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Effect of Specimen Thickness on High Strain Rate Properties of Kevlar/Polypropylene Composite

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Abstract

Characterization of Kevlar-Polypropylene based composite material system under high strain rate loading has been investigated using Split Hopkinson Pressure Bar (SHPB) test for varying specimen aspect ratios. Flat laminates of 16, 24 and 30 layered Kevlar composite were compression molded and laser machining to get cylindrical specimens of desired aspect ratios. Based on SHPB experiments, stress-strain plots were obtained and analysed to reveal compressive material behaviour as function of growing strain rate. The peak stress, strain and toughness exhibited considerable increase with growing strain rate of loading. With increasing strain rates peak specimen stress increased by 90%, for lowest thickness composite. The aspect ratio studies suggests application of thin laminates for better performance of composite laminates.

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Keywords: Kevlar; Thermoplastic matrix; High strain rate; Aspect ratio

1. Introduction

The need for light weight body armor had always been in demand. This resulted in phenomenal growth of fiber reinforced plastic composites in last five decades. The high tenacity fibers coupled with low specific gravity matrix

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results into a composite system perfectly suited for the ballistic applications. With ever increasing demand, the need to study the material behaviour under high strain rate loading becomes essential. The quasi-static testing done on universal testing machines cannot reveal the materials response under high strain rate of loading. Therefore, there was a strong need of a testing scheme to study the material behaviour under dynamic high strain rates of loading. This need was fulfilled in the form of a unique test facility developed by Kolsky [1], named as split Hopkinson pressure bar test apparatus.

It has been reported in literature that most of the material whether metallic or non-metallic have strain rate dependent properties. Allazadeh et al. [2], studied steel, aluminum, wood and graphite-epoxy composite under high stain rate of loading and reported difference in rate dependent behaviour of all these materials. Similarly, numerous studies revealed rate dependent behaviour of metals and composite. Nolting et al. [3] studied different grades of naval steel. They optimized SHPB system to suit their materials and reported rate dependency of three grades of naval steel. An increase in strength and peak strain was reported for different metals with increasing strain rate of loading [4][5].

The rate dependent behaviour of FRC's has also been studied. Song et al. [6], studied S-2 glass/SC15 composite along thickness direction and in-plane direction under high rate loading on SHPB and the peak strength obtained were 700 MPa and 500 MPa for peak strain rate with in the experimental strain rate range. Xuan et al. [7], studied woven carbon/epoxy under dynamic loading and reported dynamic strength limit higher than quasi-static strength limit. Woo et al. [8][9], studied Kevlar composite under high strain rate loading using acoustic emission along with SHPB and reported higher strength as a function of growing strain rates of loading. The peak stress acquired by Kevlar composite varied in range of 160 ~ 370 MPa for an experimental strain rate range of 1182 ~ 1460 s^{-1}. Ramadhan et al. [10], studied the effect of three different specimen thicknesses on dynamic properties of Kevlar/epoxy and Aluminum laminated panels under ballistic impact and reported change in material behaviour as a function of specimen thickness.

Nomenclature

ε_r	reflected strain
ε_t	transmitted strain
C_0	elastic wave velocity in the bars
E	Young's modulus of elasticity of bar material
A_B	cross-section area of the bar
A_S	cross-section area of the specimen
L_s	specimen length
t	time duration
υ	poisson's ratio
FRC	fiber reinforced composite
SHPB	split Hopkinson pressure bar
K-PP	Kevlar-Polypropylene

Kevlar composites have been used with thermosetting polymers for ballistic applications. However, the need arises for using thermoplastic polymers as matrix to further reduce the weight of FRC armor. A number of experimental works on varying specimen aspect ratios are available in literature. Knowing that ideal aspect ratio resulting into negligible inertial effects is given as $\sqrt{0.75\upsilon}$ [11]. The objective of present study is to characterize three different thicknesses of Kevlar-thermoplastic composite system under high strain rate of loading. The 16, 24 and 30 layered Kevlar-Polypropylene composite with constant diameter of cylindrical specimen results into three different aspect ratios (0.3, 0.42 and 0.53) were tested under high strain rate loading on SHPB. Kevlar composite having 24 layers is close to theoretical requirement and other two will serve as lower and higher value of aspect ratio. The test results are of importance due to the fact that whereas, SHPB test reveals the properties on the basis of one-dimensional loading, the physical loading while in service is three-dimensional in nature. Hence, the test results