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Validation of numerical models describing the stress-strain characteristics in the strength tests of composite materials on a metal matrix using the elasto-optic method

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Abstract: Testing the strength properties of materials intended as impact energy absorbers requires appropriate identification. The scope of tested becomes laborious when composites are the material used to build such shields. Various methods are used for this. One of them is the method based on the analytical model or Eshelby model or the method based on the finite element method. The analysis was based on AC-44200 alloy reinforced with 20% vol. and 30% vol. of Al_2O_3 particles. Numerical analysis were carried out in the ABAQUS/Explicit environment on the basis of composite material samples subjected to loads on a testing machine based on the fracture mechanics. The obtained results of the maximum stress distribution were compared with the results obtained using the elasto-optic method. The high agreement of the results proves the correctly developed numerical models and the adopted boundary conditions. The developed conclusions from the research were used for further analysis in the field of modeling the impact load of a new group of materials characterized by appropriate ballistic parameters.

Keywords: ceramic matrix composites (CMCs), impact resistance, Finite Element Method (FEM)

1. Introduction

The energy absorption in materials impulse load is a complex mathematical description process [1, 2]. The knowledge of the physical processes involved is directed towards the search for new material solutions, which should exceed the traditional material with their mechanical description properties, etc. [3, 4]. Materials of the cermet group can be a positive response to search for such solution. Cermets can largely replace the standard material in the form of classic ballistic ceramics, and conducted works, are focused mainly on finding proper structures absorbing the impact energy in to improve the yield strength. The subject matter of the study covers metallic composites reinforced with aluminum oxide (Al_2O_3) particles. This objective was achieved through numerical methods using FEM. The obtained results were validated experimentally by the elasto-optic method stress distribution.

2. Results and Discussion

The elasto-optical test was performed on a sample made of a metal-ceramic composite with a 20 and 30% $Al2O_3$ content. Strength tests were carried out on the MTS 858 Mini Bionix machine with the MODEL 031 polariscope with a power of 105W. The test sample was loaded with four forces until it cracked. At the same time, photos of the deformations shown were taken (Fig. 1). The sample was damaged under the load of 3900 N.

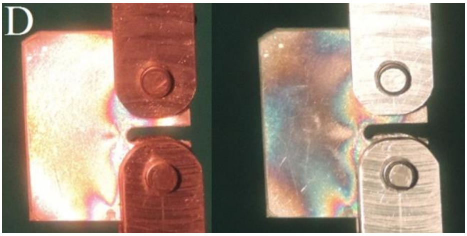
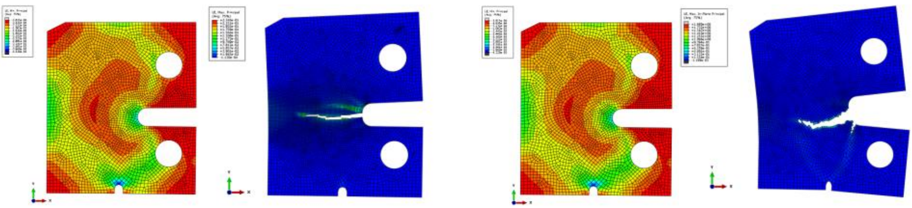


Fig. 1. Example of a deformation picture: on the left there are total isochromes, on the right there are half isochromes

In the next step, the sample was modeled in the ABAQUS environment. The model was made in two 3D variants - solid and 2D shell. Exemplary results are presented in Figure 2.



(a) (b) (c) (d)

Fig. 2. An example of numerical analysis: (a) 2D sample for *E*=168 GPa, (b) Ductile model for 2D sample, (c) 3D sample for *E*=158 GPa, (d) Ductile model for 3D sample

3. Concluding Remarks

The obtained results from the 2D and 3D models show differences. The assumptions about the non-axial fixing of the sample proved correct when the attached force was shifted to one of the walls from a symmetrical position in the 3D model. The change in Young's modulus did not affect the stress distribution in the sample. The introduced model of destruction also shown a different character.

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