CHAPTER I

INTRODUCTION

1.1 General Introduction

Using an armor to protect a person and equipment has a long history. The earliest type of armor was made from hard and rigid materials such as bronze, brass, and steel. They have the ability to resist penetration but the hard, rigid materials alone cannot provide effective energy dissipation such as material deformation and breakage.

One of the most important characteristics in armor design is comfort. Three factors which are the greatest influence on comfort of armor are weight, flexibility, and breathe ability, whereas, the metal armor lacks all these important characteristics. The invention of synthetic fiber is the great improvement in armor design which can improve the previous characteristics (Tyrone, 1991).

1.1.1 Ballistic fiber

High performance fibers used in ballistic products are characterized by low density, high strength, and high energy absorption such as glass fibers (S-and E-glass), aramid (Kevlar, Twaron), high performance polyethylene (HPPE) fibers (Dyneema, Spectra), PBO (Zylon). The first use of synthetic fiber in armor system was woven Nylon 6,6 which combined with steel plate to produce " Flak Jacket " during the World War II (Jacqueline, 1991).

One of the most favorite types of fibers used in ballistic products is Kevlar fiber because of its excellent thermal properties, highly crystalline, highly oriented structure, and high mechanical properties. Kevlar has much higher tensile strength

than steel wire, nylon, fiberglass, and polyester. It also has higher tensile modulus than nylon, fiberglass, and polyester but has lower density than glass fiber and steel wire, as compared in Table 1.1. This is the reason why Kevlar reinforced structures give high strength and stiffness with the light weight (Jacob, 2001).

Table 1.1 Comparison of industrial filament yarns

Properties	Kevlar 29 aramid	DuPont nylon type 728	Dacron polyester Type 68	E-glass	Stainless steel
Tensile strength, MPa	2760	986	1120	2413	1724
Modulus, GPa	90.0	5.5	13.8	69.0	200.0
Elongation to break, %	4.0	18.3	14.5	3.5	2.0
Density, g/cm^3	1.44	1.14	1.38	2.55	7.86

1.1.2 Ballistic polymer composite

The development of composite technology represents one of the most significant advances in material science since the 1940s. Fiber-reinforced composites are made of high strength fibers imbedded in metallic, ceramic, or polymeric matrices. The major advantages of composite material are their high strength and stiffness, light weight, and also higher flexibility than metals and natural materials. Generally, the composite material consists of three important elements which are reinforcing material, matrix resin, and huge interface between the matrix resin and reinforcing material. Consider the composite with the volume of 10 milliliters based on 60% by volume of carbon fibers of diameter 7 micrometers which contains 160 Km of fiber and 4 milliliters of resin. Its interface is around 3.5 square meters, the volume of thumb, and the area of large dining table respectively (Jacqueline, 1991).

As we have already known, although both polymer and fiber, which commonly used for composite, cannot resist the projectile, composite fabrication can raise the ballistic resistance level because the composite can be designed to have higher energy absorption mechanism. Many publications show the using fibers which

do not provide effective ballistic resistance, i.e. fiberglass, Nylon, Graphite, with the suitable polymer matrix to make the composite acting as an effective armor composite (Hartman et al., 1991, 1993, Gauchel, 1989).

1.1.3 Polymer blend

Mixing two or more polymers together is a well known technique to achieve specific properties of polymer without need to synthesize a new polymer system. Improvement of mechanical properties such as toughness is usually a main reason for blending polymers together. The other reasons for blending are to improve processability, to improve physical and thermal properties, to achieve desirable polymer to meet the market.

PC/ABS blend is considered as the largest commercial polymer alloy sold in the world and is replacing polyester and nylon-based alloys in engineering applications. The combination of the best properties of polycarbonate (PC) and acrylonitrile-butadiene-styrene (ABS) have been known to result in the commercialization of this alloy which is useful in many molding applications particularly in the automotive industry. The advantageous characteristics of PC/ABS blend are to overcome drawbacks of the neat PC such as high melt viscosity and notch-sensitivity, to retain other superior mechanical properties of the PC and to generate other useful properties including glossiness and low temperature toughness.

In the present, the fiber-reinforced armor composite is scarcely developed because the restriction in lacking of tailor-made properties of polymer matrix. Consequently, the armor composite can not be achieved its highest ballistic efficiency. Many publications exposed the various properties of PC/ABS which can be fine tuned to achieve desired quality i.e. toughness, modulus, viscosity, and polarity. With these tailor-made properties of PC/ABS, it has high ability in development for high performance armor composite.

1.2 Objectives

1. To develop the light weight ballistic armor base on Kevlar-reinforce composite using thermoplastic (PC/ABS blend) as matrix.
2. To study suitable compositions of PC and ABS and number of layer of the Kevlar cloth to produce the ballistic composite for NIJ level IIIA or higher.

1.3 Purposes of this Research

1. To find suitable conditions for material blending and test specimen processing for this research system.
2. To evaluate the composition of PC and ABS which provide the suitable mechanical properties for ballistic resistance.
3. To investigate thermal properties of the composites.
4. To examine ballistic properties of the composites by using ballistic impact test.