Preliminary Design of NIJ Level IIA-IV Bulletproof Panels Made from Ramie (*Boehmeria nivea*) Woven Fiber Reinforced Composite

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Abstract

Ramie (*Boehmeria nivea*) is one of the strongest natural cellulose fiber. Optimising abundant resources ramie as a candidate materials used for reinforcing in polymeric composite material is a must to obtained high performance natural fibers reinforced polymer (HPNFRP) especially for bulletproof panel or high impact flexibility safer structures. Ramie woven was treated using common chemical solvents that were ethanol, methyl ethyl ketone, acetone and silane as coupling agent. Composite panels were made by hand lay-up process with epoxy as a matrix. These prototype bulletproof panels were to be believed lighter in weight and much lower economic cost than conventional bulletproof panels made from ceramic plate, Kevlar/aramid composite and steel based material as a popular today in military standard antiballistic equipments. From the bullet testing result, it showed that panel could be able to resist the penetration of high impact projectile for level II with some fractures phenomenon. Level IV ballistic testing showed that all prototype panel could not resist the high impact velocity of the projectile yet. It was found that ramie fibers have sufficient breaking strength and toughness for level II bullet testing although still need improvements to optimize process parameters to meet a very high military standard and application.

Keywords: ramie fiber, prototype bulletproof panel, level IIA/IV NIJ standard, ballistic testing, fracture

1. INTRODUCTION

According to Perepelkin (2006), the relation of the structure and properties of fiber reinforced-composite is determined by the selection of the initial components and condition of manufacture, processing, use and properties. This relation is very complex and can be characterized by the following diagram in general sense.

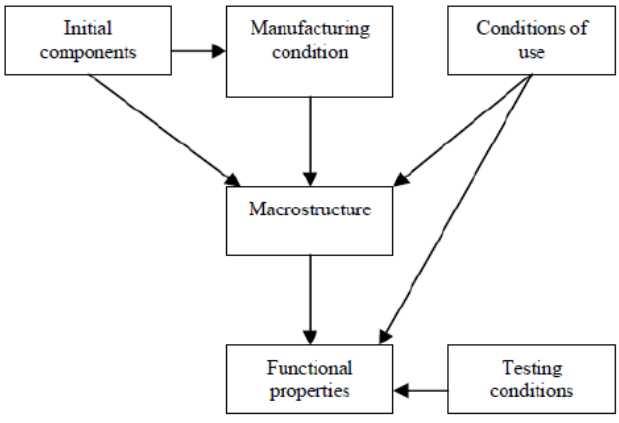

Figure 1. Diagram of the complex relation of the material components, manufacture and properties of fiber reinforced composite (Perepelkin, 2006)

Dealing with ramie fiber as the role of initial component, physical and mechanical properties of the fiber compared to other natural cellulose fibers can be seen in table 1 below (Muller and Krobjilowski, 2005).

Table 1 List of physical and mechanical properties of

		Cotton	Flax	Hemp	Jute	Kenaf	Ramie	Sisal
Fineness	dtex	1-4	1-7	2-6	2-3	5-6	5-13	-
Diameter	m	-	11-33	15-50	200	200	40-80	50-200
Length	mm	10-60	10-40	15-28	1-5	2-6	60-260	1-5
Maximum stress	cN/tex	25-50	30-62	35-70	30-34	34.5-60	40-70	30-45
Tensile strength	MPa	330-595	345-1035	690-1000	393-773	930	400-1050	511-635
Young's modulus	GPa	4.5-12.6	27.6-45.0	50.0	26.5	53.0	61.5	9.4-13.8
Density	gcm^{-3}	1.5-1.54	1.43-1.52	1.47-1.50	1.44-1.50	1.5	1.5-1.6	1.16-1.5
Maximum strain	%	7.0-8.0	2.7-3.2	1.6-1.6	1.5-1.8	1.6	3.6-3.8	2.0-2.5
Specific tensile strength	km	39.2	73.8	69.3	52.6	63.2	71.4	43.2
Specific stiffness	km	0.85	3.21	3.47	1.89	3.60	4.18	1.07

Source: Muller and Krobjilowski, 2005

Ramie as a candidate material for reinforcement in polymer composite has mechanical properties higher in average than the others. As abundant natural resources, ramie also available in continuous form with the length between 60-250 mm and this physical property is one of the benefit to be utilized for reinforcement fiber in polymer composite applied for panel.