ratio of the elastic modulus determined by strain gauge, E_{sg}, over the elastic modulus of the material without attached strain gauge, E_{spec}. Results indicated that for test sample with t_{spec} = 1 mm and E_{spec} = 1 GPa, the correction coefficient can reach almost 2.2, which corresponds to 120 % error on the strain gauge measurement. It can also be seen that even moderately stiff materials are prone to errors, e.g. if E_{spec} = 20 GPa and t_{spec} = 1 mm then the expected the correction coefficient is 1.055, i.e. strain gauge measurement error is 5.5 %. Furthermore, it is found that reduction of the correction coefficient by thicker specimen is limited, thus strain gauge measurement errors for soft materials cannot be eliminated using thick test samples.

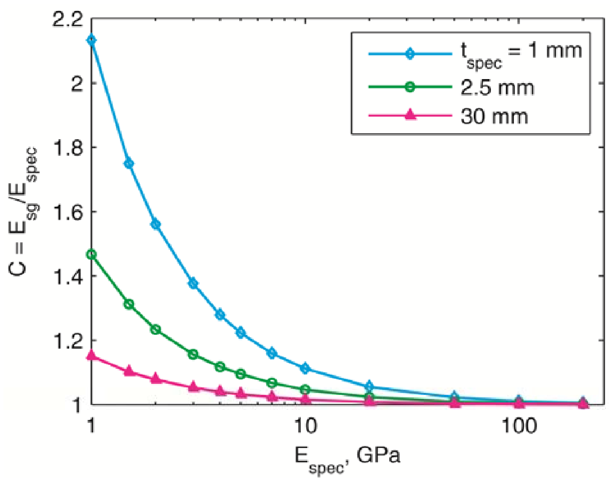

Figure 2: The 2D results of correction coefficient affected by specimen thickness and stiffness, when the specimen attached to strain gauge *HBM LY11-10/350*

Evaluation of the strain gauge length revealed that shorter strain gauges are prone to larger strain measurement errors than the longer ones. This was explained with strain distortions around the gauge ends, which occupy larger area relatively to the gauge length for shorter strain gauges. Thus to reduce the effect of the edge induced strain distortions, the improved design of the strain gauge pattern was presented by elongating the end-loops representing gauge edges. Improved design of the strain gauge reduced the correction coefficient by 50 % for specimen with E_{spec} = 1 GPa, t_{spec} = 10 mm and attached to strain gauge *HBM LY11-10/350*. Furthermore, it was observed that the correction coefficient values decrease with increasing plastic deformation of the strain gauge. Digital image correlation method measurements indicated similar observations to those obtained by the 3D simulation model.

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