A STATE-OF-THE ART COMPUTATIONAL FRAMEWORK: HYBRID MESHLESS/FINITE ELEMENT TECHNOLOGY FOR CONTACT / IMPACT OF BRITTLE TYPE /COMPOSITE SYSTEMS

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Introduction

The present research describes the state- of -the -art and some recent advances via a novel computational technology and framework involving multi-scale physics and multi-timescale integrators for integrating the complex nonlinear dynamics equations of motion for general applications involving contact-impact for finite deformation engineering applications with large nonlinear strains and deformations.

Methodology

Advances via a novel computational framework /concepts that are presented here, push the boundaries of existing numerical methods to improved levels of computational sophistication. The objectives are to enable the solution of practical engineering problems. Indeed, there exist several unresolved issues to-date that plague the research community at large as related to finite deformation and simulation based design engineering applications for contact-impact. In certain cases, existing commercial codes such as ABAQUS, LSDYNA, etc., exhibit severe limitations for finite deformations, and the presentation in this paper particularly demonstrates and circumvents several existing limitations. Low and high velocity contact-impact dynamic applications are described to effectively model practical engineering problems, and we employ hybrid meshless and finite element concepts within the same numerical framework. In particular, when severe damage and large distortions are encountered, we also convert finite elements to meshless particles. When severe distortions are present in the numerical simulations, explicit dynamic codes suffer from the drawbacks of very small time steps. This severely prohibits computational efficiency and/or may not enable the solutions to be calculated or completed in a reasonable time frame. In these cases, we employ as an alternative, multi-time scale features in the transient dynamics computations which provide a fusion of computational technology such as a hybrid explicit and semi-implicit computational technologies all fused together within the same computational environment to handle not only local damage but also to assess the global dynamic response of the structural dynamic systems. The small scale features are captured while the global dynamic response is also addressed to enable improved physical insight of the overall dynamic response. We employ a Lagrangian FE concept to analyze dynamic problems associated with finite elastic/inelastic deformation. The finite elements can be either eroded and/or converted to mass based meshless fragments or debris clouds when the internal variable of damage for the Gauss points reach a threshold limit that is determined by the material model. The multi- time scale features for integrating the nonlinear dynamic equations of motion are performed by a finite element/meshless based smart switch computational algorithm switching between a forward displacement based central difference explicit method and a forward displacement nonlinearly explicit L-stable computational algorithm to maximize the time step advantage and to yield optimal time step features to enhance the efficiency of computations.

Results

We present practical applications to engineering problems via the proposed techniques and computational framework. Figures 1 and 2 show the results for two different impact velocities of S-7 tool steel (JC model) onto silicon carbide (the JH-1 material model is used) plate edge impact and is the well known Strassburger experiment.

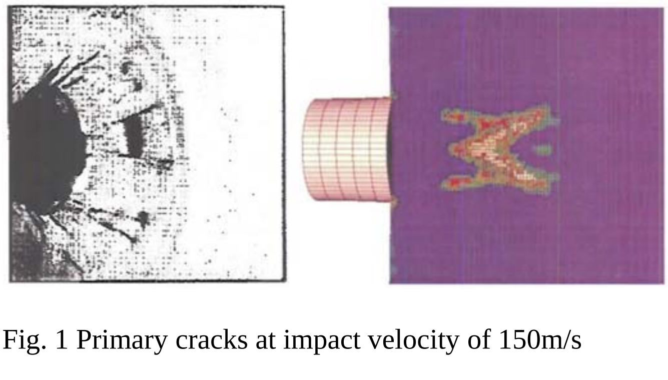

Fig. 1 Primary cracks at impact velocity of 150m/s

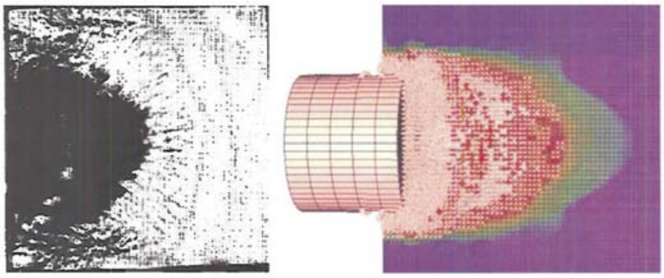

Fig. 2 Semi-circular crack front at impact velocity of 804m/s

The so-called U.S. ARL experiment is another application for characterizing the ballistic performance of ceramic materials. These experiments use tungsten-carbide spheres to impact confined ceramic targets. The depth of penetration of the spheres into the ceramic targets is measured to determine the target ballistic resistance. This example simulates a tungsten carbide ball impacting a silicon carbide (JH-1 model) plate confined by titanium (JC model) in order to predict the depth of penetration and to capture the damage process. The results indicate the superior capability over existing techniques, computational savings, and are in good agreement with experimental results and/or other codes. The overall features are demonstrated which validate the proposed developments.

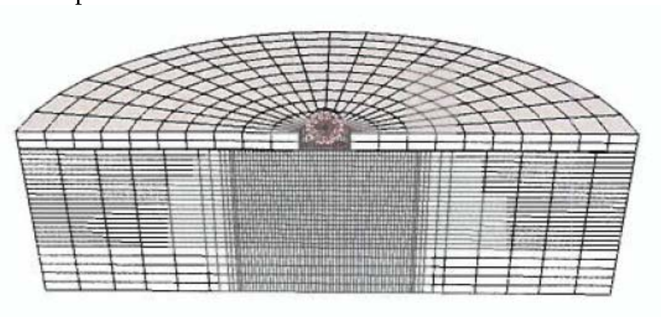

Fig. 3 FE mesh and geometry for comparison with experiment

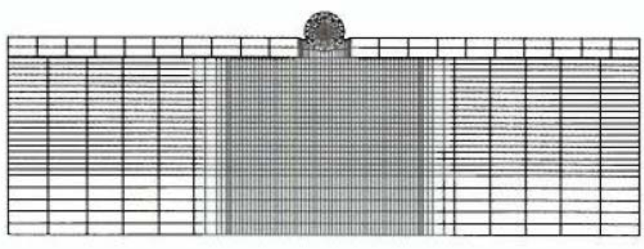

Fig. 4 FE mesh used and sectional view

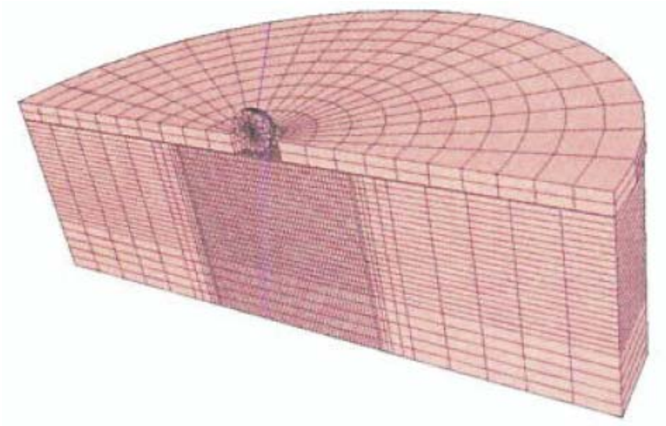

Fig. 5 Three-dimensional model and mesh

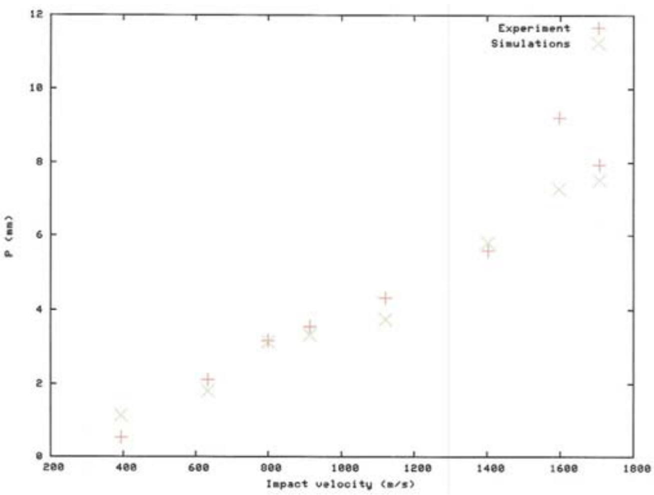

Fig. 6 Comparisons of experimental and computational depth of penetrations for various impact velocities

Conclusion

The proposed computational framework via the multi-timescale aspects are applied to the hybrid meshless/finite element computational framework within the same analysis when simulating realistic engineering applications. The techniques avoid problems for severe distortion applications and large deformations, and the verification and validation are also highlighted. Finally, the overall robustness of the physics based simulation environment to handle practical and realistic structural dynamics systems is demonstrated and is highly noteworthy.