PERIDYNAMIC MODELING OF DYNAMIC FRACTURE OF B_4C IN A SPLIT-HOPKINSON PRESSURE BAR

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Abstract

The dynamic fracture behavior of the brittle ceramic, boron carbide (B_4C), is investigated using our in-house split-Hopkinson pressure bar (SHPB), and Sandia's nonlocal peridynamics simulation code, PERIDIGM. In order to study the dynamics of this particular SHPB, the initial boundary value problem (IBVP) is solved for a 1-D impact in which a finite striker bar collides with (and adheres to) the front face of a stationary incident bar bonded to a specimen of finite thickness, with the back face of the specimen bonded to another finite transmission bar; this is the classic SHPB experiment. The solutions are analytical in the Laplace transform domain and are numerically inverted to the time domain using a modified Dubner-Abate-Crump algorithm developed by us elsewhere. The new IBVP solutions for particle velocity in a full-scale SHPB composed of maraging steel bars, and a linear elastic ceramic material, are used to verify the commercial FE codes COMSOL and ABAQUS, and open-source PERIDIGM. Subscale SHPB simulations are then conducted using PERIDIGM on jacketed/unjacketed B_4C specimens with a critical stretch failure condition that is proportional to the ceramic's critical energy release rate, G_c; also investigated is the effect of initial defect populations governed by, Weibull, uniform random, and Bobaru critical stretch distributions, on the resulting ceramic failure behavior. Computationally expensive full-scale PERIDIGM simulations are also currently underway to compare with the subscale simulation results (Fig. 1).

1. Introduction

This work studies the study of dynamic fracture in the brittle ceramic, B_4C, using data from our in-house split-Hopkinson pressure bar (SHPB), and Sandia's open-source, nonlocal peridynamics simulation code, PERIDIGM. The subscale/full-scale SHPB PERIDIGM simulations on jacketed/unjacketed B_4C dumbbell-shaped specimens provide a means for understanding the mechanics and effect of various boundary conditions during dynamic loading of brittle ceramic materials. Inasmuch as full-scale simulations require ~10 hours on 2025 processors and subscale simulations require ~4 hours on 64 processors we opted to initially study the fracture failure behavior with the subscale model (Fig. 1). Embedded gages in the simulation enable monitoring displacement, velocity, and force versus time for a quantitative comparison of full-scale and subscale simulations (Fig. 2) as well as providing a means to validate the simulations using experiments conducted on the SHPB.

2. Results

a. We have derived new analytical solutions for all space and time for our high-rate 4-bar split-Hopkinson bar apparatus; the solutions were used to verify commercial codes, e.g., COMSOL Multiphysics, ABAQUS, and Sandia's open-source PERIDIGM.
b. In general, one cannot prescribe a displacement or velocity versus time history on the boundary of a subscale model to simulate the full-scale response since wave reflections off other interfaces, and the failing ceramic material itself, will alter the "prescribed" boundary condition which is in general an unknown quantity!
c. The particle velocity versus time in the subscale simulations are independent of the initial defect distribution used in the subscale simulation results (Fig. 2).
d. It appears that the effects of initial flaw distribution in brittle ceramics, such as B_4C, using Weibull, uniform random or other distribution must be studied using full-scale SHPB simulations which are currently underway.

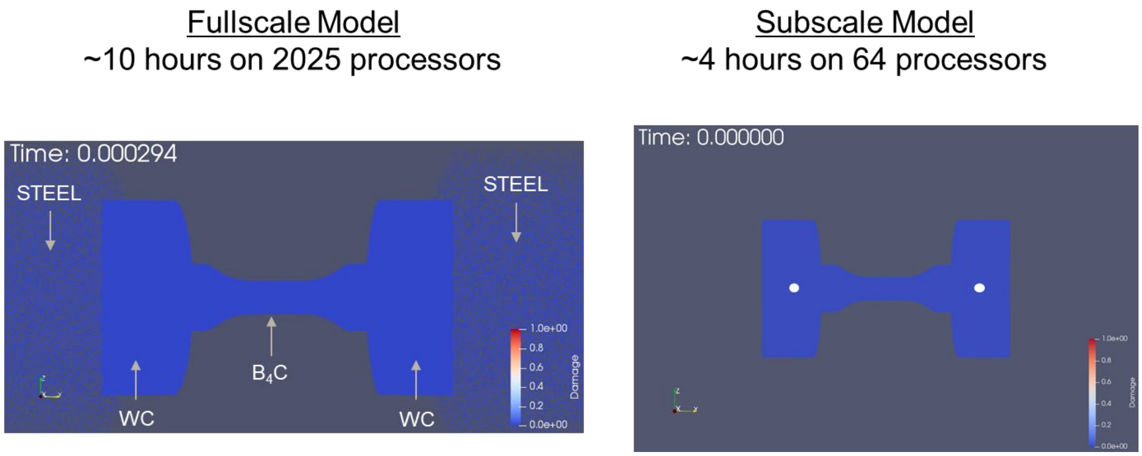

Fig.1 – Full-scale and subscale SHPB models showing specimen configuration.

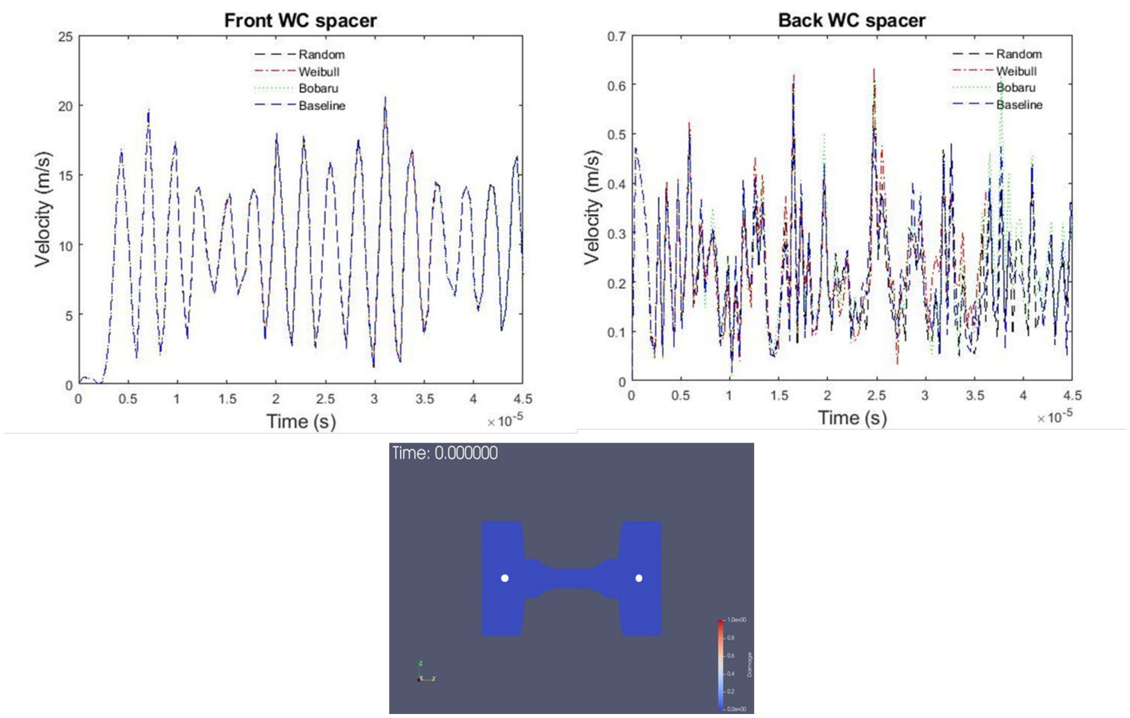

Fig.2 – Subscale simulation particle velocity versus time.

3. Conclusions

New IBVP solutions for particle velocity in a full-scale SHPB composed of maraging steel bars, and a linear elastic ceramic material, were used to verify the commercial FE codes COMSOL Multiphysics and ABAQUS, as well as PERIDIGM. The effects of initial flaw distribution in brittle ceramics, such as B_4C, using Weibull, uniform random or other distribution must be studied using full-scale SHPB simulations which are currently underway.