

BALLISTIC PROPERTIES OF POLYMER MATRIX COMPOSITES AND CERAMIC PLATES USED IN ARMOR DESIGN

Mehmet Colakoglu* and **Omer Soykasap****

*Department of Mechanical and Aeronautical Engineering, University of Pretoria, Pretoria, S.A.

**Afyon Kocatepe University, Faculty of Technical Education, Afyonkarahisar, Turkey

Introduction

Personal armors for protection against projectiles are usually manufactured today from polymer matrix composites due to lightweight and good ballistic properties. The requirement of the good ballistic protection is absorbing the kinetic energy of a bullet or projectile without any penetration and any major injury in the person. Designing the armors for only penetration is not enough for protection especially for polymer matrix composites because total back-side deformation (elastic and plastic) is large in these materials due to low elastic modulus. Therefore, a part of the body directly behind the impact point receives a hammer-like blow even though the bullet might not penetrate the armor. As a result of the back-side deformation, surface of the skin can get bruises and lacerations, and internal organs can get damaged.

The backside deformation and penetration speed are considered experimentally, numerically and analytically for Kevlar 29/Polyvinyl Butyral and Polyethylene (UHMW-PE UD-HB2) composites in our previous studies [1-2]. Ballistic tests are performed using 9 mm FMJ bullet for the backside deformation and using STANAG 2920 particle for penetration test. The effect of environmental temperature on ballistic performance is also investigated for Kevlar 29/Polyvinyl Butyral composite since polymer matrix composites have temperature dependent mechanical properties [3].

The aim of this study is to investigate the ballistic performance of woven Kevlar/Polyvinyl Butyral composite (Twaron) and ceramic plates used together in armor design against 7.62mm FMJ high speed bullet.

Experimental

Kevlar/Polyvinyl Butyral composite laminate is manufactured as 30 layers at 160°C under 6.5 MPa pressure for a total pressing time of 15 min. Alumina ceramic plate is cut by water jet and is taped to the composite plate as shown in fig. 1. Ballistic tests are

conducted using 7.62mm FMJ bullet and G3 gun to examine the backside deformation. Firings are performed from 15 m distance to the front face of the specimens. The standards of National Institute of Justice (NIJ 0101.04) are also followed in these experiments [4]. Paste is placed to the backside of the composite plate to measure total back face deformations.



Fig. 1 Kevlar-29 composite laminate and ceramic plates used in experiment.

Results and Discussion

Fig. 2 shows experimental results (the back side deformation versus speed of the bullet) for Kevlar/Polyvinyl Butyral composite and ceramic plates. An analytical method developed in our previous study [2] for 9mm FMJ bullet tests is also used to compare results. The average experimental bullet speed is 833m/s after performing 6 shots and the average back side deformation is 14.5 mm. This combination, Kevlar and ceramic plates, provides full protection against G3 weapon and 7.62 mm FMJ bullet. The main aim of the ceramic plate used in the experiment is to reduce the speed of the bullet. On the other hand, composite laminate is used for the major protection. A photograph of the plates is given in fig. 3 after a ballistic test. The ceramic plate is completely broken to many pieces. Therefore, ceramic plate can not provide protection after the first shot. According

to calculations using the analytical model and comparisons of the results with our previous experiments, the ceramic plate reduces the speed of the bullet to 300-320 m/s. Instead of using a 30-layer, a 10-layer Kevlar-29 plate also provides full protection to reduce the cost but it might be close to the critical limit.

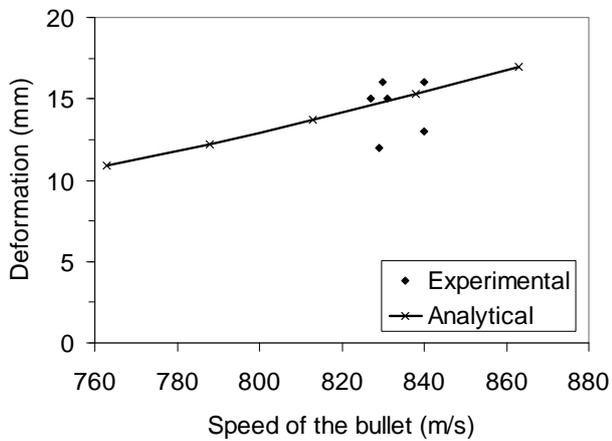


Fig. 2 The relationship between the back side deformation and speed of the bullet.



Fig. 3 Kevlar-29 and ceramic plates after an experiment.

The ballistic properties of Polyethylene fiber composite are investigated in another previous study using the same experimental setup [5] with this work. 80-layer composite plates which are laminated and simply stitched are used to measure the depth of the back side deformation against 7.62mm bullet. The simply stitched plate has critical back side deformation, 44mm, when the speed of the bullet is approximately 675 m/s according to NIJ standards as seen in fig. 4. However, the laminated plate has full protection with a maximum deformation of 30mm if the speed of the bullet is 864m/s.

When a 10-layer Kevlar-29 composite laminate with ceramic plate and Polyethylene fiber laminated composite are compared, both of them provide

protection against G3 weapon and 7.62mm FMJ bullet. On the other hand, Polyethylene is more expensive than Kevlar-29. Using Kevlar-29 – ceramic combination instead of the 80-layer laminated Polyethylene is approximately 8 times cheaper. On the other hand, Polyethylene fiber laminate is 50% lighter than that of Kevlar-29 – ceramic combination.

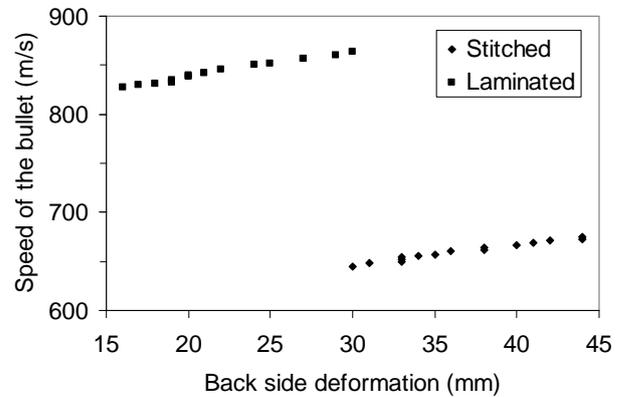


Fig. 4 Back face deformation of Polyethylene plates vs. initial projectile speed (data taken from [5]).

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