PROTECTION OF LOWER LIMBS AGAINST FLOOR IMPACT IN ARMY VEHICLES EXPERIENCING LANDMINE EXPLOSION

J. Wang, R. Bird, B. Swinton and A. Krstic

Abstract. The aim of this study was to develop a practical solution that would effectively limit load transmission through the floor of a vehicle experiencing a landmine explosion and thus help to protect the lower limbs of the occupants. A false-floor approach was proposed and a drop-test was used to examine alternative false-floor configurations. The mechanical properties of the insertion materials used in the false-floor were measured and explicit finite element method (FEM) modelling then carried out to simulate the drop-tests. Based on these tests and the FEM modelling results, a practical false-floor configuration was proposed. Finally, explosive field trials were conducted in which biofidelic surrogate legs were used. The results confirmed that the proposed false-floor approach was an effective method for limiting impact loads to the lower limbs.

INTRODUCTION

In modern forms of warfare, as well as military operations other than war, anti-vehicle landmines (AVL) have become the major threat to military vehicles [1].

AVLs cause damage to both vehicles and occupants in a number of ways. The blast pressure generated may cause the vehicle's hull to rupture, thus allowing blast overpressure and heat to enter the cabin. Fragments generated by a mine may penetrate the hull. The blast pressure and fragments may cause severe impact to the vehicle, resulting in direct-impact injury, or injury due to excessive body acceleration of the occupants. If the impact to the vehicle is excessive it may cause the vehicle to overturn or become unstable, resulting in injuries similar to those incurred in traffic accidents. Landmines may cause damage in other ways, such as fire, toxic fume, and so on.

In order to protect vehicles against AVL attack, a number of novel landmine countermeasures may be utilised. These include a V-shaped hull, deflection panels above the wheels, higher ground clearance, higher strength hulls and relatively large vehicle mass. These measures may reflect and deflect shock waves, facilitate ventilation of explosive combustion products, prevent entry of fragments, overpressure and heat into the cabin, and reduce overall acceleration and displacement of the vehicle in the event of an AVL incident.

In order to optimise vehicle design and guaranteed occupant protection, the seating and flooring need special design attention. Hirsh [2] investigated the response of an unrestrained adult human male to a rapidly applied motion, or shock delivered upward through the feet. He indicated that the subject would receive compressive injuries in the body-supporting bones near the point of load application when subjected to a peak velocity change of 3 to 4 m/s for a pulse duration shorter than 10 ms (or an average acceleration higher than 30 g). In a medium-sized armoured vehicle, localised floor average acceleration and peak velocity change may typically exceed 100 g and 12 m/s respectively under AVL attack. It is therefore highly likely that the occupant's lower limbs may be injured if special countermeasures are not taken.

The aim of this study was to develop a practical solution that would effectively limit load transmission through the vehicle's floor, thereby affording enhanced lower-limb protection for the occupants.

Though there are many literature references that discuss the application of impact load limiters and energy absorbing materials [3-6], none could be found by the authors which specifically addressed protection of lower limbs from injury derived from AVL attack.

FALSE-FLOOR APPROACH

To limit or decouple the impact load, the following mechanisms may be considered:

- soft-spring suspension,
- load limiter, and
- energy-absorbing materials.

The soft-spring mechanism may reduce the impact load by way of an impedance mismatch (similar to how an earthquake gauge works), which may be used as a footrest for seated occupants. A typical example of a load limiter is a hydraulic damper with its relief pressure threshold appropriately set. Once the load pressure exceeds the preset value, the piston will move in response, and further load increases will be prevented. Similarly, either a friction damper or a collapsible material may also be used to achieve load limiting. Energy-absorbing materials consume energy during deformation thereby resulting in a plastic impact. In an ideal case a plastic impact may reduce the peak velocity change by as much as 50% when compared with the alternative elastic impact. Any candidate decoupling mechanism must take into account the floor's essential functional constraints. Hence, the proposed mechanism needs to provide sufficient rigidity to withstand the occupant's weight during normal operational conditions. The structure, which sits on top of the vehicle's 'natural' floor, also needs to be relatively thin in order to retain the internal ergonomic clearances. In view of the above discussion, the false-floor approach, in which load-limiting and energy-absorbing materials are inserted under the false-floor surface, would seem to be a suitable solution.

PROCEDURE

At the outset of this study, the static properties of the alternative insertion materials were measured. A drop test was then conducted in which a simplified metal surrogate (MS) leg [7] was used to test the efficiency of false floors