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Analysis of material effects during perforation – experiments and attempts in numerical modelling

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The perforation test, in addition to the Hopkinson bar test, Charpy test and Taylor impact test, is often used by researchers to determine material ductility, energy absorption, crack initiation and growth and validation of constitutive model parameters at high strain rates for finite element (FE) purposes.

The damage initiation and propagation mechanism occurring during the perforation test depends on the mechanical properties of a material tested as well as other factors such as striker shape and velocity, specimen thickness and angle of impact. Moreover, a combination of basic phenomena which usually occur during perforation testing may appear as a result of material anisotropy. In summary, one can conclude that the variety and mutual relationships between phenomena associating the perforation process enforce an analysis under strictly defined experimental conditions.

The materials subjected to low-velocity perforation tests described in this article are VP159 austenitic steel, aluminium alloy and AM60 magnesium alloy. The main goal of the analysis was to determine damage initiation and propagation mechanisms with respect to the Huber-Mises equivalent stress, stress triaxiality, adiabatic heating and local strain rates at subsequent test stages using the FE method. The results obtained by the low velocity perforation test may be applied for design of protective and energy absorbing structures.

The coefficients of constitutive relations describing the visco-plastic behaviour of materials in question were calibrated using stress-strain curves obtained at a wide range of strain rates. The results of the FE simulation were subsequently compared with the experimental results determined using the drop-weight testing machine to verify the virtual model of the perforation process. Finally, an analysis of selected variables was carried out.