Project on Silk Reinforced Fiber Composites

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Mechanical Engineering

By
Ajitesh Das
10603031

Under the Guidance of
Prof. S.K.Acharya

Department of Mechanical Engineering
National Institute of Technology
Rourkela
2010

National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that thesis entitled, "**PROJECT ON SILK REINFORCED FIBER COMPOSITE**" submitted by **AJITESH DAS** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other university/ institute for award of any Degree or Diploma.

Date:

Prof. S.K.Acharya

Dept. of Mechanical Engineering

National Institute of Technology

Rourkela-769008

ACKNOWLEDGEMENT

I avail this opportunity to extend my hearty indebtedness to my guide **Prof. S.K.Acharya** Department of Mechanical Engineering, for his valuable guidance, constant encouragement and kind help at different stages for the execution of this dissertation work.

I also express my sincere gratitude to **Professor R.K.Sahoo**, Head of the Department, Mechanical Engineering, for providing valuable departmental facilities.

Date:

Ajitesh Das

Roll No: 10603031

Dept. of Mechanical Engineering

National Institute of Technology

Rourkela

CONTENTS

ABSTRACT

Now a days, the fiber reinforced composites have dramatically come into use. These composites have gained so much recognition because of their processing advantages and good technical properties like strength, stiffness, elastic modulus, creep rate, damping. Furthermore, these properties showed considerable improvement with increasing silk fabric content. The waste silk collected from the factory outlets were used to fabricate silk reinforced epoxy composites and various samples were developed with varying silk content. Silk fiber because of the presence of many functional groups like $–NH_2$-, COOH, NHCO, CH_2OH on its surface is polar in nature. This fiber has got a non-cellular structure which is expected to produce excellent adhesion between silk fiber and polymer in their composite. Also fiber reinforcement enhances the strength of the composites which can be used in various mechanical goods. This project aims to study the properties of the waste silk reinforced epoxy composites with varying silk contents.

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

A composite is a material made from two or more different constituent materials having different physical or chemical properties which do not merge in the finishing structure i.e. the individual constituents retain their properties. Nowadays, natural fiber composites have gained increasing interest due to their eco-friendly properties. A lot of research work has been done by the researchers in this field. Natural fibers are potential alternatives for artificial fibers. The composite materials exist long before we came to know about its whereabouts and most importantly its significance. Wood is a composite of cellulose fibers in a matrix of lignin. The most primitive man-made composite materials were straw and mud combined to form bricks used for structural purposes. Silk has been an important fabric in the textiles industry due to its luster and superb mechanical properties. Silk yarn is easily available as the waste product of textile industry, so the composite is cost effective and perfect utilization of waste product.

1.2 DEFINITIONS OF COMPOSITES

A typical composite material is a system of materials composing of two or more materials, mixed and bonded on a macroscopic scale. Generally, a composite material is composed of reinforcement (fibers, particles, flakes, and / or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. The composite materials are supposed to carry the advantageous properties of all the constituents used to fabricate it. There are a few definitions proposed by various researchers.

As defined by **Javitz[1]**, "Composites are multifunctional material systems that provide characteristic not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form".

Kelly[2] very clearly stresses that "the composition should not be regarded simple as a combination of two materials. In the broader significance; the combination has own distinctive properties. In terms of strength or resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them."

Berghezan[3] defines as " the composites are compound materials which different from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their shortcomings', in order to obtain an improved material."

Van suchetclan[4] explains "composite materials as heterogeneous materials consisting of two or more solid phases which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property composite."

1.3 CHARACTERISTICS OF THE COMPOSITES

Composites are the materials which consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is called as “reinforcement” which is usually harder and stronger than the continuous phase, where as the continuous phase is termed as the “matrix”.

1.3.1 Properties of composite

The following are some of the properties of composite materials for which they are widely used:

- The strength of the fibers and matrix interface significant in determining the properties of the composites.
- The interfacial bond strength must be sufficient enough for the load to be transferred from the matrix to the fibers.
- The interface must not be so strong that it does not fail for improved toughness of the composites.
- Volume fractions of the composites play a significant role in determining properties. It is regarded as the most important parameter for determining the properties of the composites.
- Homogeneity is also an important characteristic that determines the extent to which a material may differ in physical and mechanical properties from the average properties of the material.
- The isotropy of the system is affected by the orientation of the reinforcement of the matrix in the composites.

1.4 CLASSIFICATION OF COMPOSITES

Composite materials can be classified on the basis of different attributes in various ways. In general there are two phases in a composite material. One is the primary phase called matrix which keeps the secondary phase, the reinforcement undamaged from the external forces. Based on the type of secondary phase the composites are broadly classified into three categories. They are as follows:

- Fiber reinforced composite material
- Flake reinforced composite material
- Particle reinforced composite material

Based on the matrix material, the composites can be broadly classified into three categories. They are as follows:

- Metal Matrix Composites
- Polymer Matrix Composites
- Ceramic Matrix Composites

PARTICLE-REINFORCED COMPOSITES

Particle reinforced composites consist of particles of one material dispersed in the matrix of second material. The particles may be of any shape and size. Generally the particles are spherical, polyhedral, ellipsoidal, or irregular in shape. The particles which are incorporated into the matrix may be treated with chemicals or can be applied untreated. The particles are often used to improve the strength of the materials, modify the electrical and thermal conductivity, reduce friction, increase wear and abrasion resistance, improve machinability and reduce shrinkage.

Particle composites are of two types. They are:

- Composites with random orientation of fibers
- Composites with preferred orientation of fibers

FIBER- REINFORCED COMPOSITES

A fiber is defined by its length which is much larger as compared to its cross-section. Fibers improve the fracture resistance of the matrix as a reinforcement having a long dimension inhibits the growth of incipient cracks normal to the reinforcement which might otherwise lead to failure of the composites. These are high performance fiber composites made by cross linking of cellulosic fiber molecules with resins in the material matrix. Fiber reinforcement enhances the strength and modulus of elasticity of the composites. Hence it is necessary for the fibers to posses' higher modulus than the matrix material, so that the load is transferred to the fiber from the matrix more effectively. It is widely used in outdoor deck floors, railings, fences, landscaping timbers, cladding and siding, park benches, molding and trim, window and door frames, and indoor furniture.

These are composites are again classified into two groups based on the length of fibers used. They are as follows:

- Continuous Fiber reinforced composites

- Discontinuous Fiber reinforced composites

Continuous fiber reinforced composites have continuous fibers and they do not have discontinuity which is different from the discontinuous fiber reinforced composites. The discontinuous fiber reinforced composites are again of two types namely aligned FRCs and random FRCs (based on orientation of fibers).

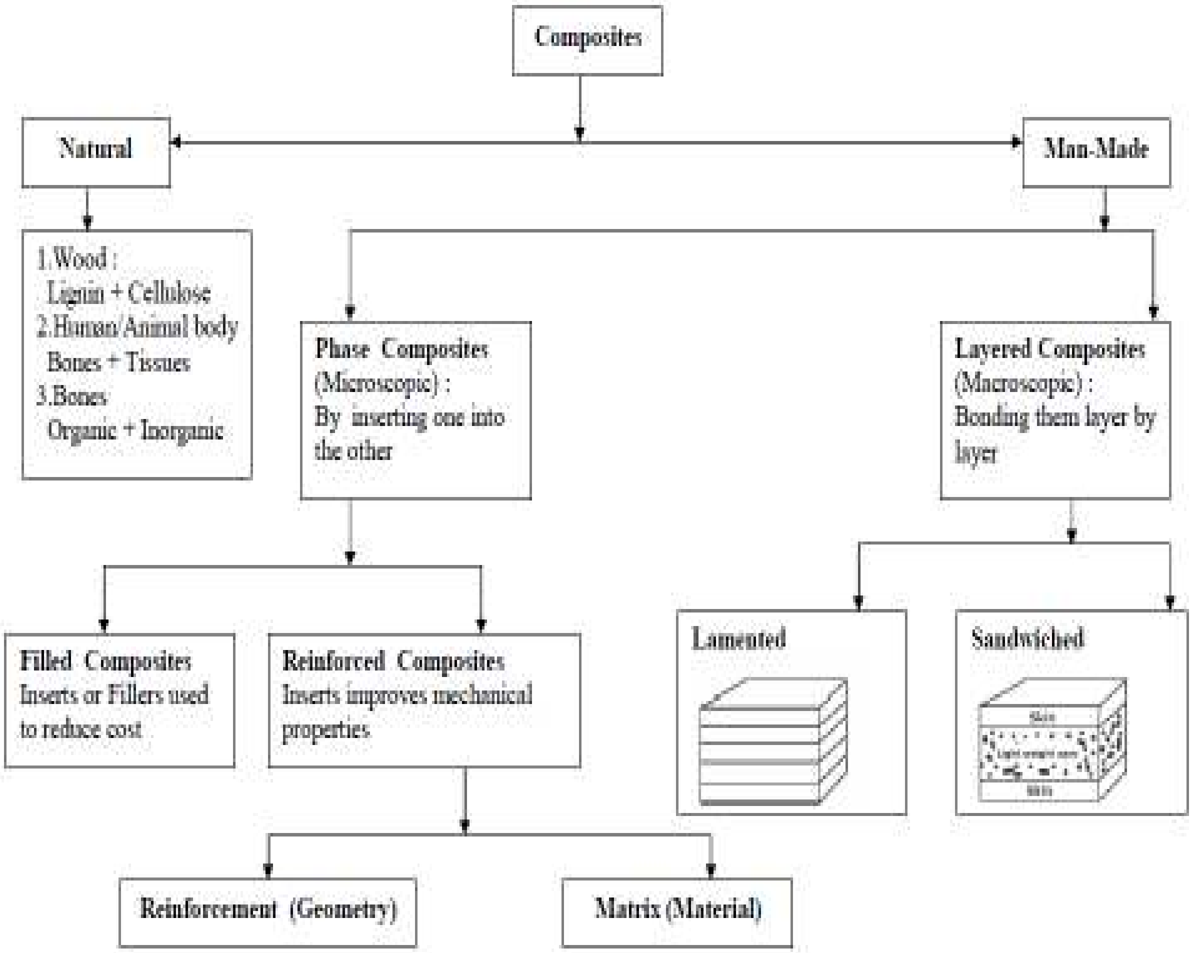

Fig 1: Classification of composites

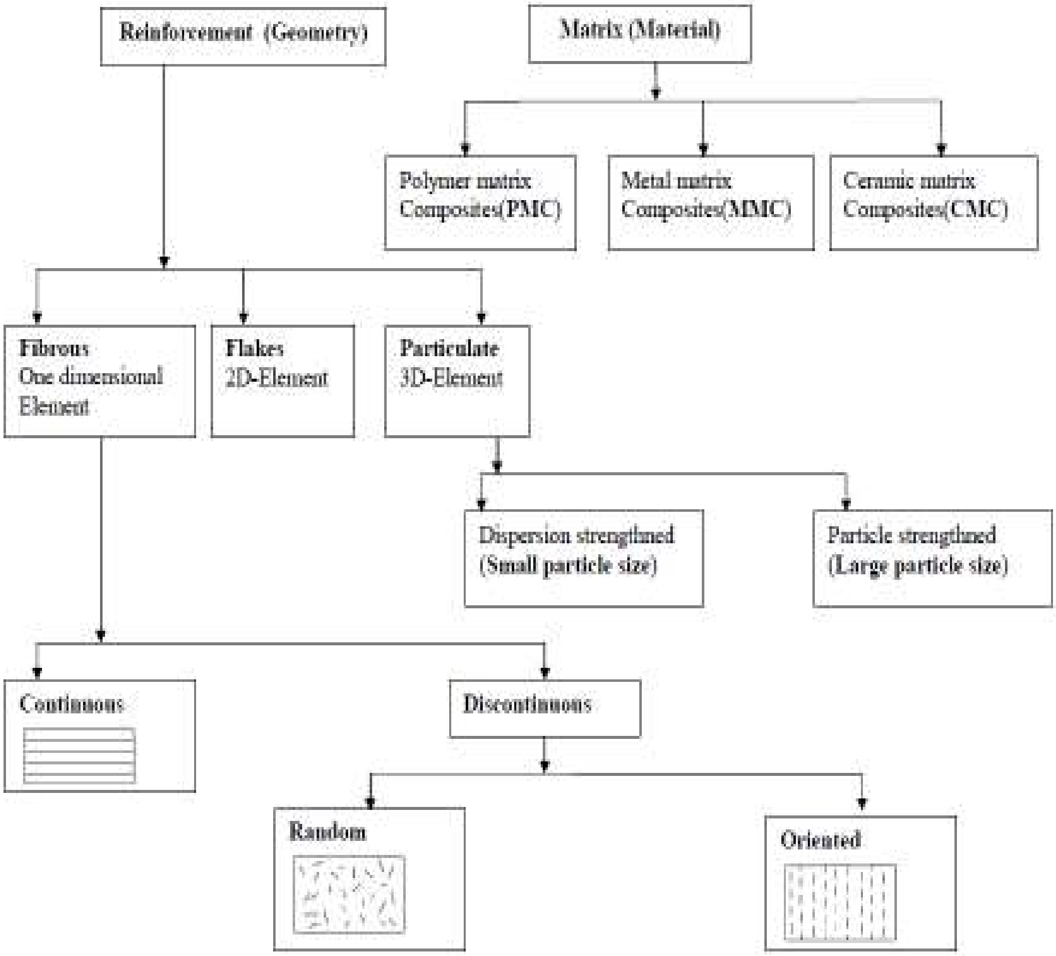

Fig 2: Classification of composites (contd…)

1.5 NATURAL FIBER COMPOSITES

Natural fiber has attracted the attention of researchers worldwide as a potential reinforcement for composites because of their easy availability, easy process ability, low density, light weight, non abrasivity, and lower cost and eco-friendly characteristics like sequestration of carbon dioxide (reduction of greenhouse effect). The silk fiber produced by spiders, silkworms, scorpions, mites and flies may have different composition, structure and material properties depending upon the specific source. These flaws can be avoided by spinning under controlled conditions to produce uniform cross-sectional area of silk fiber. Replacement of fiberglass with natural fibers removes worries about the lung disease caused by the former which is a great step towards sustainable development. These fibers are animal or plant products; the latter are essentially micro-composites consisting of cellulose fibers in an amorphous matrix of lignin and hemi cellulose. Cotton, jute, silk, wool, hemp and sisal are some of the natural fiber composites.

FIBER REINFORCED POLYMER COMPOSITES

These consist of polymer matrix embedded with high strength fibers. These are the most advanced composites that are used.

Some of the features of FRPCs are as follows:

- Low cost
- Simple Fabrication methods
- High tensile strength
- High stiffness

- Good abrasion, puncture and corrosion resistance
- Good fatigue strength

Limitations of FRPCs are as follows:

- Low operating temperature
- Low thermal and moisture resistance
- High coefficient of thermal expansion
- Low elastic properties in transverse direction

1.6 COMPONENTS OF A COMPOSITE MATERIAL

1.6.1 Matrix Materials

The primary phase having a continuous character is called matrix. Matrix is usually more ductile and less hard phase. It holds the dispersed phase and shares a load with it. Matrix is composed of any of the three material types- polymers, metals or ceramics. The matrix forms the bulk form of the part or the product.

Most of the materials when they are in a fibrous from show very good strength properties. In order to achieve these properties the fibers must be bonded by suitable matrix. The matrix separates one fiber from the other in order to prevent wear and abrasion. It also prevents the formation of new surface flaws and holds the fibers in place. A good matrix is one which possesses the ability to deform easily under applied load, transfer the load into the fibers and distribute the stress concentrations evenly. The natural fibers are embedded in a biopolymeric matrix system which serves the purpose of holding the fibers together thereby stabilizing the shape of the composite structure. This helps to transmit the shear forces between the mechanically high quality fibers, and to protect them against radiation and external forces. Polymers are classified into two categories namely thermosets and thermoplastics. Both these varieties are suitable for use as matrix in the bio composites. There are large number of ways of modifying the matrices. So it is essential that the materials for matrix are chosen according to the requirements. The criteria for choosing a suitable matrix system for high performance construction materials are the temperature in which it is to be used, amount of mechanical loading under consideration, manufacturing technology followed, etc. An important criterion for the selection of matrix is its adequately low viscosity for a good impregnation of the reinforcing fibers.

1.6.2 Reinforcement

The secondary phase is embedded in the matrix in a discontinuous form. The dispersed phase is usually harder and stronger than the continuous phase and is called reinforcement. It serves to strengthen the composites and improves the overall mechanical properties of the matrix.

The main purpose of the reinforcement in composites is primarily improving the mechanical properties of the neat resin system. The varieties of fibers used in composites have different properties and therefore impart different properties to the composites. For a large number of applications, the fibers are needed to be arranged in a form of sheet called fabric to ease the handling process. The fibers can be oriented in different permutations and combinations so as to achieve different characteristics of the composites.

CHAPTER 2

LITERATURE SURVEY

LITERATURE SURVEY

Since the past few decades, interests of researchers and engineers have been shifting from traditional bulky materials to fiber reinforced polymer-based materials due to their uniqueness such as high strength to weight ratio, non-corrosive property and high fracture toughness. Recently natural fibers are used as a substitute for synthetic fiber such as glass; the primary reason being its advantages such as renewability, low density and high specific strength. These composite materials consisted of high strength fibers such as carbon, glass and aramid, and low strength polymeric matrix. Now they have dominated in various sectors e.g., the aerospace, leisure, automotive, construction and sporting industries. Unfortunately, these fibers have serious drawbacks such as non-renewability, cannot be recycled, tend to consume large amount of energy during manufacturing process, are non-biodegradable and health hazards caused due to inhaling. Biodegradation is the chemical breakdown of materials by the action of living organisms which leads to changes in physical properties. It is a concept of vast scope, ringing form decomposition of environmental wastes involving micro-organisms to host-induced of biomaterials.

It has been found that glass fiber-reinforced composites are used at large for years together because of their low cost and moderate strength to provide structural stability in various situations. Now a days, the most concerning issue is the serious environmental problem caused by the widespread use of glass fibers. Due to the strong emphasis on environmental awareness these days, researchers are most interested in the substitute for these fibers that are recyclable as well as environment friendly. Keeping in view the environmental legislation and the increasing consumer demands of materials, the manufactures in United States produce materials and products by practicing the 4Rs which are

- *Reduce* the toxicity
- *Reuse* products
- *Repair* what is broken
- *Recycle* as much as possible

There has been a dramatic increase in use of natural fibers such as leaves from flax, jute, hemp, pineapple and sisal as reinforcement in recent years for making environment friendly composites. These recent studies have examined molding condition, mechanical properties and interfacial bonding. With the increasing global energy crisis and environmental risk, plant based fiber reinforced polymer composites have attracted the attention of researchers towards them as they are the potential alternatives for artificial fiber composites, like glass and carbon. Although the strength of such fibers are lower than that of the general traditional advanced composites but is sufficient enough for domestic and household products. Many attempts have been done in the past few years on using jute, bamboo, sisal, coir, hemp, flax, pineapple leaves, etc., for reinforcing different kinds of thermoplastic and thermoset polymers to form green composites. These fibers are more frequently used and studied due to their natural abundance, cost effectiveness, annual production rate and wide range of properties. A large number of literatures have been reported on composites based on plant based natural fibers. Animal based natural fiber composites have been rarely reported.

Animal based natural fibers can also be used as alternatives for producing biodegradable and environment friendly composite materials for bio-engineering and medical applications. The contents of these fibers are mainly made by proteins, like wool, spider and silkworm silk. The silk fibers are environmentally stable as compared to the proteins because of their extensive hydrogen bonding.

Silk fibers (Bombyx mori) spun out from silkworm cocoons consists of fibroin in the inner layer and sericin in the outer layer. Each raw silk thread has a lengthwise striation, consisting of two fibroin filaments of 10–14 lm each embedded in sericin. The chemical compositions are, in general, silk fibroin of 75–83%, sericin of 17–25%, waxes of about 1.5%, and others of about 1.0% by weight. Silk fibers are biodegradable and highly crystalline with well-aligned structure. It has been known that they also have higher tensile strength than glass fiber or synthetic organic fibers, good elasticity, and excellent resilience. Silk fiber is normally stable up to 140 ^{0}C and the thermal decomposition temperature is greater than 150^{0} C. The densities of silk fibres are in the range of 1320–1400 kg/m^{3} with sericin and 1300–1380 kg/m^{3} without sericin. Silk fibres are also commercially available in a continuous fibre type.

Sang Muk Lee, Donghwan Cho, Won Ho Park, Seung Goo Lee , Seong Ok Han , Lawrence T. Drzal [5] studied that novel short silk fibre (Bombix mori) reinforced poly(butylenes succinate) bio-composites have been prepared with varying fibre contents by a compression molding method. The mechanical and thermal properties have been studied in terms of tensile and flexural properties, thermal stability, thermal expansion, dynamic mechanical properties, and microscopic observations. The results show that chopped silk fibres play a significant role as reinforcement for improving the mechanical properties of PBS in the present system. However raw silk fibres are used without any surface modification which is normally done to improve the interfacial bonding between the natural fibre and the matrix. The tensile and flexural properties of PBS matrix resin are markedly improved with increasing the short fibre content in the composites, showing a maximum value at a fibre loading of 50 wt%.

The effect of surface treatment on the inter-laminar fracture toughness of silk/epoxy composite has been studied by Maryam, Che, Ahmad, Abu Bakar [6]. The multilayer woven silk/epoxy composites were produced by vacuum bagging process. The silk layers was increased from 8-14. Two sets of samples were prepared. In the first set, the surface of the composite was treated with silane based coupling agent and in the second treatment there was no surface treatment. Both the samples were tested for mode I inter laminar fracture using double cantilever beams (DCB) testing method. It was found that the inter laminar fracture toughness of set I was higher than that of set II. Also it was observed that the inter laminar fracture toughness goes on increasing as the number of silk fibers is increased.

Raghu, Noorunnisa Khanam and S.Venkata Naidu [14] prepared chemical resistant composite. This showed abrupt improvement in the silk fiber epoxy laminate. Hand lay up technique was used to prepare both untreated and alkali treated silk-sisal unsaturated polyester-based hybrid composites. The chemical resistance of these hybrid composites to various acids and alkalis was studied.

S.Padam Priya, S.K.Rai [13] studied the various properties of the waste silk reinforced fiber composites and the maximum strength in properties determined is observed for the optimum fabric loading.

CHAPTER 3

MATERIALS AND METHODS

3.1 PREPARATION OF COMPOSITE

3.1.1 Raw Materials Used

POLYMER

The polymer used in the preparation of composite is EPOXY. It is a thermosetting polymer. Because of its high strength, low viscosity and low flow rates, it allows good wetting of fibers and prevents misalignment of fibers during processing. Following are the most outstanding characteristics of epoxy for which it is used.

- Low volatility during cure.
- Available in more than 20 grades to meet specific property and processing requirements.
- Excellent adhesion to different materials
- Great strength and toughness resistance
- Chemical and moisture resistant.
- Excellent electrical insulating properties.
- Low shrink rates.

SILK FIBER

Both plant based fibers and animal based fibers have become potenstial alternatives for producing biodegradable, biomedical and bio-restorable composite materials for bioengineering and medical applications. Cocoons are natural polymeric composite shells made of a single continuous silk strand with length in the range of 1000 – 1500 m. This protein layer called sericin resists has a lot of excellent qualities like resistance to oxidation, antibacterial nature, UV ray resistant, and absorbs and releases moisture easily. This protein layer can be cross linked co polymerized and blended with other artificial polymers to produce composites with improved properties. In average, the cocoon production is about 1 million tonnes worldwide, and this is equivalent to 400,000 tonnes of dry cocoon.

HARDENER

In the present work Hardener (araldite) HY 951 is used.

3.2 CALCULATION

For the preparation of composites with different compositions of silk fibers and polymer, a rough estimate of volume of silk fiber and polymer was made. The following calculations show the different compositions of silk fiber composites.

Total Volume of the Sample = 15*20*0.4

= 120 cm^3

Total Mass of the Sample = Volume * Density

= 120*1.4

= 168 g

Table 1: Composition of different samples

S.No.	Weight of Composite (g)	% of fiber	Weight of silk fiber (g)	Weight of polymer (g)
1	168	2	3.36	164.64
2	168	4	6.72	161.28
3	168	6	10.08	157.92
4	168	8	13.44	154.56

3.3 SAMPLE PREPARATION

3.3.1 Mould Preparation

For the sample preparation the first and foremost step is the preparation of the mould which ensures the exact dimension of the composite to be prepared. We have to prepare moulds for the preparation of 2%, 4%, 6%, 8% fiber of the composite. A clean smooth surfaced wooden board is taken and washed thoroughly. The wooden board was covered with a mould release sheet.

3.3.2 Silk Yarn Preparation

The raw waste silk yarns collected from the factory outlets are filled with dirt, dust and are aggregated. The silk yarns collected were cleaned thoroughly with water and dried. Then the aggregations are gently dispersed with hand sitting patiently. After that the silk yarns were measured accurately for the preparation of different samples.

3.3.3 Polymer-Hardener Mixture Preparation

A measured amount of polymer was taken for different volume fraction of fiber composite (i.e. 2, 4, 6 & 8%) and mixed with the hardener in the ratio 10:1. The mixture was stirred properly for uniform mixing. Care was taken to avoid formation of bubbles.

3.4 CASTING

The silk fibers prepared in the above steps were put on the already designed mould. After putting the silk fibers in the mould, the polymer-hardener mixture was slowly poured over it. The silk fiber due to its light weight and high volume gets swelled up. For that reason only we roll a roller gently till the sample fits in the mould. Then we cover the sample with a non-reacting plastic cover and place the glass on it such that no voids or air gaps leave behind. These voids weaken the composite and makes testing difficult. For the composite of perfect dimension weight should be carefully put above it. Weight should be put in such a way that no polymer hardener mixture seeps out of the glass. The composite sheet takes 72 hrs for curing in room temperature. Then the samples were cut into desired dimensions for experimental purposes depending on the standards.

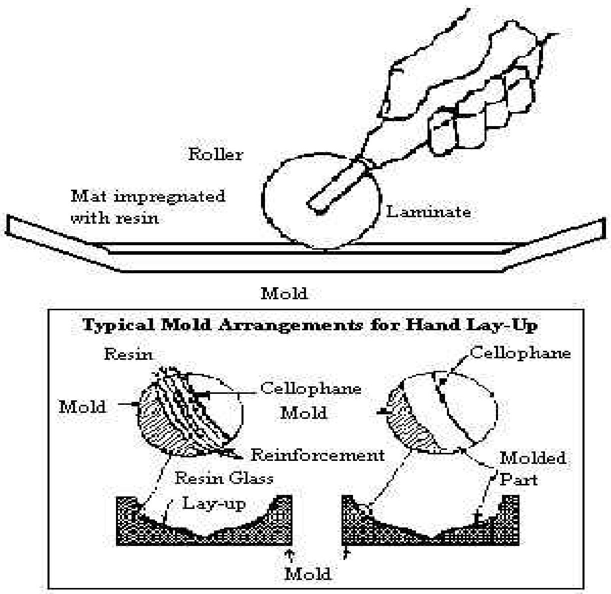

Fig 3: Hand lay-up technique used for sample preparation

3.5 EROSION WEAR

The progressive loss of material from its surface is called wear. It is the response of the material to the external stimulus and can be mechanical and chemical in nature. Wear is an unwanted phenomenon that takes place on the surface of the material and its effects on the reliability of industrial components is recognized widely; also, the cost of wear has also been recognized to be high. The efforts in wear research were started around in 1960s in industries. The direct costs of wear failures, such as replacements of wear parts, increased work and time due to wear, reduction in productivity, as well as indirect losses of energy and the increased environmental burden, are the major problems in everyday work and business. In catastrophic failures, there is potential threat to human lives. Although wear has been extensively studied scientifically, numerous wear problems exist in the industrial applications in the 21st century. This actually reveals the complexity of the wear phenomenon

A typical wear mode named as solid particle erosion wear is defined as the loss of materials from the surface by the repeated impingement of small solid particles. Solid particle erosion is an useful phenomenon in sand blasting and high speed abrasive water jet cutting but in enginnering systems like steam jets and turbines, pipelines and valves these cause serious problems. Solid particle erosion is expected to take place when hard particles entrained in gas or liquid medium impinge on the solid surface at a significant velocity. Composites are often used as engineering and structural components where erosive wear takes place. The study of erosion wear characteristics of silk fiber composites is highly essential due to their operational requirements.

3.6 EROSION WEAR TEST APPARATUS

Description of equipments

Major parts of air-jet erosion test rig are:

- Sand hopper.
- Sand flow control knob.
- Sand nozzle height adjustment
- Vibrator pad, pneumatic type
- Conveyor belt system
- Mixing chamber funnel
- Specimen holding heater blocks, specimen shape and indexing unit

- Double disc assembly motor, upper disc units slit, lower disc without slit.
- Dust collecting unit
- Display panel

Fig 4: Air Jet Erosion Test Rig

Table 2: Mass Loss during Erosion wear test for different angles at different pressures.

2 % reinforcement												
Angle	Pressure = 1 bar				Pressure = 2 bar				Pressure = 3 bar			
	Initial weight (g)	Final weight (g)	Difference in weight(g)		Initial weight (g)	Final weight (g)	Difference in weight(g)		Initial weight (g)	Final weight (g)	Difference in weight(g)
90°	3.43	3.41	0.02		2.49	2.47	0.02		2.41	2.39	0.02
	3.41	3.40	0.01		2.47	2.46	0.01		2.39	2.36	0.03
	3.40	3.39	0.01		2.46	2.45	0.01		2.36	2.34	0.02
	3.39	3.39	0.00		2.45	2.45	0.00		2.34	2.31	0.03
	3.39	3.38	0.01		2.45	2.44	0.01		2.31	2.29	0.02
60°	3.81	3.79	0.02		3.90	3.88	0.02		3.03	3.00	0.03
	3.79	3.78	0.01		3.88	3.87	0.01		3.00	2.99	0.01
	3.78	3.77	0.01		3.87	3.86	0.01		2.99	2.96	0.03
	3.77	3.76	0.01		3.86	3.85	0.01		2.96	2.93	0.03
	3.76	3.76	0.00		3.85	3.84	0.01		2.93	2.90	0.03
45°	3.69	3.67	0.02		3.70	3.68	0.02		2.90	2.88	0.02
	3.67	3.66	0.01		3.68	3.67	0.01		2.88	2.84	0.02
	3.66	3.65	0.01		3.67	3.66	0.01		2.84	2.81	0.03
	3.65	3.64	0.01		3.66	3.65	0.01		2.81	2.80	0.01
	3.64	3.63	0.01		3.65	3.64	0.01		2.80	2.78	0.02
4 % reinforcement												
90°	3.82	3.80	0.02		3.43	3.40	0.03		3.38	3.35	0.03
	3.80	3.79	0.01		3.40	3.38	0.02		3.35	3.33	0.02
	3.79	3.78	0.01		3.38	3.37	0.01		3.33	3.31	0.02
	3.78	3.77	0.01		3.37	3.35	0.02		3.31	3.30	0.01
	3.77	3.76	0.01		3.35	3.33	0.02		3.30	3.28	0.02
60°	3.65	3.63	0.02		4.48	4.45	0.03		3.46	3.42	0.04
	3.63	3.62	0.01		4.45	4.42	0.03		3.42	3.39	0.03
	3.62	3.61	0.01		4.42	4.39	0.03		3.39	3.37	0.02
	3.61	3.61	0.00		4.39	4.37	0.02		3.37	3.36	0.01
	3.61	3.60	0.01		4.37	4.34	0.03		3.36	3.33	0.03
45°	2.90	2.88	0.02		3.78	3.76	0.02		3.61	3.55	0.06
	2.88	2.87	0.01		3.76	3.74	0.02		3.55	3.52	0.03
	2.87	2.86	0.01		3.74	3.71	0.03		3.52	3.48	0.04
	2.86	2.85	0.01		3.71	3.69	0.02		3.48	3.45	0.03
	2.85	2.84	0.01		3.69	3.67	0.02		3.45	3.42	0.03
6 % reinforcement												
90°	4.20	4.18	0.02		4.27	4.25	0.02		6.19	6.15	0.04
	4.18	4.16	0.02		4.25	4.24	0.01		6.15	6.12	0.03
	4.16	4.15	0.01		4.24	4.23	0.01		6.12	6.10	0.02
	4.15	4.13	0.02		4.23	4.22	0.01		6.10	6.07	0.03

	4.13	4.11	0.02		4.22	4.21	0.01		6.07	6.04	0.03
60°	4.24	4.23	0.01		3.80	3.78	0.02		6.32	6.29	0.03
	4.23	4.21	0.02		3.78	3.77	0.01		6.29	6.23	0.06
	4.21	4.20	0.01		3.77	3.76	0.01		6.23	6.20	0.03
	4.20	4.19	0.01		3.76	3.76	0.00		6.20	6.17	0.03
	4.19	4.17	0.02		3.76	3.75	0.01		6.17	6.14	0.03
45°	6.46	6.44	0.02		4.50	4.47	0.03		4.01	3.96	0.05
	6.44	6.43	0.01		4.47	4.45	0.02		3.96	3.93	0.03
	6.43	6.42	0.01		4.45	4.44	0.01		3.93	3.90	0.03
	6.42	6.41	0.01		4.44	4.42	0.02		3.90	3.88	0.02
	6.41	6.40	0.01		4.42	4.40	0.02		3.88	3.85	0.03
8 % reinforcement											
90°	6.70	6.69	0.01		5.90	5.88	0.02		6.90	6.88	0.02
	6.69	6.68	0.01		5.88	5.87	0.01		6.88	6.87	0.01
	6.68	6.67	0.01		5.87	5.86	0.01		6.87	6.86	0.01
	6.67	6.67	0.00		5.86	5.84	0.02		6.86	6.84	0.02
	6.67	6.66	0.01		5.84	5.83	0.01		6.84	6.82	0.02
60°	6.14	6.12	0.02		6.69	6.68	0.01		6.28	6.24	0.04
	6.12	6.11	0.01		6.68	6.67	0.01		6.24	6.21	0.03
	6.11	6.10	0.01		6.67	6.66	0.01		6.21	6.19	0.02
	6.10	6.09	0.01		6.66	6.65	0.01		6.19	6.17	0.02
	6.09	6.07	0.02		6.65	6.64	0.01		6.17	6.14	0.03
45°	6.09	6.08	0.01		6.84	6.83	0.01		6.45	6.42	0.03
	6.08	6.07	0.01		6.83	6.80	0.03		6.42	6.39	0.03
	6.07	6.07	0.00		6.80	6.80	0.00		6.39	6.37	0.02
	6.07	6.06	0.01		6.80	6.78	0.02		6.37	6.34	0.03
	6.06	6.05	0.01		6.78	6.76	0.02		6.34	6.30	0.04

CHAPTER 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The following results were obtained from the experiment conducted. The graphs plotted below show the amount of erosion taking place in the silk fiber reinforced composites.

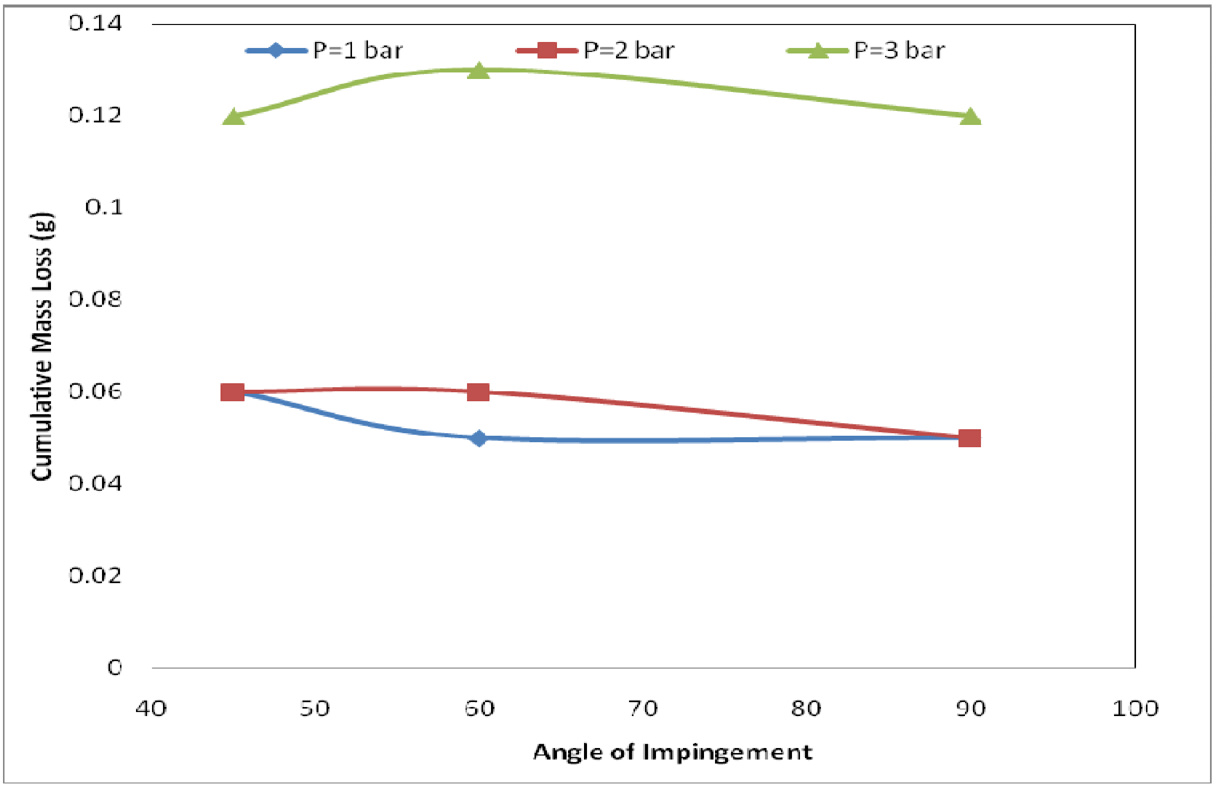

Fig 5: Cumulative Mass Loss (CML) in 2% silk reinforced fiber composite at different impingement angles at different pressures.

The graph above shows the cumulative mass loss of the composite at various impingement angles (45°, 60°, and 90°) during the erosion wear test at various pressures for 2% silk fiber composite. It is clearly observed that at low pressures the amount of material removed is relatively less and as the pressure is increased, the material loss increases. For different impingement angles, the cumulative mass loss decreases on increasing the angles.

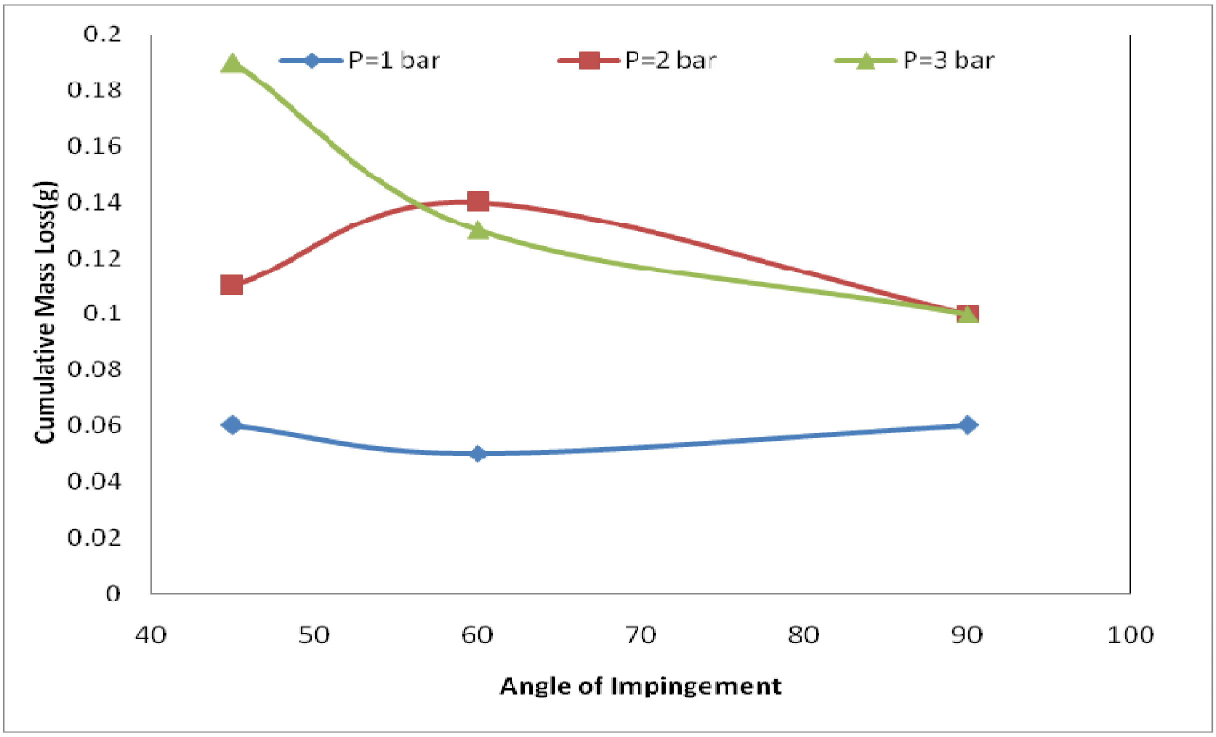

Fig 6: Cumulative Mass Loss (CML) in 4% silk reinforced fiber composite at different impingement angles at different pressures.

The graph above shows the cumulative mass loss of the composite at various impingement angles (45°, 60°, and 90°) during the erosion wear test at various pressures for 4% silk fiber composite. It is clearly observed that at low pressures the amount of material removed is relatively less and as the pressure is increased, the material loss increases. Here at 3 bar pressure, the mass loss remains almost same for all the impingement angles. For different impingement angles, the cumulative mass loss decreases on increasing the angles.

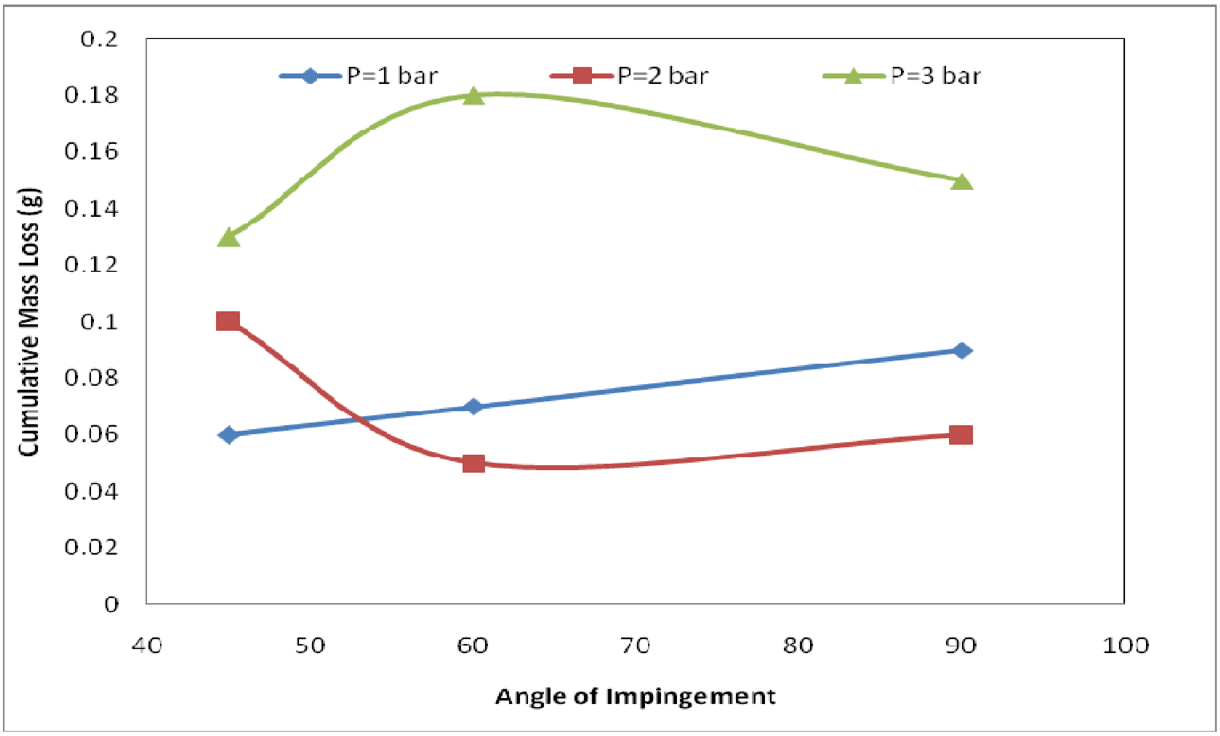

Fig 7: Cumulative Mass Loss (CML) in 6% silk reinforced fiber composite at different impingement angles at different pressures.

The graph above shows the cumulative mass loss of the composite at various impingement angles (45°, 60°, and 90°) during the erosion wear test at various pressures for 6% silk fiber composite. It is clearly observed that at low pressures the amount of material removed is relatively less and as the pressure is increased, the material loss increases. For different impingement angles, the cumulative mass loss decreases on increasing the angles.

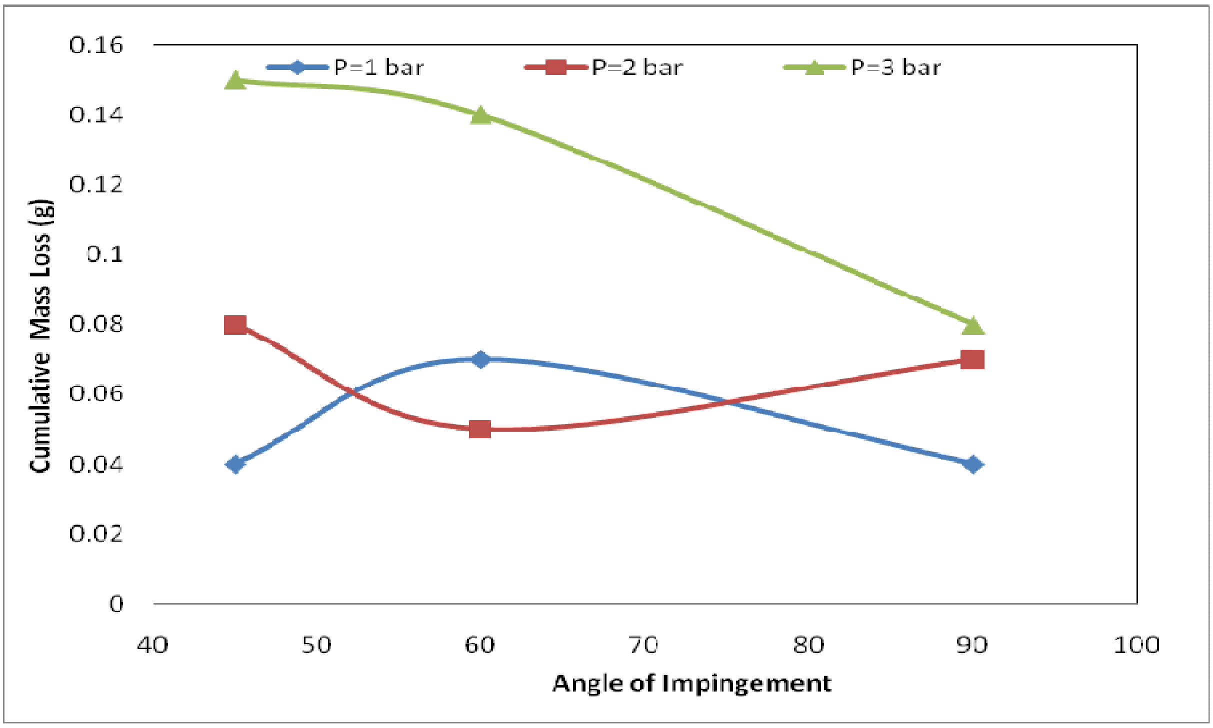

Fig 8: Cumulative Mass Loss (CML) in 8% silk reinforced fiber composite at different impingement angles at different pressures.

The graph above shows the cumulative mass loss of the composite at various impingement angles (45, 60, and 90) during the erosion wear test at various pressures for 8% silk fiber composite. It is clearly observed that at low pressures the amount of material removed is relatively less and as the pressure is increased, the material loss increases. For different impingement angles, the cumulative mass loss decreases on increasing the angles.

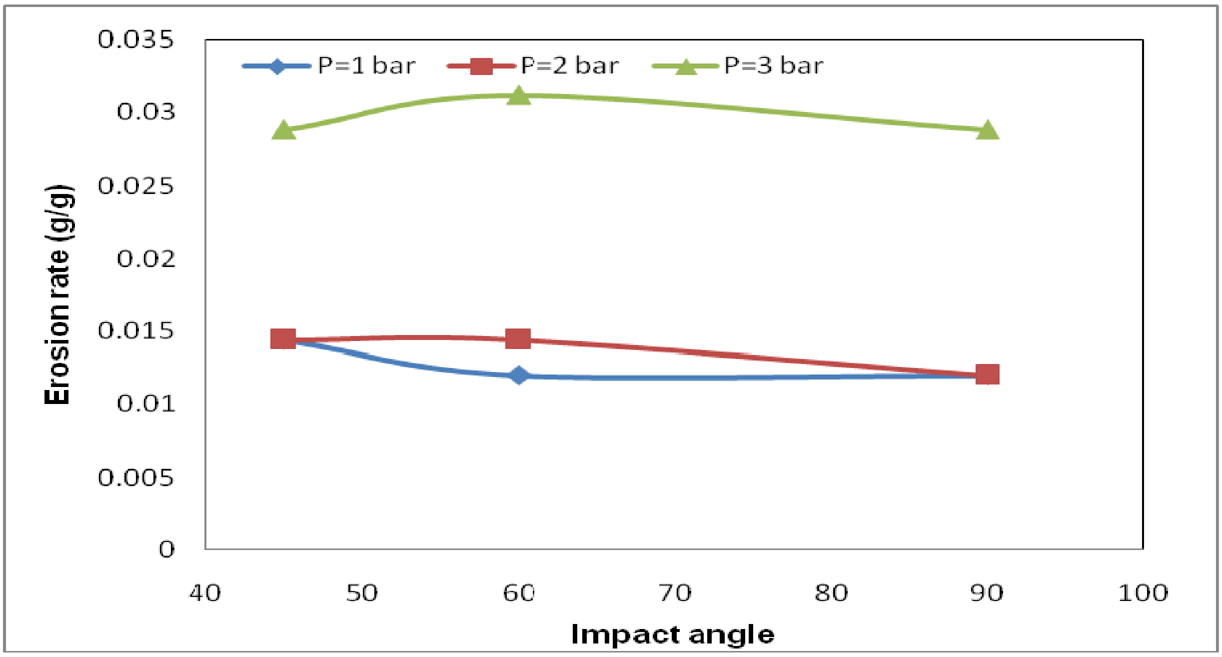

Fig 9: Erosion rate v/s Impact angle for 2% fiber reinforcement composite

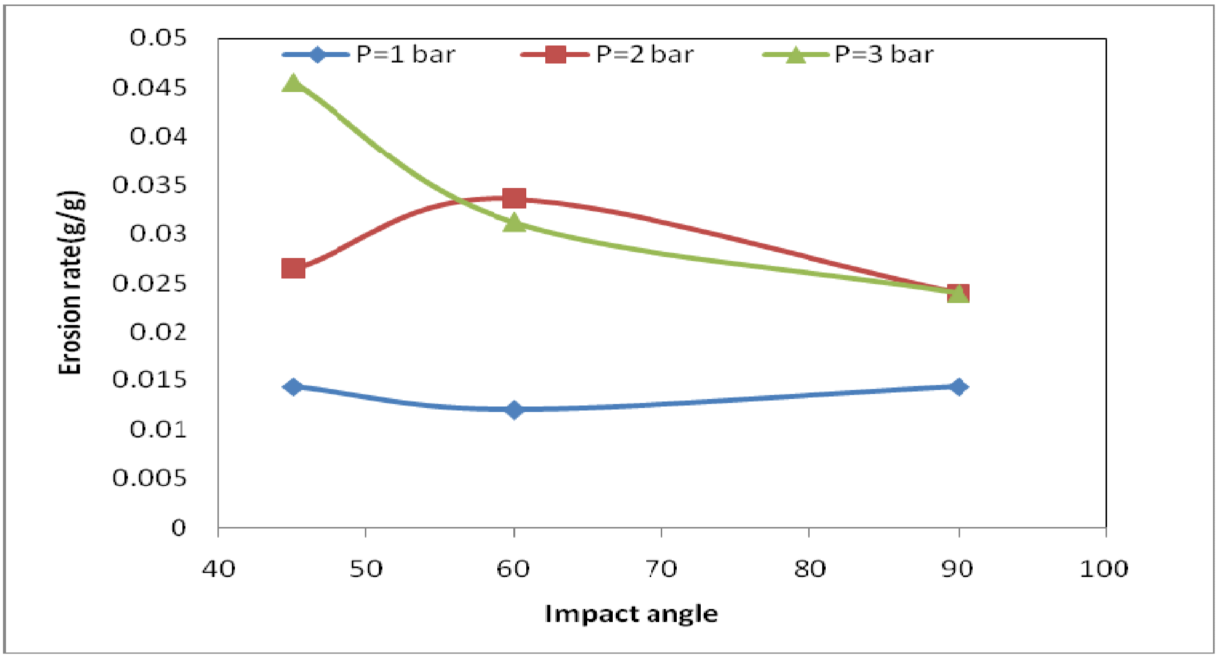

Fig 10: Erosion rate v/s Impact angle for 4% fiber reinforcement composite

.

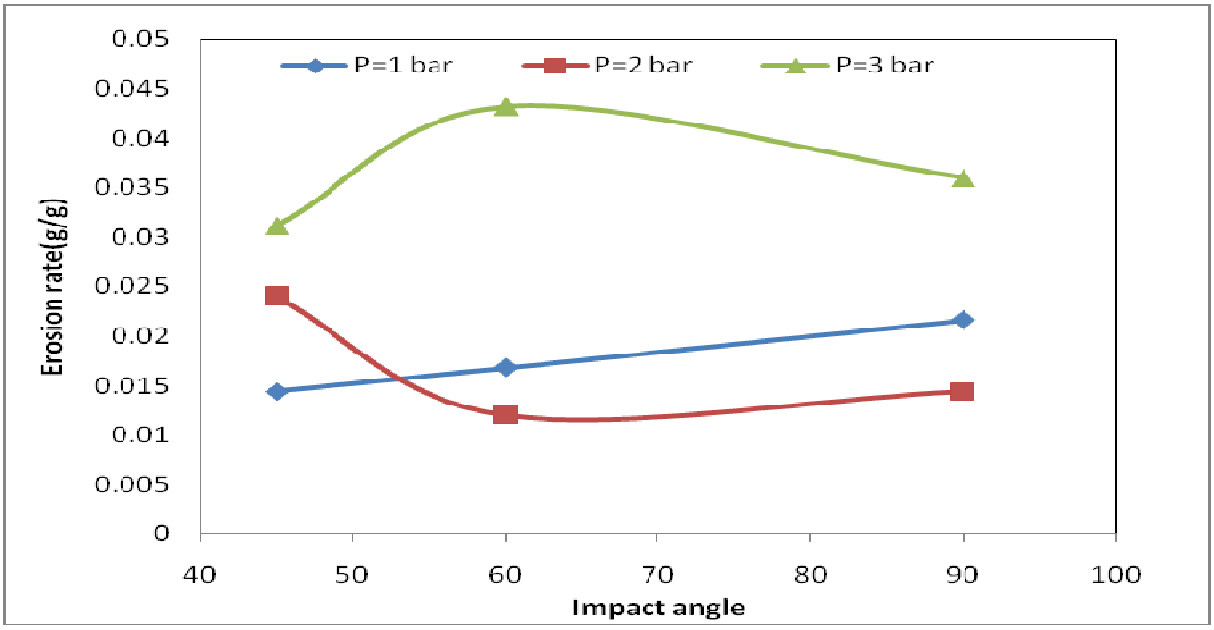

Fig 11: Erosion rate v/s Impact angle for 6% fiber reinforcement composite

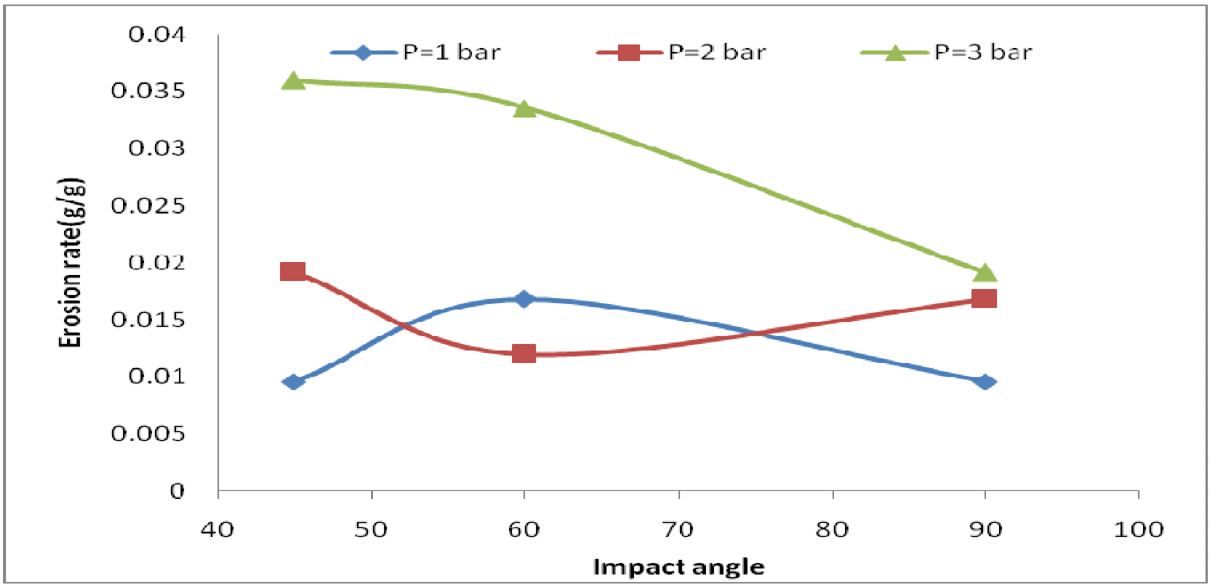

Fig 12: Erosion rate v/s Impact angle for 8% fiber reinforcement composite

The graphs plotted above show the whether the material is brittle or ductile. The peak of the curve decides this property depending on whether the peak lies between 45^0 and 60^0 .

CHAPTER 5
CONCLUSION

CONCLUSION

1. The waste silk fibers obtained from the textiles outlet was successfully used to fabricate composites of different amount of silk content (2%, 4%, 6%, and 8%). These waste fibers are very cheap.
2. The results of erosion wear test indicate that the angle of impingement and the pressure are the two most important parameters during erosion.
3. At higher applied pressures, the erosion rate increases and the cumulative mass loss is higher as compared to lower applied pressures.
4. The silk fibers are highly crystalline and well aligned in structure which leads to higher tensile strength, thereby making silk fibers potential alternatives for glass fibers.

CHAPTER 6

REFERENCES

References

[1]. Javitz, A.E. Design 1965, p-18.

[2]. Kelly, A. (1967) Sci. American 217, (B), 161

[3]. Berghezan, A.Nucleus, 8(5), 1966, (Nucleus A. Editeur, 1, rhe, Chalgrin, Paris, 16(e).

[4] Van Suchetclan, Philips res.repts, 27,1972,28

[5] Sang Muk Lee, Donghwan Cho. Department of Polymer Science and Engineering, Kumoh National Institute of Technology, Korea

[6] Maryam, Che, Ahmad, Abu Bakar, Department of Mechanical and Materials Engineering, Universiti Kebangsaan Malaysia

[7] Annamaria S., Maria R., Tullia M., Silvio S. and Orio C. The microbial degradation of silk: a laboratory investigation. International Biodeterior Biodegrad. 1998; 42: 203-211.

[8] Nomura M., Iwasa Y. and Araya H. Moisture absorbing and desorbing polyurethane foam and its production. Japan Patent 07-292240A, 1995.

[9] Hatakeyama H. Biodegradable sericin-containing polyurethane and its production. Japan Patent 08-012738A, 1996.

[10] Ishikawa H., Nagura M. and Tsuchiya Y. Fine structure and physical properties of blend film compose of silk sericin and poly (vinyl alcohol). Sen'I Gakkaishi. 1987; 43: 283-287.

[11] Park S.J., Lee K.Y., Ha W.S. and Park S.Y. Structural changes and their effect on mechanical properties of silk fibroin/chitosan blends. Journal of Applied Polymer Science. 1999; 74: 2571-2575. [14] Kweon H., Ha H.C., Um I.C. and Park Y.H. Physical properties of silk fibroin/chitosan blend films. Journal of Applied Polymer Science. 2001; 80: 928-934.

[12] Lee S.M., Cho D., Park W.H., Lee S.G., Han S.O. and Drzal L.T. Novel silk/poly (butylenes succinate) biocomposites: the effect of short fiber content on their mechanical and thermal properties. Composites Science and Technology. 2005; 65: 647-657.

[13] S. Padma Priya and S.K.Rai, Department of Polymer Science, University of Mysore: Impact, Compression, Density, Void content, and Weight Reduction Studies on Waste Silk Fabric/Epoxy Composites.

[14] K. Raghu, P. Noorunnisa Khanam and S. Venkata Naidu, Department of Polymer Science and Technology, Srikrishnadevaraya University, Andhra Pradesh, India

[15] Hoi-yan Cheung, Mei-po Ho, Kin-tak Lau, Francisco Cardona, David Hui, Department of Mechanical Engineering, The Hong Kong Polytechnic University: Natural fiber-reinforced composites for bioengineering and environmental engineering applications.