EXPERIMENTAL AND NUMERICAL ANALYSIS OF OCCUPANT SAFETY IN BLAST MINE LOADING UNDER VEHICLES

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INTRODUCTION

Personnel safety is crucial in (military) operations where mines pose a threat. In peacekeeping and peace-enforcing operations occupant safety has the highest priority. In the past years, the TNO Defence Research Organisation participated in projects for the improvement of the mine protection of several military vehicles. These vehicles included both the lightweight Aardvark mine-clearing vehicle, a mine-protected M113 armoured carrier, the 30-tons MAN truck and the heavy Leopard 2 main battle tank. In case of a mine detonation under a vehicle the shock and the (vertical) global impulse load will affect the occupants inside this vehicle. The objective is to obtain a good understanding of the process of a mine detonation under a vehicle and the effects for the occupants, and to determine 'low level' criteria for the high and short vertical loading conditions.

METHODS

In full-scale tests, the loads on the occupants were measured using instrumented HYBRID III 50%-tile male crash test dummies. Additionally, MADYMO simulations of the full-scale tests as well as parameter studies are performed using both the crash dummy model and the human body model.

EXPERIENCES

In Figure 1 an example of a full-scale test with the Aardvark mine-clearing vehicle is shown. Figure 2 shows the time sequence of a mine detonation process in general. Due to the blast load caused by a mine detonation deformation of the bottom plate (local effect) together with a vertical displacement of the whole vehicle (global effect) will occur. The seriousness of these effects depends on the mine and its boundary conditions, on the bottom structure and on the vehicle type and mass. The severity of the loads on the occupant depends on the interior structure, like seat and seat mountings, and foot plate configurations.

Figure 1: Full-scale test with dummy (left window) in Aardvark mine clearing vehicle

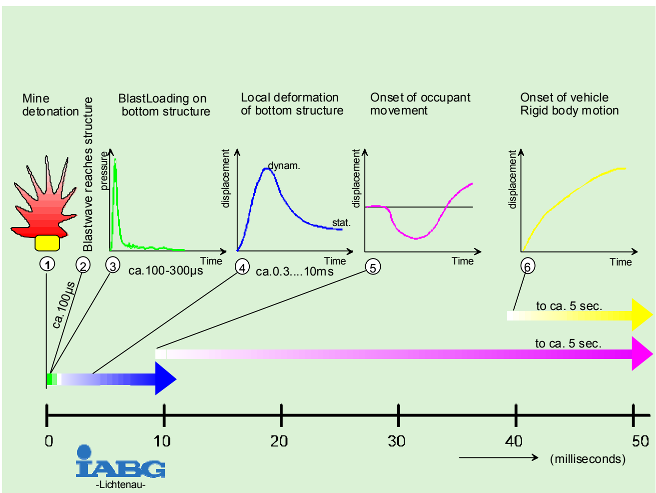

Figure 2: Time sequence of events during a mine detonation [Römer, 2000].

When a seat or a footrest is mounted on the deforming bottom plate or close to this, large loads will be transferred to the spine and the lower legs. Additionally, risk of injury of the head and neck increase with head contact. The time sequence of the loading process in the human body is shown in Figure 3. The data is gathered from full-scale experiences with dummies.

Accelerations up to 50g are measured in the pelvis due to the seat motion. This vertical acceleration causes compression of the spine. To quantify spinal compression occurring in emergency escapes with an ejection seat a simple first order mass-spring model has been developed which is called the Dynamic Response Index (DRI) model [Stech, 1969]. A DRI threshold of 16 which correlates with a 5% risk of spinal injury is used to predict injury in vehicle mine protection studies. In aerospace regulations the lumbar spine load is used as injury criterion. The DRI is compared to the lumbar spine load for experimental and numerical vehicle mine detonation studies and linear correlation is found. Therefore, the lumbar spine loads may be used to predict the injury risk, which is practical, since the dummy measurements directly produce these values.

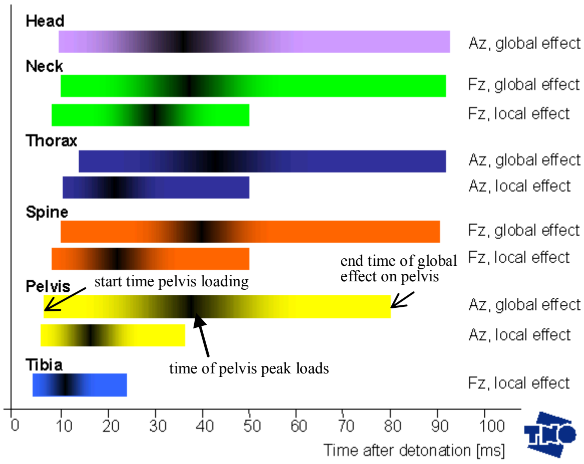

Figure 3: Time sequence of loading process in human body due to mine detonation (Fz is axial compression force, Az is vertical acceleration)

Experimental results showed that the lower leg loads could be extremely high due to the bottom plate deformation. The effect of floor plate deformation on the lower leg loads has also been simulated in MADYMO using a simple vehicle model with a Hybrid III crash dummy model. The duration of the footplate velocity was only 1.5 ms and the peak footplate velocity ranged from 1 to 30 m/s. The results indicated that a footplate velocity of 15 m/s (which corresponded to a 11 mm deformation) was just below the tibia critical force compression level (TCFC < 8 kN). Deformation of 15 mm in such a short time (velocity of 20 m/s) gave already forces of 13 kN, which is about 60% larger than the tibia injury criterion level.

DISCUSSION

In case of a mine detonation under a vehicle the head, the spine and the lower extremities are vulnerable body parts. Tolerance levels for body loads are not available for vehicle mine accidents, therefore, injury criteria based on automotive and aerospace industry are used so far. It should be noted that these tolerance levels are mostly defined for the risk on moderate and severe injuries, whereas in case of working in peacekeeping and peace-enforcing operations ‘low-level’ tolerances are needed. To define the relation between low-level tolerances of injury criteria and the risk on injury and its severity, further research is needed.

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