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FEM SIMULATION OF HIGH VELOCITY SHOCK WAVES IN FIBER REINFORCED COMPOSITES

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Abstract: *Fiber reinforced composites are very efficient in damping shock waves. Computational simulations enable to evaluate the damping properties and to design the structure of the fiber reinforced materials (FRM) and response of the whole structure to explosion and impact load. Especially important is the case when fibers are much stiffer than the matrix. The shock waves reflect, refract and interact in such material and the shock wave is damped and attenuated in this way. Material properties of fibers, matrix and volume content of both components are material design parameters, which define the structural response to explosion and impact load in computational simulations by multi-level modeling. We will present computational models for elastic material. The modulus of elasticity of fibres is 100 times larger than that of the matrix. .*

Keywords: ***Computational simulation, high velocity impact, fiber reinforced composite.***

1. Introduction

Composite materials have been used more extensively in the recent years in many fields of industry. Composite materials reinforced by stiff particles or fibers are important materials possessing excellent mechanical and also thermal and electro-magnetic properties. One of the important tasks is to assess the critical stress state for static or dynamic loadings. There are many criteria which are used to predict the failure of composite materials. The accuracy of prediction of failure strongly depends on the criterion (Kormaníková, et al. 2011). In present time creating new scientific discipline „ Simulation-Based Engineering Science (SBES)“, which on basis of mathematical methods and computer simulated engineering system behavior. Simulation provides a powerful alternative to the techniques of experimental science and the observation when phenomena are not observable or when measurements are impractical or too expensive. Wave propagation in heterogeneous material is a very old and complex problem (Brepta, 1997; Okrouhlik, 2001). The phenomenon of material and geometric dispersion are so far very little studied. It is a complex problem with regard to interaction of pressure and tension phase waves generated on the boundary of an inhomogeneous material.

The aim of this paper is to contribute better understanding and modelling of scattering and dispersion of shock waves using commercial software ABAQUS.

2. Wave propagation in elastic solids

In this section we first present the basic considerations about physical problems and then we mentioned about most important wave forms in solids. We note that we consider only an elastic, isotropic homogeneous isotropic medium.

These equations are used to describe:

- the kinematics of solid continuum, the equations which present relation between displacements and corresponding displacement gradient for finite displacements in material and spatial description, strain tensors for finite strain formulation, strain measures and strain rate tensors,

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- material and spatial time derivatives of deformations, velocity and velocity gradients,
- corresponding stress measures,
- formulation of equilibrium,
- conservation equations (conservation of mass, momentum and energy),

Thermodynamic laws give:

- the first law – the conservation of total energy,
- the second law – change in entropy,
- thermodynamic potentials – internal energy, enthalpy, Helmholtz and Gibbs free energy.

2.2 Wave forms

Waves in solids are basically perturbations in the velocity field propagating through the continuum in different forms and at related different velocities. The propagating perturbation leads to wave form specific motion of the particles. The most important wave forms in solids are:

- Longitudinal wave,
- shear or secondary wave,
- Rayleigh wave,
- flexural wave.

3. Computational simulations

In following example the composite material with modulus of elasticity and density equal to 210 GPa and 7830 kg m^{-3}, respectively, is reinforced by straight fibres regularly distributed parallel to the upper surface (see Fig. 2). The modulus of elasticity of fibres is 100 times larger than that of the matrix. The loading of the material is perpendicular to the surface and it is increasing from zero to 0.0315 GPa in 0.05 μs and decreasing back to zero in same time.

Calculations were made for following 4 variants:

Variant 0 - model without fibers.
Variant 1 - model with fiber radius r_f= 1 mm and volume fraction of fiber v_f= 35%.
Variant 2 - model with r_f= 0.5 mm and v_f = 17,5%.
Variant 3 - model with r_f= 0.5mm and v_f= 35%.

4. Conclusions

The problem of shock wave propagation was studied in this work. Computational simulations were performed in FE software ABAQUS. The FEM simulation was based on the RVE model. Simulations are carried out with fibers with different diameters and volume fraction of fiber. The proposed procedure allow very effectively without expensive experiments to study the behaviour of composite materials.

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