ROBUST DESIGN DEVELOPMENT OF LIGHTWEIGHT VEHICLE SHELL STRUCTURES FOR BLAST MITIGATION

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The protection of lightweight ground vehicle crews from rapid acceleration events in hostile operating environments is an active field of study in defense research [1, 2]. Vehicle up-armoring traditionally entails the upgrading of standard shells with additional sacrificial components to improve blast protection capabilities. Resulting weight increment diminishes effectiveness and speed, increases vulnerability, and wears out vehicle components more quickly.

Previous investigations explored the use of structural optimization methodologies under dynamic blast loading conditions that allow armor weight reduction without sacrificing occupant safety, including the application of a novel optimization approach referred to as the hybrid cellular automaton (HCA) method. This method relies on the discretization of the design space into cellular automata and the decomposition of a global optimization problem into local control rules. Test problems demonstrate 90% reduction in cabin penetration and 10% vertical acceleration reduction by optimally shaping standard shells and avoiding the use of armor additional components.

The objective of this research is to establish an efficient shape optimization method to mitigate blast loads under uncertainty in the context of vehicle shell design. The objective is to minimize the variance of protective system performance caused by the variation of the uncontrollable environmental factors, namely the magnitude and location of the blast with respect to the design space.

Due to the complexity of the dynamic event and the nonlinear response of the system, the analysis of the problem is treated as a black-box type. The robust design optimization method combines a response surface methodology (RSM) and elements of the compromise decision support problem (DSP) [3]. Uncertainty propagation is quantified using a dimension reduction strategy [4]. The three-dimensional numerical models are incorporated in LS-DYNA. Results are compared with their deterministic counterparts in simply supported plates and complex shape design in the context of full vehicle simulation.

REFERENCES

1. Song, G. and C.A. Tan, *Vehicle and occupant safety protection CAE simulation.* SAE International Journal of Materials and Manufacturing, 2010. **3**(Compendex): p. 750-758.
2. Ma, Z.D., et al., *Functionally-graded NPR (negative Poisson's ratio) material for blast-protective deflector*, in *2010 NDIA Ground Vehicle Systems Engineering and Technology Symposium*2010: Dearborn, Michigan.
3. Chen, W.A., J.K.; Tsui, Kwok-Leung; Mistree, F., *A Procedure for Robust Design: Minimizing Variations Caused by Noise Factors and Control Factors.* Journal of Mechanical Design, 1996. **Vol. 188**(December 1996): p. 478-485.
4. Lee, S.H.C., Wei, *A Comparative Study of Uncertainty Propagation Methods for Black-Box Type Functions*, in *ASME 2007 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*2007, ASME: Las Vegas, Nevada, USA.