NUMERICAL AND EXPERIMENTAL MODELS OF THE FRACTURE IN THE MULTI-LAYERED COMPOSITES

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Abstract: Advanced mechanical and structural applications require accurate assessment of the damage state of materials during the fabrications as well as during the service. Due to the complex nature of the internal structure of the material, composites including the layered composite often fail in a variety of modes. The failure modes very often are influenced by the local material properties that may develop in time under heat and pressure, local defect distribution, process induced residual stress, and other factors. Consider a laminate composite in plane stress conditions, multi-layered beam bonded to planes having shear modulus $G_i$ and Poisson’s ratio $\nu_i$ respectively, subjected to bending. The behaviour of the cracks depends on the cracks configuration, size, orientation, material properties, and loading characteristic. The fracture mechanics problem will be attacked using the photoelastic visualisation of the fracture events in a model structure. The proposed experimental method will developed fracture mechanics tools for a layered composite fracture problem.

1. INTRODUCTION

The development of the failure criterion for a particular application is also very important for the predictions of the crack path and critical loads.

Recently, there has been a successful attempt to formulate problems of multiple cracks without any limitation. This attempt was concluded with
the series of papers summarising the undertaken research for isotropic [2], an isotropic [4] and non-homogeneous class of problems [5] and [4].

Crack propagation in multi-layered composites of finite thickness is especially challenging and open field for investigation. Some results have been recently reported in [5]. The numerical calculations were carried out using the finite element programs ANSYS 5.4 and 5.6 [8]. Two different methods were used: solid modeling and direct generation.

2. MATERIAL PROPERTIES

Material properties exert an influence on the stress distribution and concentration, damage process and load carrying capacity of elements. In the case of elastic-plastic materials, a region of plastic strains originates in most heavily loaded cross-sections. In order to visualise the state of strains and stresses, some tests have been performed on the samples made of an "araldite"-type optically active epoxy resin (Ep-53), modified with softening agents in such a way that an elastic material has been obtained. Properties of the components of experimental model are given in table 1.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Young's Modulus $E_i$ [MPa]</th>
<th>Poisson's ratio $\nu_i$ [1]</th>
<th>Photoelastic constants in terms of stresses $k_\sigma$ [MPa/fr.]</th>
<th>Photoelastic constants in terms of strain $f$, [-/fr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3450.0</td>
<td>0.35</td>
<td>1.68</td>
<td>$6.572 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>2</td>
<td>1705.0</td>
<td>0.36</td>
<td>1.18</td>
<td>$9.412 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>3</td>
<td>821.0</td>
<td>0.38</td>
<td>0.855</td>
<td>$14.31 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>4</td>
<td>683.0</td>
<td>0.40</td>
<td>0.819</td>
<td>$16.79 \cdot 10^{-4}$</td>
</tr>
</tbody>
</table>

3. EXPERIMENTAL RESULTS

The stress distribution in was determined using two methods: **Shear Stress Difference Procedure** (SDP – evaluation a complete stress state by means the isochromatics and the angles of the isoclines along the cuts) [3].

**Method of the characteristics** (the stress distribution were determined using the isochromatics only and the equations of equilibrium [8].

In a general case [7], the Cartesian components of stress: $\sigma_x$, $\sigma_y$ and $\tau_{xy}$ in the neighbourhood of the crack tip are: