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Investigations on the Performance of Metallic and Composite Body Armors

Lakshmi L[a,*], Nandakumar C G[b]

[a]PG Student, Department of Ship Technology, Cochin University of Science and Technology, Cochin,682022,India
[b]Associate Professor, Department of Ship Technology, Cochin University of Science and Technology,Cochin, 682022, India

Abstract

Body armor systems made of various materials and exhibiting distinct ballistic energy absorption mechanisms need to be considered for improving ballistic performance and energy absorbing mechanism of body armor. Modern armor materials such as composites and fabrics replace high density metals and alloys which hindered mobility and offered less protection. Armors are designed to prevent penetrating threats and internal damage that penetration will produce to human torso. The interaction between armor and human torso should be considered for actual performance of armor and for evaluating quality of protective effectiveness of armor against non-penetrating threats. Hence, linear elastic analysis of curved metallic and composite armors with continuum model and discrete model for the human surrogate target has been considered.

*Keywords:*Body Armor;metals;composites;surrogate target;continuum model;discrete model

1. Introduction

During the early years of industrial revolution, due to continuously escalating threats it became essential even for small armies to be fully equipped with armor or the need for ballistic protection was felt. Ballistic protections are protection from bullet impact and protection from stab or slash threats of knives during attacks as per National Institute of Justice Standard [1]. The improvement in production techniques enabled or made it possible to provide even large armies with complete kits of armor. Hence, body armor emerged as efficient ballistic protective clothing. History of armor materials is vast and use of metal as a ballistic material became common since the medieval period and men became more skilled in operating them which prevented ballistic impact to some extend.

*Lakshmi L. Tel.:8606846624
*E-mail address:*l.lakshmi37@gmail.com

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With the metallic armor being found to provide more enhanced protection from ballistic impact, investigation continued in this field for stronger and better performing materials and their improvement for providing strength. Mobility and protection are the two major demands by the wearer of the body armor. Mobility and protection perplexed armor developers such that the mobility demands the lightest possible armor whereas protection increases with increase in weight of metallic armor thus impeding mobility. It has encouraged innovation and ingenuinity in armor materials research and armor system design [2]. Thus, development of armor materials mainly focussed on reducing the weight of existing armor materials for saving energy and for more enhanced mobility. Thus, damage resistant, flexible, lightweight and great energy absorbing materials became the main attraction of the field. As a result, composites and fabrics emerged as modern armor materials [3].

For better performance of body armor, it is necessary to consider proper fit of armor to human torso since the real situation to be considered is that when the armor is worn by a wearer. Hence, curved armor should be considered with valid human surrogate target for proper fit which most of the investigations did not consider. Also, interaction among bullet, target plate and human torso should be considered for improving the performance of armor effectively by eliminating biomechanical threat. Body armors are intended to resist penetrations and the internal damage that penetration will produce to human torso. But, non-penetrating ballistic threats may induce blunt trauma or biomechanical injuries. They are designed to prevent wounding from penetration and deformation, but do not address the biomechanical threat. The energy of a non-penetrating ballistic impact must either be deflected and absorbed or dissipated within the target. Little definitive data is available which defines the limits of energy, which can be safely endured by the human body.

So, various material systems with proper fit should be considered for improved strength performance of armor. In this paper, finite element analysis of curved metallic and curved laminated composite armor with human surrogate target of continuum model and discrete model has been considered.

2. Structural behaviour and idealization

Ballistic panel is the main structural component of body armor. It can be idealized as flat or curved panel. Considering proper fit when worn by a wearer, curved target plate with valid human surrogate target need to be considered for which target plate on elastic support for discrete model or target plate with clay as backing material for continuum model is considered.

When the projectile strikes the target plate, energy from projectile is transferred to target plate. The impact energy will be distributed over a larger area. The target plate absorbs the energy due to impact load. Larger volume of target plate will be associated in the energy absorption process. As the volume of the target plate involved in the process is larger, the deformation process is more homogeneous resulting in increased performance of armor. Failure modes of metallic panels included ductile hole formation, adiabatic shear plugging and discing [4]. Impact resistance of metallic target deals with the amount of work done in plastic deformation. The damage due to impact in metallic armor starts from the surface and can be detected by the visual inspection of target surface. But impact damage of composites including delaminations, matrix cracking and fiber breakage causes strength reduction and are not detectable by visual inspection of the surface of the target. Impact damage of laminated composites is influenced by thickness, size and boundary condition of the laminated composite panel [5]. Main difference of the failure of laminated composite from the metallic armor is its tendency to delaminate. The disturbed area of impact energy for composites is larger when compared to the disturbed area of monolithic armor. Hence, ballistic impact modelling for understanding damage mechanisms of laminated composites provides the possibility of reducing physical experimentation which reduces design time, cost of material and testing cost.

Panels are simply supported at its edges since normal force is mostly affecting the target plate and no deflection has been observed along the edges. Human surrogate targets need to be considered for the actual performance of armor. When the panels have been considered with valid surrogate target of discrete model and continuum model, it resists deformation in response to the impact loading and are equivalent to the resistance offered by the human torso.

3. Types of analysis

Rigorous analysis which account for the geometries of the interacting bodies, elastic-plastic and shock wave propagation, hydrodynamic flow, finite strains and deflections, strain rate effects, work hardening, heating or