Numerical Simulation of Dynamic Impact Mechanical Properties of Coal-Rock Mass Using LS-DYNA: Postprint

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Abstract

Research on the dynamic mechanical properties of coal rock has gradually become a current research hotspot; however, most dynamic loading experiments are completed instantaneously, making it impossible to investigate the details of damage and failure. Therefore, this study conducts a numerical simulation of the Hopkinson pressure bar experiment on coal rock specimens under low-velocity impact loading, based on the rock Holmquist-Johnson-Cook (HJC) constitutive model and utilizing LS-DYNA software. Simultaneously, the entire experimental process is reproduced using the LS-PrePost post-processor, thereby recreating the damage process and failure details of coal rock under impact loading. The research demonstrates: (1) The stress-strain curves from the HJC constitutive model-based simulation of the coal rock impact loading experiment agree well with the measured stress-strain curves, wherein the simulated stress peak value is 7.03 MPa, with a relative error of 18.1% compared to the measured value. (2) Under an impact loading of 3.693 m/s, the ends of the coal rock specimen first undergo failure, forming small fragments; subsequently, tensile failure occurs along the axial direction of the coal rock, creating axial cracks that propagate through the specimen, and finally, radial cracks are generated. Under low-velocity impact conditions, the coal rock failure produces fragments of varying sizes without obvious patterns, with large and small fragments each accounting for approximately half. (3) The energy dissipation of coal rock under impact loading can be divided into three main stages: the energy dissipation rate first increases slowly, then increases sharply, and finally tends to level off.

Full Text

Preamble

Numerical Simulation Study on Dynamic Impact Mechanical Properties of Coal and Rock Mass Based on LS-DYNA

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Abstract

Research on the dynamic mechanical properties of coal and rock has emerged as a prominent area of investigation. However, most dynamic loading experiments are completed instantaneously, which prevents detailed examination of damage and failure mechanisms. To address this limitation, the present study employs the Holmquist-Johnson-Cook (HJC) constitutive model for rock and utilizes LS-DYNA software to conduct numerical simulations of Split Hopkinson Pressure Bar (SHPB) experiments on coal-rock specimens under low-velocity impact loading. The LS-PrePost post-processor is further employed to reproduce the entire experimental process, thereby revealing the detailed damage evolution and failure characteristics of coal-rock under impact conditions.

The simulation results demonstrate three key findings. First, the stress-strain curves obtained from the HJC-based simulation show good agreement with experimental measurements, with the simulated peak stress of 7.03 MPa exhibiting a relative error of 18.1% compared to the measured value. Second, under an impact velocity of 3.693 m/s, failure initiates at both ends of the specimen, forming small fragments, followed by tensile failure along the axial direction that creates through-thickness axial cracks, and finally resulting in radial cracking. Under low-velocity impact, the coal-rock fractures into fragments of varying sizes without a discernible pattern, with large and small fragments each comprising approximately half of the debris. Third, energy dissipation in the coal-rock under impact occurs in three distinct stages: the energy consumption rate initially increases slowly, then rises sharply, and finally stabilizes.

Keywords: coal-rock; Split Hopkinson Pressure Bar; LS-DYNA; HJC model; impact loading

Note: Figure translations are in progress. See original paper for figures.