CHAPTER I

INTRODUCTION

1.1 Reinforced Plastics

Reinforced plastics are combinations of fibers and polymericbinders or matrices that form composite material. The strongest geometry in which any solid can exist is as a wire, a fiber, or a wisker, ie., the strength of any solid is determined by the defects it contains such as void, cracks, discontinuity, etc. and the magnitude of their weakening influence depends upon their absolute size. Thus if a fine-diametered fiber can be drawn or grown from a material, any defects it contains must be very small : the material will be stronger when pulled, having very limited structural utility by themselves. They bend easily, especially if they are small in diameter, and when pushed axially, they buckle under very low forces. To remedy these inadequacies, a supporting medium is required, surrounding each fiber, separating it from its neighbors, and stabilizing it against bending and buckling. These are the functions of the matrix and they are best fulfilled when good adhesion exists between the two. If the fiber-matrix interaction is only a mechanical fit, without adhesion, the combined function is impaired and both components are underutilized.

Adhesion requires intimate contact, on the scale of a few hundred picometers (10^{-12}m), over large surface areas. The best practical way to achieve this is by rendering one component a liquid, having it completely wet the surface of the other, and then solidifying it after the contact has been established. Polymerization readily makes the liquid-solid phase change, and does not require much energy or elaborate processing to do such an intimate contact. Many thermoplastic polymers melt in the range of 150 - 250°c without large input of heat, and they readily solidify upon cooling. During the molten stage, even though their viscosity may be high, they are liquids and they posses the ability to wet most surfaces so that their adhesion potential is readily available. The thermosetting polymers pass through a liquid phase just one time in their life, while they are being polymerized and cross-linked into heat-infusible form. During their liquid phase, the viscosity is very low, however, they can easily infiltrate fiber bundles and fabrics, encapsulating every fiber; once this is done, solidification by catalysis on mild heating is quite straightforward.

The combination of strong fibers and synthetic polymers to form reinforced plastics and laminates derives from several basic considerations of materials science: the inherent strength of fine fibers, the resulting requirement for adhesion, and the ease of the liquid-solid phase change by synthetic polymers. These and other factors are responsible for the continuing rapid growth in the production of reinforced plastics which has averaged about 10-12 % per year for many years and which has shown no signs of lessening, despite the availability problem of energy and raw materials .

1.2 Reinforcement

Reinforcements ordinarily are natural or synthetic fibers that are chosen to improve specific physical, chemical, or thermal properties to the reinforced plastics. The reinforcement may be used as continuous filaments or as chopped fibers. Reinforcing fibers are related on the basis of their physical properties and thermal stability, depending on the desired end use of the final composite.

Many different fibers and wires are used as reinforcements.

The choice of reinforcement depends on the required properties of the product. The strength-to-weight ratio of the reinforced plastics is attributed largely to the nature of the reinforcements. The matrix material or resin, though not in itself proving much strength, is essential, for it serves to bond the reinforcements together and transmits the load to the reinforcing fibers.

1.2.1 Glass fiber

Glass fiber is one of the strongest reinforcements available in large quantities. It is relatively low in density, inexpensive, stiff, chemically resistant, fairly submissive to textile-manufacturing techniques, and capable of some modifications in composition. It is available as continuous filaments, fabrics, mats, or chopped fibers. Glass fiber is readily bonded to most of the thermosetting resins in common use. At the present time, continuous-filament glass-fiber is the most important reinforcement for filament-wound products. It furnishes high strength and good thermal stability up to relatively high temperature. About 10% of all reinforced plastics use glass fibers and about 15% of all reinforced plastics incorporate glass as fibers, flakes, beads, etc.(1)

1.2.2 Cellulose fiber

Cellulose fibers come from many sources and are used in many forms. Cotton, jute, hemp, sisal, coir and bagasses from sugar cane provide economical comparatively long fibers with attractive properties of stiffness, strength, low specific gravity, and resistance to handling damage. Cellulose is the reinforcing fiber found in vegetation. In its crystalline form, it is the backbone of wood fibers and of various natural textile fibers. Although it is the most widely occuring reinforcement, the exact details of the chemical growth process, which links sugar molecules by oxygen bridges and forms cellulose are uncertain (2). Because reactants have to be transported in solution to the growth sites in the cell walls, the natural fiber structure are tubular, usually a few micrometers. The tube walls consist, a greater or lesser extent of cellulose crystallites, depending on the plant.

1.2.3 Carbon fiber

Carbon fibers are made either from polyacrylonitrile fibers or pitch based fiber. The former are oxidized and stretched at the same time, whereas the latter do not have to be held under tension during the oxidation process. The low negative coefficient of thermal expansion can be utilized in the design of zero thermal expansion structures. Most carbon fibers can be woven into fabrics.

1.2.4 Boron fiber

Boron fibers have appoximately eight times the strength the of aluminum but are 10% less dense; their modulus is nearly twice of steel. Although these properties offer great advantages in aircraft-structure applications, the outlook for producing boron fibers for less than $200/Kg is not promising and the development of carbon fibers has greatly reduced the interest in boron fibers.

1.2.5 Aramid fiber

Aramid fibers offer attractive strength, stiffness, and density properties and a high degree of toughness. They are marketed under trade name Kevlar (Du Pont). They are made by treating poly(p-phenylene terephthalamide) with strong acid and extruding the resulting fibers from spinnerates.

Table I Mechanical Properties of Reinforced Fibres.

Fibres	Tensile strength kgf/cm^2	Elongation percent	Price dollars/metricton
Sisal	5166	2.80	360
Palm	5558	3.30	264
Jute	8400	1.80	297
Glass	28198	3.00	3250

TABLE II CHEMICAL COMPOSITION OF COIR FIBER

Constituent	Maturity		
	Very Young	Young	Mature
	Per Cent (Dry Basis)		
Organic matter	–	–	98.8
Mineral matter (ash)	–	–	1.2
Water–soluble substances (ws)	15.5	16.0	5.2
Pectin	4.0	2.7	3.0
Pectin (as per cent of total ws)	25.8	16.9	57.7
Hemicelluloses	0.25	0.15	0.25
Hemicelluloses (as per cent of total ws)	16.1	9.4	4.8
Water–insoluble substances (wi)	84.5	84.0	94.8
Lignin	41.0	40.5	45.8
Lignin (as per cent of total wi)	48.5	48.2	48.3
Cellulose	36.1	32.9	43.4
Cellulose (as per cent of total wi)	42.7	39.2	45.8
Mineral elements			
K			0.02
P			0.01
Ca			0.06
Mg			0.04
Nitrogen (as N)			0.35
Protein (N x 6.25)			2.2

1.3 Resins

The major thermosetting plastics used with the glass composites are polyester, phenolic, and epoxy resins. The general properties, uses, and limitations of the common thermosetting resins used in reinforced plastics are summarized in Table III (1).

Table III Characteristics and Uses of Reinforced Thermosetting Resins

Resins	Characteristics	Uses	Limitations
diallyl phthalate polymer[a]	good electrical properties; dimensional stability; chemical and heat resistance	prepregs, ducting, radomes, aircraft, and missiles	
epoxy	good electrical properties; chemical resistance; high strength	printed-circuit-board tooling, filament winding	require heat curing for maximum performance
melamine–formaldehyde[b]	good electrical properties; chemical and heat resistance	decorative, electrical (arc and track resistance), circuit breakers	
phenolic	low cost; chemical resistance; good electrical properties; heat resistance; nonflammable; can be used to 350–400°F	general—diverse mechanical and electrical applications	dissolve in caustic unless specially treated
polyester	good all-around properties; ease of fabrication; low cost; versatile	corrugated sheeting, seating, boats, automotive, tanks and piping, aircraft, tote boxes	degraded by strong oxidizers, aromatic solvents, concentrated caustic
silicone (qv)	heat resistance; good electrical properties	electrical, aerospace	

Thermoplastic materials also are used as matrix resins. These include nylon, polystyrene, polyethylene, polypropylene, styrene/acrylonitrile, etc.

1.4 Coupling agent

The concept of coupling agents is well known in the field of reinforced and filled plastics. Their main function is to overcome incompatibility between two phases. A coupling agent, usually a bifunctional molecule, is capable of forming covalent bonds with both the organic plastic matrix and the fiber or filler. The bonds across the interphase between the plastic matrix and the reinforcement achieved via the coupling agent provide good adhesion (3). Coupling agents have three main effects in resin composites as follows:

1. longer retention of strength under wet conditions,
2. increased flexural strength,
3. increased tensile strength (much rarer)

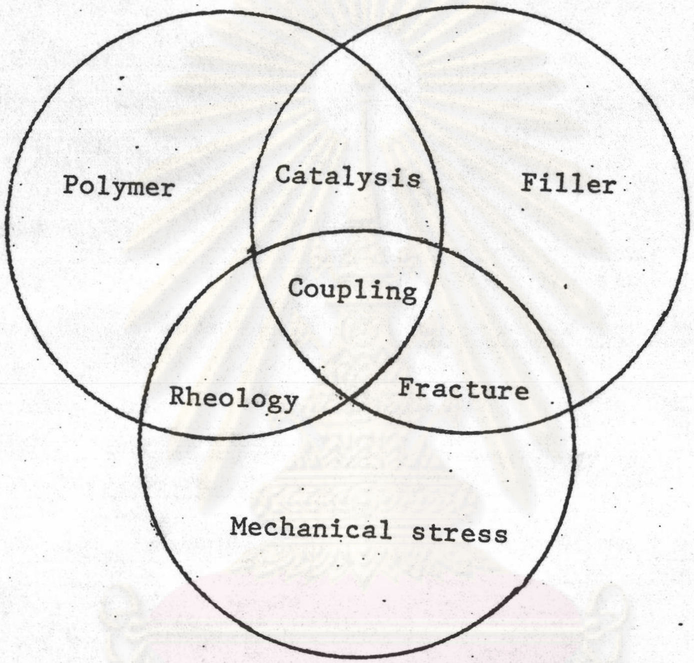

Figure I Interrelationships of polymer, fiber, and mechanical stress in composites.

1.5 Products and Processes

1.5.1 Hand lay-up

The hand lay-up process is the oldest and simplest method for making glass fiber-reinforced parts. Male or female molds can be made of easily worked materials such as wood, plaster, or reinforced plastics. In hand lay-up, resin and reinforcements in the form of fabric, woven roving or mat are simply placed in the mold manually. Entrapped air is then removed with squeezer or serated metal rollers. Successive layers of reinforcement and resin can be added to build the part to the desired thickness. If a smooth colored surface is required, a pigmented material (called a gel coat) can be sprayed on the mold before lay-up.

1.5.2 Die-Molding

Most automotive parts and general hardware are made in heated matched metal dies or molds mounted in hydraulic presses operating semi-automatically. A charge of BMC (bulk-molding compound) or SMC (sheet-molding compound) is placed in the molds and cured under moderate heat and pressure (120-175°c, 3.5-13.8 MPa (500-1200 psi)) for cycles ranging from 15-90 seconds. The molded piece is removed hot and allowed to air-cool before undergoing further operations such as trimming, assembly or painting. The quality of the product is fairly consistent, much subassembly work normal to metal practice can be avoided, and die costs are much lower than for sheet-metal stamping or metal die casting. Thus shorter production runs are economical and more design flexibility and variety can be achieved.

1.5.3 Filament Winding

Pipes, tubes, and cylindrical tanks are made by a process known as filament winding. A mandrel or form is rotated about one axis as continuous yarn or roving which passes through a bath of liquid resin is wet-wound on it, usually in complex patterns controlled by automated machinery. Once the required wall thickness is reached, heat curing in autoclaves, ovens or by heating the mandrel is begun. Because the reinforcement is continuous and its orientation subject to close control, very efficient structures can be produced consistently by this method, and in the case of smooth-bore pipes, the process can be continuous. Once cured, the pipe is removed from the metal mandrel and cut into proper lengths. Mandrels for tanks and pressure bottles often are inflatable, soluble or collapsible, so they can be removed through end ports. Pipe production for oil fields, the chemical processing industry, water distribution, and sewage disposal has reached very large volumes, in diameters from several centimeters to as long as 6 metres; fittings also can be filament wounded or die-molded.

1.5.4 Injection Molding

Injection-molded, fiber-reinforced thermoplastics compete directly with die-cast metals in many hardware and automotive parts. Higher production rates, lighter weight, and assembly simplification are their principle advantages. The fiber stiffen and allow higher operating temperatures. Often, however, the flow patterns of the molten material into the mold cavity cause significant orientation of the fibers and the resulted localized anisotropy can adversely affect strength and thermal-expansion properties. Considerable skills are required of the mold designer and the machine operator. Also the reuse of fiber-reinforced thermoplastic scrap material from runners, sprues, gates, and flash presents problems that can impair the overall efficiency of material utilization. Despite these difficaulties, however, this is the fastest growing segment of the entire composites family.

1.5.5 Miscellaneous

The four processing techniques that have been mentioned are the dominant ones in use today: hand lay-up/spray-up; matched metal die molding (including flat-press laminating); filament winding; and injection molding. However, there are many others that may be variations of the above or are themselves distinctive. For example, vacuum-bag techniques can be used to help remove air from hand lay-up and to provide modest positive pressure on large, low cost molds too bulky for mechanical pressing. Better quality composites result from the reduction in void content and from the superior impregnation of fiber bundles by liquid-matrix resin.

1.6 Natural Fiber Reinforced Composite

Several attempts have been made to utilise naturally occurring plant fibers (for example jute and sisal) as reinforcement in composites (4). However, most of the publications deal with laminates fabricated with jute fiber. The mechanical properties of jute composites are generally poor. Therefore, jute fibers have been considered for use as low cost filler in glass-reinforced plastics (5,6). The major problems associated with the application of natural fibers as reinforcement for organic matrix resins are:

(a) absorption of moisture by fibers,

(b) poor wettability

(c) weak interfacial bonding between natural fiber and commercial available organic matrix resins such as unsaturated polyesters, vinyl esters and epoxy resins.

Pawel Zadorecki and Per Flodin (7,8) had reported their detailed studies of surface modification of natural fibers. Cellulose fibers treated with different coupling agents based on 2,4,6-trichloro-1,3,5-triazine have been evaluated for their reinforcement effects on unsaturated polyester. The treatment with coupling agent containing double bonds resulted in the formation of covalent bonds between fiber and matrix.

Usmani and his colleges (9) used bagasse for different composite materials on the basis of phenolic resin, rubber, or thermoplastic binders. Bagasse can be grafted with acrylonitrile before bringing it in composites.

Coconut fiber (coconut hair, or coir) is produced in the order of 5 million tons per year in the tropical countries of the world (10). Besides the conventional utilization of coir for mats, rugs, carpets, and ropes, a significant amount is used for "rubberized coconut hair", which is a random mat binded with synthetic and/or natural latex, used as upholstery material. Recently coir has been used in plastic composites as well (11).

Owolabi and his co-workers (11) applied short cut coconut hair as reinforcement in thermosetting press materials. Thermosetting plastic composites have been prepared with phenol-formaldehyde resins as well as unsaturated polyesters as binder and coconut hair as fiber reinforcement. Using resole-type for phenol-formaldehyde resins, is one kind of phenol-formaldehyde resins.

The aim of this work has been made to utilise bristle coir fibers with surface modification for reinforcement of unsaturated polyester resins. In order to improve adhesion, the coir fibers were treated with a coupling agent, 2-diallylamino-4,6-dichloro-1,3,5-triazine. This coupling agent was synthesized by the Thurston Method (12), and was characterized by infrared spectrometer, mass spectrometer, NMR spectrometer and elemental analysis.

The mechanical properties of composites of unsaturated polyester and treated fibers were investigated.