Analytical Shock Response Of a Transversely Point-Loaded Linear Rectangular Plate

R. David Hampton & Kip P. Nygren
Department of Civil & Mechanical Engineering
United States Military Academy
West Point, New York

Ting H. Li
Ordnance Materials Branch
Weapons & Materials Research Directorate
U. S. Army Research Laboratory
Adelphi, MD

ARL Sponsors: Ami Frydman[+], Morris Berman [‡], and Ting H. Li [*]
[+]Chief, Structural Dynamics Section
[‡]Mechanical Engineer
[*]Mechanical Engineer
Ordnance Materials Branch
Weapons & Materials Research Directorate
U.S. Army Research Laboratory
Adelphi, Maryland

ABSTRACT:

Ballistic shock, the strong vibrations that propagate through a vehicle structure after a ballistic impact, can damage electronic components that are mounted on various interior locations of the vehicle. To protect onboard critical electronic components from ballistic shock damage, predicted shock response spectra (SRS) are used as design guidelines in the selection of shock isolation devices. Current technology to predict shock response intensity at component mounting locations includes Finite Element Analysis, Statistical Energy Analysis, and various other modeling approaches. The Army Research Laboratory is implementing a process to determine component damage probability based on a numerical modal superposition method. This process allows detailed modeling of an entire vehicle (including instrumentation racks) but requires months of effort to perform skillful FEA modeling. Such an expenditure is acceptable only for unique high value vehicles, and is impractical for analysis of many vehicles. Therefore it is desirable to investigate alternative shock analysis methods that are simple and general (i.e., independent of specific vehicle configurations). Although such methods could entail reduced accuracy, for situations that are applicable they would eliminate the need of time-consuming finite element modeling, and could used in a variety of vehicles. As such, the methods could be used for "screening" for rapid identification of potential shock-damage issues. If necessary, further detailed analysis could be accomplished subsequently.

When an armored vehicle is subjected to a non-perforating large-caliber munitions impact or blast, direct mounted components that are near the impact location will always risk the highest damage potential. Live fire ballistic tests and laboratory experiments as well as numerical modeling have proved this observation. The research presented in this paper develops, from an exact continuous model, a constant- and lumped-parameter, linear matrix model of a homogeneous, rectangular, simply-supported plate subject to transverse ballistic shock. The model is provided in a form suitable for eigen-analysis intended to yield kinematic responses for SRS determination. Damping can be included in either Rayleigh or modal form. The enabled "same-plate" shock analysis, while not encompassing an entire military vehicle, would treat the most severe cases of shock response, for components mounted directly on the impacted plate.

KEY WORDS: Shock, Shock Response Spectrum, Vibration, Plate, SRS

CONTACT: Dr. R. David Hampton, Department of Civil and Mechanical Engineering, USMA, West Point, NY 10996 Tel: (845) 938-8398; email: Roy.Hampton@usma.edu

COL Kip P. Nygren, Department of Civil and Mechanical Engineering, USMA, West Point, NY 10996 Tel: (845) 938-3272, Email: Kip.Nygren@usma.edu

Ting H. Li, Mechanical Engineer, Structural Dynamics Section, Ordnance Materials Branch, Weapons & Materials Research Directorate, ARL, Adelphi, MD, 21005 Tel: (301) 394-2939, Email: tli@arl.army.mil

Morris Berman, Mechanical Engineer, Structural Dynamics Section, Ordnance Materials Branch, Weapons & Materials Research Directorate, ARL, Adelphi, MD, 21005, Tel: (301) 394-4188, Email: mberman@arl.army.mil

Ami Frydman, Ph.D., Chief, Structural Dynamics Section, Ordnance Materials Branch, Weapons & Materials Research Directorate ARL, Adelphi, MD, 21005Tel: (301) 394-2806, Email: frydman@arl.army.mil