Identification of rate dependent material model parameters based on Split Hopkinson Pressure Bar test and high speed camera with Digital Image Correlation

Tomasz Garbowski[†], **Tomasz Gajewski**[†*], **Tomasz Łodygowski**[†]

[†]Institute of Structural Engineering, Poznan University of Technology
Piotrowo 5, Poznan, Poland
(tomasz.garbowski, tomasz.gajewski, tomasz.lodygowski)@put.poznan.pl

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ABSTRACT

The Split Hopkinson Pressure Bar (SHPB) technique (also called the Kolsky bar [1]) is the most commonly used method of measuring material behavior (stress-strain curve) at strain rates between about 400 and 5,000 s^{-1} (see e.g. [2, 3]). The extensive and still growing use of finite element simulation of processes at high strain rates, requires an improvement in the quantity of data obtained from mechanical testing in order to properly calibrate all parameters in rate-dependent constitutive models. This contribution discusses a method of providing numerous of additional data through the application of Digital Image Correlation (DIC) for displacement and strain measurements on specimen surface in the SHPB test. These additional measurements are particularly important also when a significant deformation is taking place outside the gage section, and when necking develops; in such cases the strains determined from the waves and gages are not valid anymore, in contrary DIC method can still provides the accurate full field strain history. By the use of Inverse Analysis as a tool which combines the measurements from DIC, strain gages and recorded wave in SHPB test together with the corresponding measurable quantities computed by Finite Element (FE) test simulation, the identification of the large number of parameters embed in the rate dependent material models can be assess. Here the iterative gradient based deterministic Trust Region Algorithm (TRA) is employed for the minimization of the discrepancy between measured and computed measurable quantities.

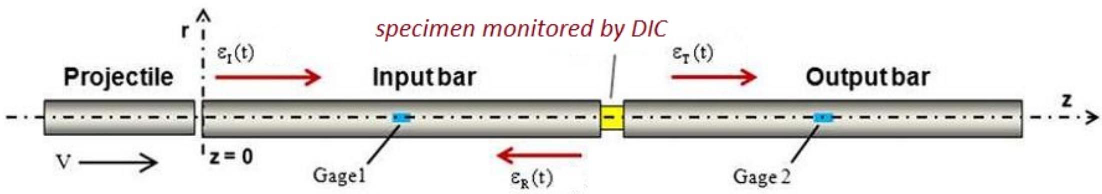

Figure 1: Experimental setup of SHPB (reproduced from Jankowiak et al. [3])

The image correlation technique is applied here for full field measurement of displacements and strains (and strain rates) in split Hopkinson pressure bar experiments. It uses the image correlation software and digital high-speed camera Phantom v711 which is capable to record about 79,000 and 215,600 frames per second on an array of 256x256 and/or 128x128 pixels respectively.

The image correlation algorithm uses the dot pattern (sprayed on the surface of the specimens) to define a field of overlapping virtual gage boxes (small zones composed of 10 to 20 pixels) and through cross-correlation it computes displacements of the center of each gage box at each frame. The displacements are then used for calculating the strains on the surface of the monitored specimen.

Many authors in order to examine the validity and accuracy of the tests compare the strains computed by the image correlation method with those determined from analyzing the elastic waves in the bars, and strains measured with strain gages placed on the specimen (see e.g. [4, 5]). In present application the DIC strain measurement serves as counterpart to strains computed from the FE model of SHPB test simulation in the inverse procedure in order to solve iteratively for constitutive constants embedded in numerical model. The technique which combines the inverse analysis, experimental data provided by DIC and the FE test simulation was used by various authors but mainly (if not only) in quasi-static tests (see e.g. [6, 7, 8]).

The contribution of this communication is a novel procedure for characterization of the parameters in the rate-dependent Johnson-Cook plasticity model through the (pseudo) experimental DIC data, FE test simulation of the SHPB test and the inverse analysis. Such numerical exercise followed by the sensitivity analysis serves as a validation of the proposed technique and a preliminary investigation before the real test will be designed and performed in our laboratory.

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