THE EFFECT OF ORIENTATION ON THE SHOCK WAVE STRUCTURE OF A CARBON FIBRE-EPOXY COMPOSITE

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Summary. The effect of the fibre orientation on the shock wave structure of a carbon fibre-epoxy composite (CFC) of any symmetry has been studied using an anisotropic equation of state (EOS) for accurate extrapolation of high-pressure shock Hugoniot (anisotropic and isotropic) states to other thermodynamic (anisotropic and isotropic) states. The proposed EOS, using a generalised decomposition of a stress tensor, represents a mathematical and physical generalisation of the Mie-Grüneisen EOS for isotropic material and reduces to this equation in the limit of isotropy. A two-wave structure between the generalised anisotropic bulk shock velocity and particle velocity (non-linear anisotropic and isotropic elastic waves) that accompanies damage softening process was proposed for describing CFC behaviour under shock loading. The final set of governing equations describing isothermal steady-state shock wave propagation is the hyperbolic and has a divergent form. The Rankine-Hugoniot equations for the two-wave shock structure expressing the conservation laws of the governing equations are derived as:

\[ \rho^i_{a} U^i_{a} = \rho^0_{a} U^0_{a} = m_{i,a}, \quad \frac{m_{i,a}^2}{\rho_{a}^0} - \sigma_{n}^i_{a} = \frac{m_{i,a}^2}{\rho_{a}^0} - \sigma_{n0}^i_{a} \]

where \( \rho^i_{a} \) and \( \rho^0_{a} \) are the densities behind and in front of the isotropic and anisotropic shock waves, \( m_{i,a} \) are the given mass flux values across the isotropic and anisotropic shock waves, \( \sigma_{n}^i_{a} \) and \( \sigma_{n0}^i_{a} \) are the stress behind and in front of the isotropic and anisotropic shock waves. The constitutive equations (contraction by repeating low indexes is assumed here) are written as:

\[ \sigma_{kl}^i_{a} = -p^{*} \alpha_{kl}^i_{a} + \tilde{\sigma}_{kl}^i_{a}, \quad p^{*} = p^{EOS} + \frac{\beta_{kl}^i_{a} \tilde{\sigma}_{kl}^i_{a}}{\beta_{kl}^0}, \quad \sigma_{n}^i_{a} = n_{k} \sigma_{kl}^i_{a} n_{l} \]

where \( \sigma_{kl}^i_{a} \) and \( \tilde{\sigma}_{kl}^i_{a} \) are the isotropic and anisotropic stress and generalised deviatoric stress tensors, \( \alpha_{kl}^i_{a} \) and \( \beta_{kl}^i_{a} \) are the material tensors, \( n_{k} \) is the components of the normal to the shock wave surfaces. An analytical calculation showed that Hugoniot Stress Levels (HELS) in different directions for a CFC composite subject to the isothermal compressive two-wave structure agree with experimental measurements at low and at high shock intensities.