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The Dynamic Response of Polymeric Composites

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Abstract: Knowledge of the properties of soft, viscoelastic materials at high strain rates are important in our understanding of their role during blast or impact events. Although there is a large body of literature containing compressive data, this rarely deals with strain rates above 250 s^{-1} which becomes increasingly important when looking at the design of composite structures where energy absorption during impact events is high on the list of priorities. The high strain-rate characteristics of a specific porous blast energy absorbing material measured by modified Split Hopkinson Pressure Bar apparatus is presented in this study. Testing these low impedance materials using a metallic split Hopkinson pressure bar setup results in poor signal to noise ratios due to impedance mismatching. These difficulties are overcome by using polymeric Hopkinson bars. Conventional Hopkinson bar analysis cannot be used on the polymeric bars due to the viscoelastic nature of the bar material. Implementing polymeric Hopkinson bars requires characterization of the viscoelastic properties of the material used. In this paper, 16 mm diameter Polycarbonate bars are used as Hopkinson pressure bars. This testing technique is applied to materials composed of porous glass/ceramic filler and polymeric binder, with density of 125 - 300 kg/m^3 and particle size in range of 50 μm – 2 mm. Testing of polymeric composites at high strain rates allows the development of better constitutive models that is necessary for next numerical simulations.

Introduction

The aim of this study was to analyze properties of dynamic impact absorbing materials composed of porous glass/ceramic filler and polymeric binder. This complex investigation was based on experimental testing in order to determine an applicable material model for practical material selection and next numerical simulations as well. Two kinds of experiments were performed, dynamic Split Hopkinson Pressure Bar (SHPB) test and surrogate projectile impact on material layer as a verification test. Two types of absorbing with different filler type (trade name Liaver and Liapor) were fully compared.

Problem description

The structure and material properties of analyzed samples did not allow a standard SHPB test because of large impedance difference between analyzed material and testing bars material. Moreover standard steel testing bars can significantly harm an analyzed sample because of high hardness of interaction area and high mass of bars in motion. To ensure accurate measurement, standard steel testing bars were replaced by high sensitivity polymeric bars. An example of recorded input and output strain gauge signals are depicted in Fig. 1.

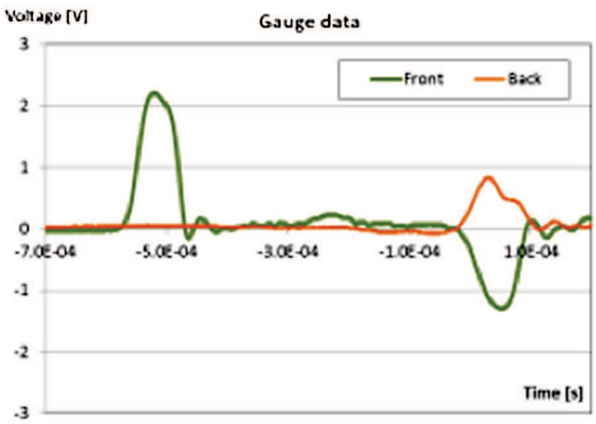

Fig. 1: Experimental data – SHPB test.

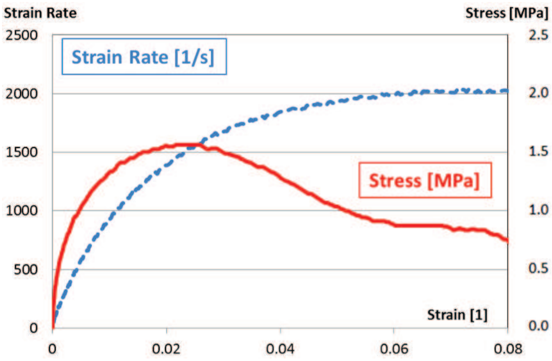

Fig. 2: SHPB result–Stress–Strain–Strain Rate

Measuring the high strain rate response of the above described absorbers, the material of testing bars has to be taken into account due to viscoelastic behavior of the bar during impact wave propagation. Ahonsi [1] implemented this viscoelastic model in wave propagation theory by complex evaluation of testing bars material. It can be defined on the SLS material model that is combination of standard Hook's law and Maxwell material model. The complex behavior of material properties leads to evaluation of measured data in frequency domain. I.e., the attenuation coefficient of bars material referred in [2] is frequency dependent too. Practically measured data should be analyzed by FFT method and afterwards an inverse FFT method can quantify stress, strain and strain rate dependency according to [3].

Numerical material model

The most convenient and universal material model has to be defined based on the results from the first investigation step. More material models were analyzed, the most suitable models were found in LS-Dyna explicit code named Mat_Honeycomb respectively Mat_Crushable_Foam. The major use of the first mentioned model is for honeycomb and foam materials with real anisotropic behavior. A nonlinear elastoplastic material behavior can be defined separately for all normal and shear stresses. The second material model is dedicated to modeling crushable foam with optional damping and tension cutoff. Unloading is fully elastic. Tension is treated as elastic-perfectly-plastic at the tension cut-off value.

Verification of the numerical simulation in real tests

Subsequent experiment was performed due to validation of achieved numerical material models of samples (Liaver and Liapor). This test is based on the surrogate projectile impact on the rectangle sample with dimensions of 100x100x5 mm. This experiment result was compared with an explicit numerical simulation of experiment setup with material model from previous step.

Conclusion

This study analyzed a problem of testing of absorbing materials in high velocity conditions. Whole testing and evaluating procedure was applied to materials composed of porous glass/ceramic filler and polymeric binder, with density of 125 - 300 kg/m^3 and particle size in range of 50 μm – 2 mm. SHPB experimental method adapted for viscoelastic testing bars was used. The obtained material properties were used for adjustment of numerical material model. This numerical model was successfully verified in next experiment including high velocity projectile impact.

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