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Investigation of Shock Wave Compressibility of Carbon Fiber and Fiberglass for experiments at PRIOR

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The experimental investigation of shock wave compressibility of heterogeneous anisotropic materials carbon fiber and fiberglass were conducted. Carbon fiber and fiberglass are polymeric composite materials consisting of interwoven fibers with a diameter of 5-10 microns and an epoxy matrix. A feature of these materials is a strongly pronounced anisotropy of properties. For these materials the value of the sound speed along the fibers is several times higher than the sound speed for the transverse direction. The shock wave profiles were recorded by laser interferometer VISAR with a nanosecond time resolution. The structure of compression pulse and the shock wave velocity of carbon fiber and fiberglass were obtained in each experiment. The goal of this study is development of targets for experiments at a novel diagnostic system proton microscope (PRIOR). Shock waves will be produced by a two stage light gas gun, which is developing at the TU Darmstadt.
As a result of processing of experimental results Hugoniots of carbon fiber for longitudinal and transverse fibers orientation were plotted in the coordinates of the shock wave velocity D – particle velocity u. For carbon fiber in the investigated range of pressures at the transverse orientation of the fibers experimental data are approximated by a linear dependence of D = 1.70 + 2.3*u, km/s. The Hugoniot for the parallel orientation is approximated by D = 2.3 + 2.0*u, km/s. In contrast to the trans-verse orientation, in this case a complex shock wave structure is observed. Almost in the entire pressure range two-wave configuration is recorded which is most clearly expressed at low pressures. In this case the two-wave configuration is due to anisotropic structure of the sample. The velocity of propagation of disturbances along the carbon fibers is higher than the shock wave velocity, that results in the formation of precursor.
For fiberglass the two-wave configuration in the entire pressure range was recorded for both orientations of the fibers. But amplitude of precursor along the fibers is much higher than the amplitude for the transverse direction. From the obtained experimental data Hugoniots of fiberglass for two orientations of fibers were plotted. Within the error Hugoniots for both directions coincide (D=1.85+1.1*u, km/s).
Also a study of spall strength for carbon fiber and fiberglass was conducted. For carbon fiber the value of spall strength at perpendicular direction of fibers was equal to 40 MPa. For parallel orientation of the fibers it was about 175 MPa. For fiberglass it was found that the value of spall strength when shock wave propagated perpendicularly to the fibers was equal to 11.7 MPa. For parallel direction it was about 82 MPa.
Thus, from the obtained results it can be concluded that the correct description of the dynamic de-formation of anisotropic materials is possible only within the framework of the two-component model considering the real motion of the fibers and their interaction with the matrix. But complex behavior of heterogeneous anisotropic materials doesn't allow obtaining of the correct form of the equations of state and rheological relations based on the traditional methods for recording of the pressure, particle velocity and temperature used in the physics of shock waves. An important addition of these data is the density distribution, which is realized in the medium at the pulse compression, which can be measured by proton radiography method at PRIOR.

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