XVII Konferencja Naukowo-Techniczna
TKI2024
TECHNIKI KOMPUTEROWE W INŻYNIERII
15–18 października 2024

Numerical analysis and experimental validation of split Hopkinson pressure bar setups: Proposal for a standard experimental design

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Abstract: The main goal of this work is to numerically analyze different split Hopkinson pressure bar setups and validate the obtained results with experiments. To achieve this, three different numerical models were created based on existing setups in three major scientific centers in Poland. Using the created finite element models, a range of numerical simulations was performed to compare the influence of crucial parameters such as the diameter of the bars, their length, and boundary conditions. The numerical simulations deal with the dynamic compression of cylindrical steel samples at different strain rates up to 10000 1/s. The material samples were identical for all studied cases, and any discrepancies in the results arose solely from the model setups. The main feedback from the analysis is the proposal of a standard setup for the method, which provides a basis for the future design of such experiments.

KEYWORDS: split Hopkinson pressure bar, numerical analysis, metrology

1. Introduction

The split Hopkinson pressure bar (SHPB) is a widely used experimental method for studying the dynamic behavior of materials under high strain rates [1-4]. However, variations in setup configurations can significantly influence the results, leading to challenges in standardization and comparability [5]. This study aims to address these challenges by numerically analyzing different SHPB setups and validating the findings with experimental data. Specifically, three numerical models were developed, each replicating setups from leading scientific centers in Poland. These models were used to conduct finite element simulations, focusing on key parameters such as bar diameter, length, and boundary conditions during the dynamic compression of cylindrical steel samples at strain rates up to 10,000 1/s. By maintaining uniform material properties in all cases, the study isolates the impact of the setup configurations on the results.

2. FE model of SHPB setup

The finite element models of the analyzed split Hopkinson pressure bar setups were created using the Abaqus software. The models (three in total) consist of cylindrical steel bars and a test specimen, along with the unique construction supporting the bar system (Figs. 1–3). Key parameters, such as bar diameter, length, and boundary conditions, were defined based on existing setups from scientific centers in Poland. A dynamic explicit analysis was employed to simulate the high strain rate conditions typical of SHPB experiments. Mesh refinement was applied to critical areas, particularly around the specimen, to ensure accurate stress and strain calculations. The interactions between the bars and the specimen were modeled using contact algorithms, accounting for friction and impact effects. The model was validated against experimental data, demonstrating its capability to replicate the dynamic behavior observed in real SHPB tests.

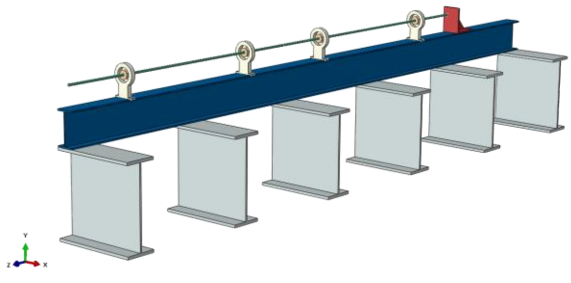

Fig. 1. FE model of the first SHPB setup.

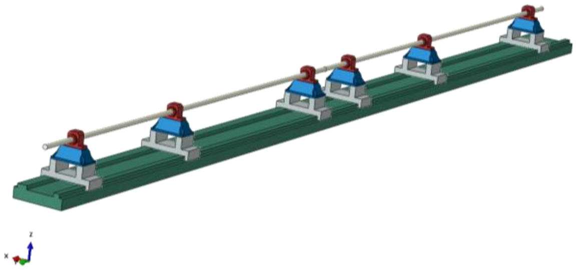

Fig. 2. FE model of the second SHPB setup.

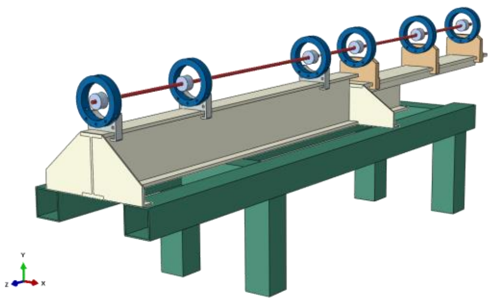

Fig. 3. FE model of the third SHPB setup.

3. Experimental setups

The experimental investigation of the dynamic behavior of materials were performed using three distinct split Hopkinson pressure bar setups. The experiments were conducted in different laboratories, each employing a unique configuration to assess how variations in setup parameters affect material response under high strain rates. The example setups are presented in Fig. 4. Each of them possesses a unique configuration of the bar system, which differs in the assembly of elements and dimensions.

Fig. 4. Three different configurations of SHPB setup

4. Summary and Conclusions

The results of numerical simulations provide a clear framework for standardizing SHPB setups, ensuring more consistent and reliable results across different laboratories. Ultimately, this work highlights the importance of simulation in guiding experimental design and improving the accuracy of high strain rate testing methods.

Publikacja dofinansowana ze środków budżetu państwa w ramach programu Ministra Nauki pod nazwą Polska Metrologia II, nr projektu PM-II/SP/0077/2024/02 kwota dofinansowania 906 930 zł, całkowita wartość projektu 906 930 zł. (Publication financed from the state budget under the program of the Minister of Science called Polish Metrology II, project no. PM-II/SP/0077/2024/02, funding amount 906930 PLN , total project value 906930PLN).

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