

CHAPTER I

INTRODUCTION

1.1 General Introduction

Human-being has a long history with wood utilization such as in home project, building, furniture applications etc. The advantages of natural wood are its high strength (flexural strength of *hevea brasiliensis* = 66 MPa) and beautiful surface texture whereas the obvious drawbacks of natural wood product are high water uptake (30-200%) [W. Simpson *et al.*, 1999], high flammability (LOI = 21) and termite irresistibility. In addition, high flammability of natural wood indicates relatively high burning potential which limits its use in some applications. Wood-substituted composites from waste wood materials i.e. sawdust or woodflour and resin binder, play a key role to solve these problems by combining those complementary properties of the filler and the polymer matrix.

The types of polymer matrices for making composites can be classified into thermoplastic and thermosetting groups. Conventional properties of thermoplastic wood composites are ease of processing and recyclability but typically rendering products of low fire resistance, low thermal stability, low strength, and low compatibility with natural wood [A.K. Bledzki *et al.*, 1999]. Generally thermoplastics, such as polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC), occur in a form of linear or branched chains which are held together by a weak van der Waals force [E.A. Turi, 1981]. These polymers possess a low strength for load-bearing applications. In addition, when burning takes place, these linear or branched structures are easily decomposed.

One major goal of a development of wood composites is to achieve properties that are close or superior to those of natural wood. PVC resin is one of the most utilized thermoplastics as a matrix polymer for fire resistant wood composites due to its inherently low flammability (LOI = 50) [C.A. Harper, 2004]; however, the polymer can

release HCl gas during its combustion. Though HCl is an effective combustion inhibitor, it is an acid gas that is both corrosive and toxic. Some systems of wood composites are incorporated with flame retardants for improving their fire resistant ability. Basically, flame retardants function under heat to yield products that would be more difficult to ignite than virgin plastics, or that do not propagate flame readily. Although an addition of flame retardant reduces flammability of materials, the mechanical properties are usually sacrificed. Furthermore, the use of flame retardant obviously increases the material cost. Antimony trioxide (Sb_2O_3), decabromodiphenyl oxide (DBDPO), and alumina trihydrate (ATH) are examples of the major flame retardants used in PVC systems [Encyclopedia of chemical technology, 1991].

Mechanical properties of thermoplastics wood composites have been investigated by several workers. The flexural strength of PVC wood composites was reported to be approximately 46 MPa compared to the value of 66 MPa of *hevea brasiliensis* wood [W. Chetanachan *et al.*]. Whereas flexural characteristics of woodflour-reinforced polyethylene were investigated by S.I. FARID *et al.* The properties of the PE wood with 50% by weight of woodflour content showed a relatively low flexural modulus value of 1.05 GPa and low flexural strength value of merely 19 MPa. These results suggest that thermoplastics wood may not effectively be used for high load-bearing applications.

From the above shortcomings of thermoplastics wood, thermosetting wood composites play an increasingly crucial role in wood product industries due to their various superior properties to thermoplastic wood such as lower flammability, and higher thermal stability of the network structure, greater strength, and higher processability. Regarding the fire resistant characteristics, thermosetting polymers will thermally decompose to yield less volatiles and provide greater char residue upon burning. In general, volatile amount decreases as the degree of cross-linking increases. In addition, some polymers are capable of undergoing cross-linking during pyrolysis thus further generating a greater amount of char. For example, composites made of an unsaturated polyester/styrene thermosetting and woodflour (at 40% by weight) [N.E. Marcovich *et al.*, 2001] showed the degradation temperature of 246°C and char yield about 20%. These

values are significantly higher than most thermoplastic wood composites, comparing at the same woodflour contents, i.e. char yield of PE wood is 7.4% [E. Jakab *et al.*, 2000].

One thermosetting resin system invented recently possesses various characteristics suitable as a high performance composite matrix namely a benzoxazine resin. Benzoxazine resin, a new class of phenolic resin, shows some intriguing properties such as no by-products released upon curing, very low A-stage viscosity, near-zero shrinkage, low water absorption, high thermal stability, and good fire resistant characteristics [H. Ishida *et al.*, 1996]. One intriguing characteristics of the benzoxazine resin is its ability to be alloyed with various existing resin systems such as phenolic novolac [S. Rimdusit and H. Ishida, 2000], urethane [S. Pirstprindwong, 2003], and epoxy [S. Rimdusit and H. Ishida, 2000]. In this work the utilization of the benzoxazine and phenolic novolac alloys as a wood composite matrix will be evaluated. The advantages of phenolic novolac resin are their high compatibility with wood, high char yield (55-70%) [A. Gardziella *et al.*, 1999], no toxic by products from burning, low cost, and excellent flame retardance [M. Sohoni *et al.*, 1999]. Therefore, the incorporation of the phenolic novolac resin in the wood composite can potentially enhance fire resistant capability of sample as well as the compatibility between the filler and the matrix. The phenolic novolac systems had already been reported to be utilized as a curing initiator for the benzoxazine resin [S. Rimdusit and H. Ishida, 2000]. An addition of an appropriate amount of phenolic novolac resin to form alloys with benzoxazine resin is thus expected to render a hybrid matrix resin with outstanding processability of the benzoxazine resin and the high flame resistant characteristics as well as the curing acceleration effect of the phenolic novolac resin.

In this research, woodflour from *hevea brasiliensis* is selected as a reinforcing filler because of its great availability in a form of low cost waste wood materials in Thailand. The woodflour-filled systems of these benzoxazine and phenolic novolac alloys at various alloy compositions and at the fixed woodflour contents of 50% by weight and 70% by weight will be investigated for an application as high performance and improved fire resistant wood-substituted products.

1.2 Purposes of the Present Study

The major objective of this work is to investigate the fire resistant property of benzoxazine (B) / phenolic novolac (P) alloys, i.e. BP resins. The effect of the polymer alloy compositions at two different woodflour contents (i.e. 50% by weight and 70% by weight) on the fire resistant, mechanical as well as thermal properties will be examined. In addition, some essential physical properties of the composites as wood-substituted products are also investigated. The good interfacial bonding between woodflour and BP alloys is one key contribution to the desirable high thermal stability and mechanical properties of the resulting composites. The property will also be evaluated based on its fracture surface morphology using a scanning electron microscope.



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