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PRESTRESS EFFECT ON THE BALLISTIC BAHAVIOR OF CERAMIC ARMOR

Ahmad Serjouei[1(*)], Runqiang Chi[1], Idapalapati Sridhar[1], Tan B. Eng Geoffrey[2]

[1]School of Mechanical & Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798

[2]School of Materials Science & Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798

[(*)]*Email:* ahma0015@e.ntu.edu.sg

ABSTRACT

In this work, a new method for simulation of pre-stressed ceramic targets under high velocity impact, using explicit software, AUTODYN®, is proposed. Simulation parameters such as static damping, hourglass damping and smooth particle hydrodynamics (SPH) linear viscosity are validated through comparison with available experimental results in literature. Simulations with three pre-stress statuses, namely radial, axial and hydrostatic, with small and large pre-stress values, as well as without pre-stress status are performed. The effect of pre-stress on the ballistic behavior of ceramic targets is captured through simulations. It is shown that pressure contour highly affects: 1) interface defeat on the impact surface at the impact side and 2) rate of penetration through the ceramic armor within the ceramic armor.

Keywords: pre-stress, ceramic target, interface defeat.

INTRODUCTION

Ceramics are strong in compression however weak in tension. It is known that adding confinement to ceramics increases its ballistic performance. The effect of pre-stressing ceramics in compression is increasing their strength and ductility and also hindering early failure in tension (Holmquist, 2005). Simulation of pre-stressed ceramic has been done by other authors, however, either the impact simulation results of the pre-stressed target were not agreed well with experimental data of the pre-stressed target (Holmquist, 2005) or the simulation results of the targets without pre-stress were compared with experimental data of the pre-stressed target (Quan, 2006).

In this work, a new method for simulation of pre-stressed ceramic targets under high velocity impact, using explicit software, AUTODYN®, is proposed. This method includes six steps: 1) target components are generated separately and the ceramic size is set primarily larger than confinement size, and damping parameters are set for subsequent static process 2) an inward velocity is applied at the ceramic periphery, thereby compressing the ceramic to a size smaller than the confinement), 3) all the target components are put together in their correct positions, 4) the velocity on the ceramic periphery is removed, thereby increasing ceramic size until it contacts the inner surface of the confinement and a pre-stress is developed, 5) static damping parameter is gradually reduced to zero for subsequent impact simulation, 6) initial projectile impact velocity is set and impact simulation is performed.

RESULTS AND CONCLUSIONS

Rigorous choices of damping and viscosity parameters, namely, static damping, hourglass damping and smooth particle hydrodynamics (SPH) linear viscosity, are critical in obtaining stable pressure contour before impact and finally good simulation results. Fig. shows comparison of simulation results of radial pre-stress with its counterpart experiments (Lundberg, 2000), for impact velocities of 1645 m/2 and 2175 m/s. It can be seen that the simulation results accord well with available experimental data.

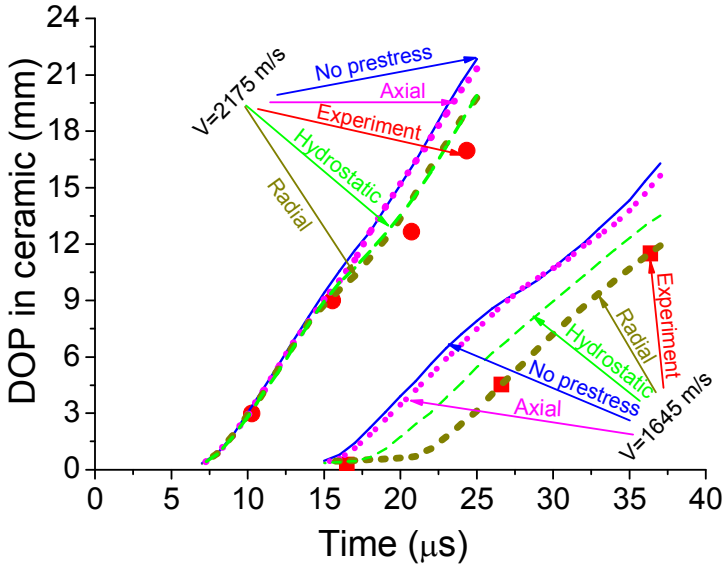

Fig. 1 - Comparison of simulation results of radial pre-stress with its counterpart experiments together with other simulation results

Simulations of axial and hydrostatic pre-stress statuses are also shown in Fig. for comparison. The effect of pre-stress on the ballistic behavior of ceramic targets is captured through simulations. Based on different ceramic/confinment geometric ratios, used to obtain the three pre-stress statuses, the pressure contour formed in the ceramic is different. Two important concepts are discussed: 1) interface defeat on the impact surface which is highly affected by the pressure contour at the impact side 2) rate of penetration through the ceramic armor which is highly affected by the pressure contour within the ceramic armor. Optimized pressure contour is sought through varying ceramic/confinment geometric ratios for the purpose of obtaining best ballistic behavior in terms of longest interface defeat time and lowest rate of penetration. Successful simulations of pre-stressed ceramic targets can be exploited for further optimization and design purposes of ceramic armor materials.

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