High Velocity Impact Analysis of Kevlar Composite by MATLAB

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ABSTRACT
The Kevlar composites are very promising material due to unique mechanical properties mostly used in aerospace and army utilities, where impact energy absorption and high strength to weight ratio material required. In present paper a polymeric sandwich composite of the woven orthotropic fiber of Kevlar with leather layers is considered for analysis of high velocity impact. A mathematical model based on theory of single yarn impact, is applied using MATLAB code to calculate the energy absorption and strain induced in the composites (Kevlar and leather layers). The energy, strain profile and impact of cone of layers were plotted with respect to the time using MATLAB software.

Keywords: High Velocity Impact, Kevlar, Leather, MATLAB

1. INTRODUCTION
The kinetic impact energy absorption and perforation properties are main deciding parameters for selecting armor materials for various applications. In personal body armor aramid or spectra fiber composites were used to avoid perforation and evaluated by repeated impacts to obtain the value of the striking velocity [1]. The targets of Kevlar 29 and 129 were subjected to ballistic projectile impact with velocity between 130 and 250 m/s and differences were selected until enhanced by different failure mechanisms including penetration and delamination [2]. The two-dimensional woven fabric E-glass/epoxy composites impact energy absorption behavior depends upon the projectile and target parameters [3]. The targets of composite laminated Kevlar-29/vinyl ester plates [4] were used in the ballistic experiments, which were firmly clamped at the edges. The projectile impact velocity of approximately 400 m/s, depending on the number of plies, the shear force of the material, as well as other variables used to evaluate the energy absorption and various damages during impact was studied by numerical models in the helmet composite shell [5]. The ballistic impact behavior of projectile and target parameters were evaluated as critical parameter through experimental investigations and results were verified by simulation using finite difference methodology on the two-dimensional woven fabric E-glass/epoxy composites [6]. The basalt/nylon fibers ratio is found to have significant effects on the impact behavior of intra-ply hybrid composites [7].

The parametric studies were carried out on woven fabric E-glass/epoxy thick composites and the energy absorption, ballistic limit velocity and contact duration were reported as affecting parameter to ballistic impact [8]. The multi-layered beams were more effective in resisting perforation than monolithic beams of the same weight under projectile impact [9]. The double/triple-layered armor is superior in ballistic resistance to a monolithic plate if the total thickness did not exceed a critical value [10]. The ballistic limit of a monolithic plate was even higher than that of a multilayered armor of the same total thickness [11-12]. The experimental and numerical studies were performed on the perforation resistance of double-layered steel armor plates [13-14] and reported that ballistic impact with a flat-nose projectile, the ballistic limit of multi-layered armor was found to be 30% higher than that of the monolithic case [15]. The normal impact and perforation of conically-tipped hard-steel cylinders was done on laminated Kevlar-29/polyester targets and pneumatic and powder guns, with a 12.7 mm barrel diameter were used for dynamic tests. Ballistic limits, terminal velocities and perforation were
determined on target plates [16]. The parametric analysis, considering various projectiles and target plate variables, were carried out to find their effect on the response of the plate, ballistic limit and absorbed energy by using °C eight-noded serendipity quadrilateral finite elements based on first-order shear deformation theory (FSDT) for phenomenon of a cylindro-conical impactor on the Kevlar/epoxy-laminated composites [17]. In the present work, MATLAB script file is generated for a mathematical model based on theory of single yarn impact to analyze high velocity impact on a polymeric sandwich composite of the woven orthotropic Kevlar fiber and leather layers. The energy, strain profile and impact of cone of layers were plotted with respect to the time using MATLAB software.

2. MATERIALS FOR STUDY
The woven orthotropic fiber of Kevlar 49 and cow top grain leather were used for different layers and araldite is used as an adhesive for polymeric sandwich composite which is considered for study. The arrangement of layers is shown by side view of composite in Figure 1.

![Figure 1: Polymeric sandwich composite of Kevlar and leather](image)

3. SELECTED MATHEMATICAL MODEL AND PROGRAMMING
A mathematical model was selected to compute the total energy absorbed and its components from the data of the projectile’s position in time. The model is based on theory of single yarn impact to calculate the fabric’s total absorbed energy in terms of strain and kinetic energy components. It is assumed that upon impact, longitudinal strain wave is generated in the strained yarns and then followed by transverse wave, which causes the material to move in direction perpendicular to the fabric’s plane. The transverse displacement of the material within this wave forms a pyramid (deformation pyramid or cone) and material move out-of-plane with the speed of the projectile. The panels discussed here are considered to be square targets with clamped edges (all the degrees of freedom of the nodes on the boundary are restrained). The MATLAB script file was developed for calculating the energy absorption and strain induce in the layers of Kevlar and leather. The flow chart of program describing composite structure analysis is shown in Fig. 2, describes the input values required and use of the mathematical equations for calculation of various output parameters.

4. RESULTS AND DISCUSSION
The developed MATLAB script file is capable of capturing the nature of impact in a fabric, it is only useful over a short span of time; from the impact incident till the moment when the first reflection of the longitudinal strain waves returns to the impact point. Then the interaction of the waves makes the study more complicated and the formulations more extensive. The variation of area of cone, absorbed energy and strain developed in Kevlar and leather layer with time of impact are shown in figures 3 and 4. In both the layers the stored energy increases and strain decreases with increase in impact time. The damage is high at the time of initial impact of impactor. The area of cone developed in the Kevlar layer is more in comparison to leather layer. So Kevlar layers can absorb more energy than lather layers.

4. CONCLUSION
In the present study the MATLAB script file was developed for selected mathematical model and absorbed energy, area of cone and strain developed were computed and plotted against impact time. The following conclusions were drawn from study 1. The stored energy increases and strain decreases with increase in impact time due to initially high kinetic energy utilising of impactor for deformation than the absorbed in layers. As the impact time increases, tendency of deformation reduces and energy absorption improves.

2. The strain energy is high at the time of impact in beginning, due to kinetic energy of impactor is more than the energy absorbing capacity of layers, results maximum damage of the layers.

3. The cone area developed in the Kevlar layer is more in comparison to leather layer it has absorb more energy than leather layers.

4. The outcomes may be used as preliminary design tool for an assembly of rigid and semi-rigid materials in an armor system to reduce the experimental cost and time.

5. REFERENCES
[3].

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Figure 2: Flow chart of program describing composite structure analysis.

Figure 3: The variations in Kevlar layer with time of impact (a) Area of cone (b) Energy stored (c) Strain developed with panel.

Figure 4: The variations in leather layer with time of impact (a) Area of cone (b) Energy stored (c) Strain developed with panel.


