EXPERIMENTAL AND COMPUTATIONAL RESEARCH FOR CONCEPTUAL DESIGN OF MINE-RESISTANT BOOTS

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Abstract. Experimental and computational research has been conducted for conceptual design of mine-resistant boots. In the experiment an explosive charge generated a shock impact to a metal wedge supporting a steel surrogate leg. The impact load received by the leg was recorded via strain gauges. The effect of a number of factors such as standoff distance, wedge-angle and energy absorbing materials on the impact load was explored. It was found that the impact load is sensitive to the standoff distance but less sensitive to the change of the wedge angle. Use of honeycomb materials may reduce the impact load significantly. A Dyna3D finite element analysis was also performed. The modelling results were in close agreement with the measured results thus demonstrating the utility of the finite element method as a useful tool in the design and development of mine-resistant boots.

INTRODUCTION

Anti-personnel landmines (APLs) are generally used in military operations for area denial of dismounted personnel. Those areas also include anti-vehicle landmine (AVL) fields where APLs are used to protect the AVLs from clearance by deminers. It is estimated that over 100 million APLs are currently deployed throughout the world [1]. These mines pose a severe threat to military and NGO personnel, as well as to the local civilian population.

APLs are classified by their primary injury mechanism as being either of the fragmentation, or the blast type. Blast-type APLs are the most prevalent type worldwide. Their resultant injuries are characterized by traumatic amputation, lacerated, contused and devitalised tissues, disruption of local blood supply, the presence of non-sterile foreign bodies and infectious contamination by various micro-organisms. APL's general design purpose appears targeted at causing traumatic amputation of the distal portion of the unprotected lower limb, leaving the adversary injured, but alive.

In order to protect people, in particular military personnel, from APL injury, efforts have long been made to develop mine-resistant boots. In the 1950s a model of air-cushioned mine-protective footwear appeared in England. This was followed in the 1960s by a model from the USA, incorporating a honeycomb-filled shank, wedge-shaped heel cut outs and metal heel counters. The latter was tested against US M14 APLs and it was reported that 63% of the protective boots resulted in a foot damage level that could possibly be "salvaged from amputation" [2]. In recent years several new mine-protective boot options have been developed and are now commercially available.

Testing was conducted at the Weapons Systems Division, of the Australian Defence Science and Technology Organisation (WSD, DSTO) to evaluate some of these commercially available mine-resistant boots. Evaluation testing has also been carried out in the USA and Canada [3]. The results from these tests indicated that in order to achieve satisfactory performance, further developmental effort is needed.

Figure 1 gives a section view of a typical mine-resistant boot. The metal wedge is used to protect the sole from rupture and thus diminish the erosive effects of the explosive products. The V-shaped wedge also serves to reflect and deflect the shock wave and thus reduces impact load transmission. The honeycomb material is used to limit impact load and absorb impact energy.

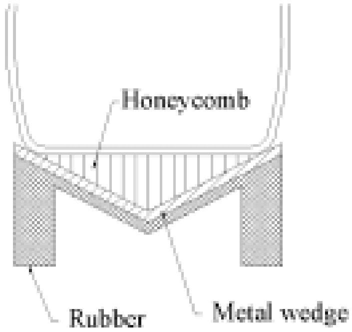

Figure 1. Section view of a typical mine-resistant boot (from rear to front, at the heel location).

In general terms, mine-resistant boots cannot fully prevent foot and leg injury. The design is targeted at reducing injury level, particularly the prevention of severe injuries that would otherwise lead to amputation. Because APL injury level is directly related to the load transmitted through the boot, the load must therefore be minimised through smart boot design. On the other hand, a quantitative injury criterion related to the load level, however, has not been established in published literature known to the authors. Thus, ultimately, a novel boot design will still need to be evaluated by means of APL tests involving bio-fidelic surrogate legs.

In most available literature regarding the development of mine-resistant boots, novel protective mechanisms were proposed and incorporated in the designs. The prototype boots developed were then evaluated against APL explosions. What has hardly been reported however is fundamental research such as computational and experimental analyses of individual underlaying factors. For the optimal design of mine-resistant boots, such research is essential. WSD's preliminary research in this area is summarised below.

For the purpose of this study, only the blast-type mine is considered.

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