

# **EROSIVE WEAR BEHAVIOUR OF ORANGE PEEL CHAR REINFORCED EPOXY COMPOSITES.**

**A THESIS SUBMITTED IN PARTIAL FULFILMENT  
OF THE REQUIREMENTS FOR THE DEGREE OF**

**Bachelor of Technology  
In**

**Mechanical Engineering**

**By**

**SK NOOR MOHAMMAD NOOR  
(111ME0313)**

Under the Guidance of

**PROF. S. K. ACHARYA**



**Department of Mechanical Engineering**

**National Institute of Technology**

**Rourkela - 769008**

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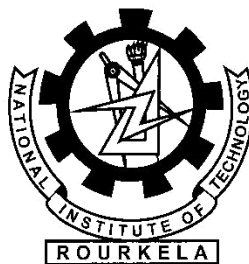
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DEPARTMENT OF MECHANICAL ENGINEERING  
NATIONAL INSTITUTE OF TECHNOLOGY,  
ROUR KELA, ORISSA,  
INDIA-769008

# CERTIFICATE

This is to certify that the thesis entitled, “**EROSIVE WEAR BEHAVIOUR OF ORANGE PEEL CHAR REINFORCED EPOXY COMPOSITES**”, submitted by **Mr. SK NOOR MOHAMMAD NOOR** in partial fulfilment of the requirements for the award of **Bachelor of Technology Degree in Mechanical Engineering** at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other university/Institute for the award of any degree or diploma.

**Place: Rourkela**

**Date:**

**Prof. S. K. ACHARYA**

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**(SK NOOR MOHAMMAD NOOR)**  
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## CONTENTS

<b>Title</b>		<b>Page No.</b>
CERTIFICATE		i
ACKNOWLEDGEMENT		ii
LIST OF FIGURES		v
LIST OF TABLES		vi
ABSTRACT		vii
CHAPTER-1	INTRODUCTION	1
1.1	Background and motivation	1
1.2	Thesis Outline	5
CHAPTER-2	LITERATURE SURVEY	6
2.1	Literature Survey	6
2.2	Related Work	8
2.3	Objectives of the Present Work	9
CHAPTER-3	MECHANICAL CHARACTERIZATION	10
3.1	Materials and Method	10
3.1.1	Materials used	10
3.1.2	Epoxy resin	11
3.1.3	Hardener	11
3.1.4	Preparation of Orange peel char(500 <sup>0</sup> C and 700 <sup>0</sup> C)	11
3.2	preparations of composite	12

CHAPTER-4	STUDY OF EROSION WEAR RATE	13
4.1	Introduction	13
4.2	Definition	13
4.3	Solid particle erosion of polymer composite	14
4.4	Experiment	15
	4.4.1 Preparation of the test specimen	15
	4.4.2 Test apparatus & Experiment	15
4.5	Results & Discussion	18
4.6	Conclusions	25
CHAPTER-5	CONCLUSIONS	26
CHAPTER-6	REFERENCES	27

## LIST OF FIGURES

<b>Figure No.</b>	<b>Title</b>	<b>Page No.</b>
Fig 1.1	Classification of Natural Fibres	3
Fig 2.1	Overview of Natural fibres	7
Fig 3.1	Procedure of making Orange peel powder.	10
Fig 3.2	procedure of making carburized orange peel char.	11
Fig 3.3	Mould used for making the composite.	12
Fig 4.1	Details of erosion test rig.	16
Fig 4.2	Variation of erosion rate with impingement angle of various at 500°C carburized Orange peel char epoxy composite at impact velocity of 70 m/s	24
Fig 4.3	Variation of erosion rate with impingement angle of various at 700°C carburized Orange peel char epoxy composite at impact velocity of 70 m/s	24

## LIST OF TABLES

Table No.	Title	Page No.
Table 4.1	Experimental condition for the erosion test.	17
Table 4.2	Particle velocity under different air pressure.	17
Table 4.3	Weight loss and Erosion rate of 5% carbonized Orange peel char at 500°C epoxy composites with respect to impingement angle due to erosion for a period of 3min	20
Table 4.4	Weight loss and Erosion rate of 10% carbonized Orange peel char at 500°C epoxy composites with respect to impingement angle due to erosion for a period of 3min	20
Table 4.5	Weight loss and Erosion rate of 15% carbonized Orange peel char at 500°C epoxy composites with respect to impingement angle due to erosion for a period of 3min.	21
Table 4.6	Weight loss and Erosion rate of 20% carbonized Orange peel char at 500 <sup>0</sup> C epoxy composites with respect to impingement angle due to erosion for a period of 3min.	21
Table 4.7	Weight loss and Erosion rate of 5% carbonized Orange peel char at 700 <sup>0</sup> C epoxy composites with respect to impingement angle due to erosion for a period of 3min	22
Table 4.8	Weight loss and Erosion rate of 10% carbonized Orange peel char at 700 <sup>0</sup> C epoxy composites with respect to impingement angle due to erosion for a period of 3min	22
Table 4.9	Weight loss and Erosion rate of 15% carbonized Orange peel char at 700 <sup>0</sup> C epoxy composites with respect to impingement angle due to erosion for a period of 3min	23
Table 4.10	Weight loss and Erosion rate of 20% carbonized Orange peel char at 700 <sup>0</sup> C epoxy composites with respect to impingement angle due to erosion for a period of 3min	23



## **ABSTRACT**

The rise of Polymer technology has been indispensable in the last couple of decades. Polymers have proved to be integral part of our everyday life, epoxy or Polyepoxide are some of the examples of polymers used in daily life. But in recent years, the advent of synthetic fillers used in reinforcing epoxy have proved to be the better choice in comparison to Polymer reinforced epoxy. However, over the years the shift has been towards using natural fillers and fibre materials as alternative to synthetic materials. Natural fibres due to their easy availability, abundance, renewability and cost effectiveness are gradually turning out to be an area of supreme interest.

In recent years composites obtained by using carbon blacks as fillers reinforcing epoxy has surfaced and is gaining recognition. These fillers are added to achieve various desirable properties. Commercially carbon blacks are manufactured by thermal cracking of natural gas and by incomplete combustion of hydrocarbons. But due to the scarcity of these resources, alternative sources like agricultural waste, bamboo stem, fruit's shell rich, rich in carbonaceous content are gaining importance. This biomass can be converted to carbon black thereby reusing it and making it more valuable

A few scientific research have been done to study the behaviour of natural fibre reinforced composites with respect to the mechanical behaviour of epoxy composites, emphasizing mainly on fibres and their weight percent's inside the composites.

Keeping this in mind, the present study has been done to make composites using orange peel char at 500°C and 700°C and study its erosive wear behaviour. The orange peel carbon black has been prepared by carbonising raw orange peel particulate in two different temperature 500°C and 700°C in furnace. The composites are prepared with different weight fraction of orange peel char.

# Chapter1

## INTRODUCTION

# CHAPTER 1

## INTRODUCTION

### 1.1 Background and Motivation

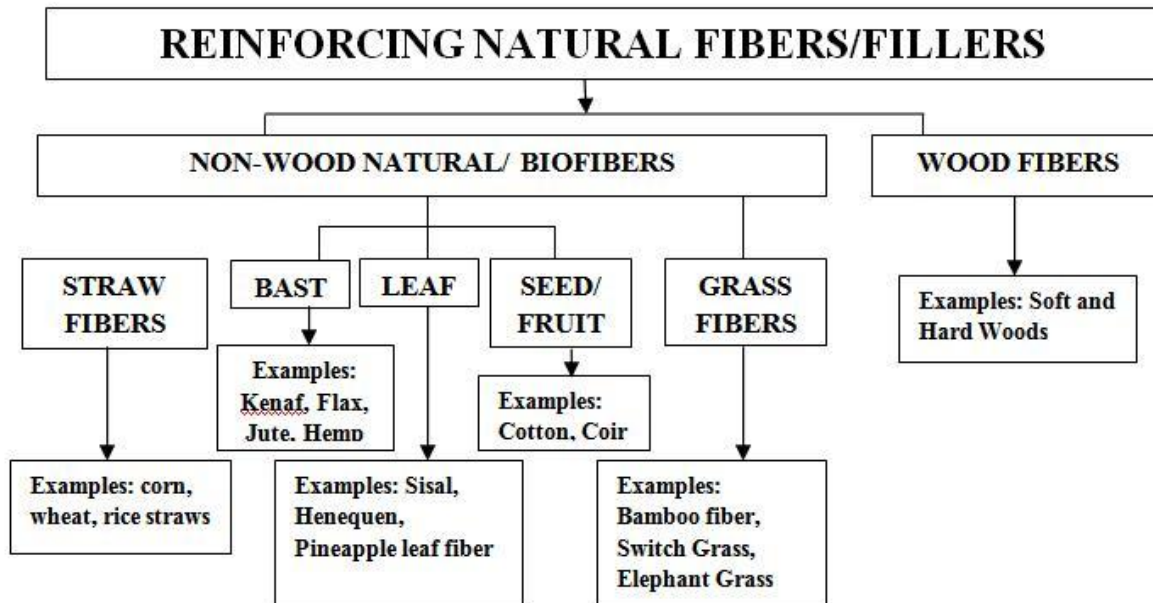
Due to the dwindling exhaustible resources like natural gas, crude oil, and due to environmental consciousness, there has been a lot of development made or tried in renewable sources. This has led to the worldwide researchers to investigate the properties and applications of fibre reinforced composites. The fact that natural fibres are easily available and abundantly present on earth works to its advantage. This has enticed the analysts to give more emphasis to study fibre reinforced composites and to what degree they can fulfil the diverse needs of the populations. This field shows a lot of promise in the future. Natural fibre provides a decent renewable and biodegradable alternative.

When two or more material with diverse properties is joined together they frame a composite material. The constituents are joined in such a way, that they keep their individual physical phases and are non-soluble in one another or don't frame another chemical compound. That is the reason a composite is thought to be any multi-stage material framework that displays a blend of properties that makes the composite better than each of the constituent stages. This rule has given the fundamental inspiration to the innovative work of composite material around the world. There are fundamentally two class of constituent material, one constituent is called reinforcing stage and one in which the reinforcing phase is inserted is called matrix. The essential capacity of lattice is to hold the fibre to shape a certain shape. The capacity of strengthening stage in framework is to enhance the mechanical properties, for example, strength, stiffness and so on. According to Berghezan the composite material is to be designed in such a fashion, to the point that the components retain their characteristic are incorporated to the point that the composite exploit their unrivalled properties without bargaining on the shortcoming of either. There are essentially three sorts of composite materials according to the matrix material incorporated in the grid. They can be metallic, polymeric or can even be ceramic. When the lattice is made of polymer, the composite is called polymer matrix composite. Fibber reinforced polymer (FRP) composite are the most widely recognized propelled composites. These composites comprise of a polymer lattice strengthened with meagre breadth filaments. The reasons why they are the most well-known composite incorporate minimal effort, high quality, and basic assembling

methodologies, basic manufacturing techniques. There are polymer resin system utilized as frameworks as a part of FRP composites. They can be delegated thermos plastic (polyethylene, polypropylene, nylon and so forth.) and thermoset (epoxies, polyesters, vinyl ester and so on.) polymer. Thermoplastic polymer can be over and again mollified and framed by expanding the temperature or solidified by diminishing the temperature, while the thermoset polymers are insoluble and infusible after cure.

Superior manufactured filler materials, for example, thermoplastic polymers have been utilized in the course of the most recent couple of decades to be used as fillers in composites as they have shown better thermal properties and rigidity. The most recent couple of years have seen resurgence in exploration endeavours towards discovering environment neighbourly arrangements, solutions that would prompt generation of more natural filler materials. Natural filler materials can serve as successful different options for manufactured filler materials for purposes of support of polymeric composites. Natural filler materials exhibit a few preferences. They are biodegradable. They are not toxic as they are organic. They can be used to get excellent strength and rigidity in comparison to the synthetic composites. They are a plenteous asset, exceptionally accessible, renewable, and can prompt financially savvy generation. A percentage of the hindrances of characteristic filler materials are dampness affectability, and in this way decreased adequacy with hydrophobic polymers, natural rot, non-uniformity in filler shapes and sizes, powerlessness to indigenous habitat assaults, and absence of vigour under higher temperatures. Then again, regular filler materials can be post transformed to decrease some of these inconveniences, to be specific, corruption under dampness and other environment impacts.

Composite materials are broadly utilized as a part of automobile engineering, constructions and bundling application because of their low density, superb stiffness, and great thermal and mechanical properties. Late improvements on different uses of polymer composites are very much recorded in numerous written works, however the basic and connected investigations of these materials are still of unmistakable fascination to numerous analysts. Writing study uncovers different endeavours made to create epoxy composites changed with different fillers, (for example, silica, carbon, carbon dark,  $Al_2O_3$ ,  $CaSiO_3$ , and so on.) so as to enhance the execution of this matrix. Particulate fillers of which carbon dark is remarkable sample are generally utilized as fortifying fillers as a part of polymer industry. These fillers are used in polymers to achieve desirable properties and improve the item benefits. Industrially accessible carbon blacks are acquired from natural gas thermal cracking and



furnace black manufactured by inadequate combustion of hydrocarbon oil. This carbon dark is moderately costly because of its reliance on diminishing supply of raw petroleum. It is in this manner vital to create suitable option wellspring of fillers from renewable assets, for example, agrarian waste, bamboo stem, and oil palm vacant natural product clusters and Orange peel which are carbonaceous in nature and rich in natural materials. This biomass can be changed over into carbon dark consequently decreasing undesirable, low esteem rural diminishes and underutilized product into helpful, high esteem materials. Carbon black and initiated carbon can be gotten from any carbonaceous materials. Biomass waste, for example, bamboo, orange peel Orange peel, cherry stones, sugarcane bagasse, oil palm waste and rice husk are a portion of the crude materials known to have favourable circumstances to supplant the business man-made carbon.

The regular fibre composites can be extremely cost effective material for following applications:

- Building and development of industry, factories: boards for segment and false roof, divider, floor, window and floor edges, rooftop tiles, portable pre-assembled structures which can be utilized as a part of times of common cataclysms, for example, surges, twister, quakes and so on.
- Storage gadgets: post boxes, grain stockpiling storehouses, bio gas holders and so forth.
- Furniture: seat, table, shower, shower units and so on.
- Electric gadgets: electrical machines, channels and so forth.

- Everyday applications: lampshades, bags, caps and so on.
- Transportation: car and rail route mentor inside, pontoon and so on.
- Toys

The explanation behind the use of regular fibre composites in the car business incorporates:

- Low thickness: This may prompt a weight decrease of 10 to 30%
- Acceptable mechanical properties, great acoustic properties.
- Favourable handling properties, for occasion low wear on devices, and so on.
- Options for new generation advances and materials.
- Favourable mishap execution, high soundness, less chipping.
- Favourable eco offset for part generation.
- Favourable eco offset amid vehicle operation because of weight investment funds.
- Occupational medical advantages contrasted with glass filaments amid generation.
- No off-gassing of poisonous mixes (rather than phenol resin reinforced wood and reused cotton fibre parts.)
- Minimizing fogging behaviour
- Price advantage both for the fibres and the applied technologies.

Composite materials because of their low density, astounding stiffness and great thermal and mechanical properties are especially better than numerous conventional materials, for example, metals. Late improvements on different utilizations of polymer composite are very much archived in numerous written works. Distinctive sorts of polymer show diverse Mechanical and tribological behaviour. However neat polymers is once in a while utilized as bearing materials and wear resistance material on the grounds that unmodified polymer couldn't fulfil the requests emerging from the circumstances wherein a mix of good mechanical and tribological properties is obliged [3]. Imagining the significance of polymer composite reinforced with cellulosic fibre like sisal, Orange peel (coir), bamboo, banana in their characteristic shape and a few waste cellulosic items. For example, shell flour, wood flour and mash have been utilized as reinforcing agents of distinctive thermosetting and thermoplastic composites.

Oxy composite loaded with the bio-based fillers like bamboo stems, Orange peel and oil palm fibre groups. Their outcomes demonstrated that there was improvement in thermal stability of the carbon dark filled composite compared with the perfect epoxy. Christian

J.Espionze Santos [5] performed points of interest characteristics based on Orange peel fibers. He watched that increment in weight percent of fibre reinforcement expand the flexural quality of the composite. Keeping all these in perspective in the present work an endeavour has been made to study the mechanical and flexural conduct of orange peel fortified epoxy composite

## **1.2 Thesis Outline**

The rest of this thesis is organized as follows:

Part 2: Previous work pertinent to the present examinations accessible in literary works is depicted in this section

Part 3: This section depicts the subtle elements of materials obliged, fabrication strategies and the outcomes from the tests for erosive wear conduct of the crude Orange peel powder strengthened epoxy composite has been accounted for.

Part 4: In this section the Orange peel char delivered by physical initiation system has been utilized as reinforcement filler to create composite material. The change in the mechanical and rough wear conduct of the composite by the incorporation of char in place of raw Orange peel powder has been reported.

Part 5: Conclusions from the above work and suggestions for future work are displayed in this part

# Chapter 2

## LITERATURE SURVEY



## CHAPTER 2

### Literature survey

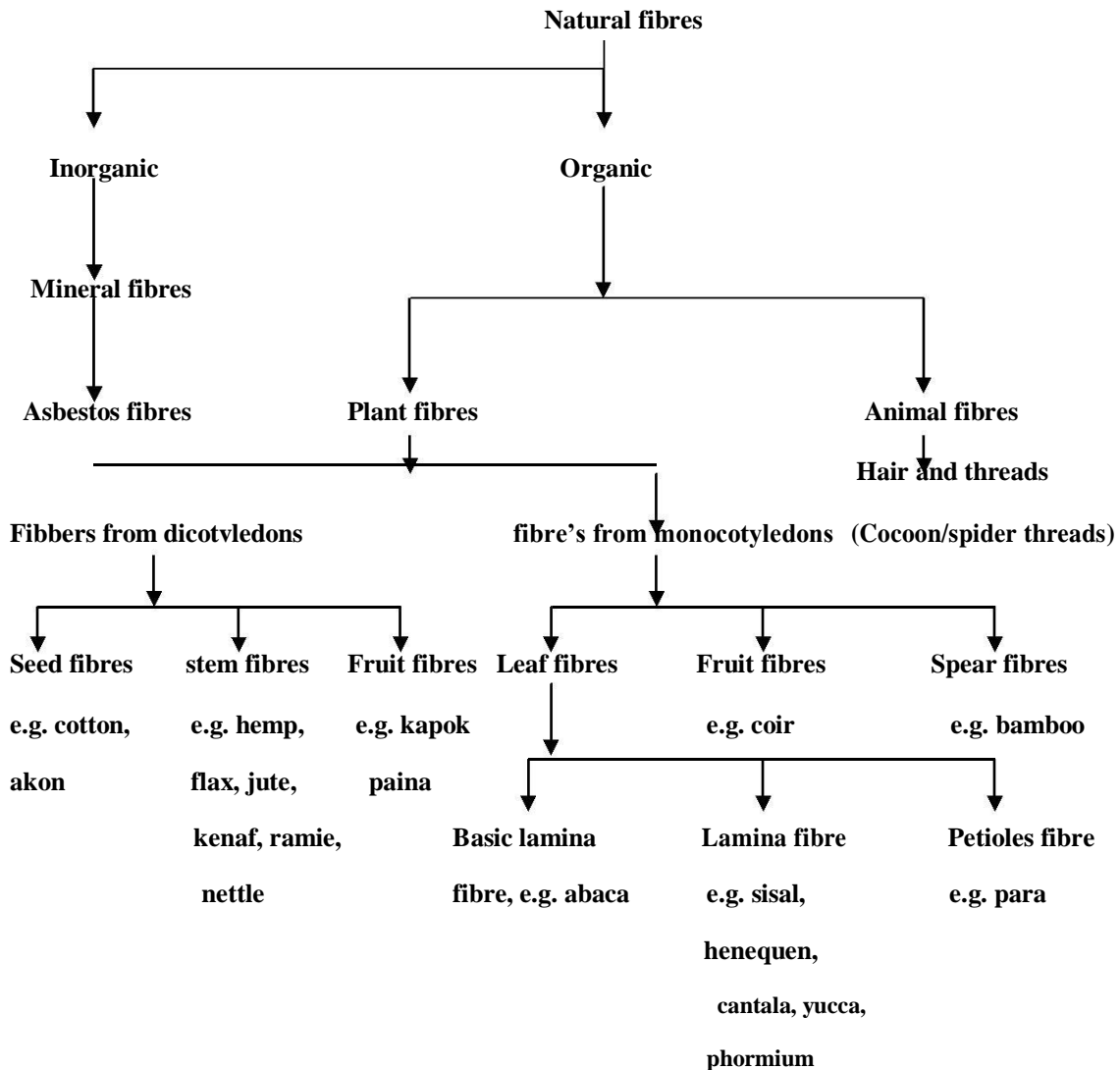
#### 2.1 Literature survey

Literature survey is done to get the foundation data on the issues to be considered in the present examination work and to centre the significance of the present study. The design is likewise to present an exhaustive comprehension of different parts of bio polymer composite with exceptional accentuation on their mechanical properties. In reinforced strengthened polymer composites, the fibre can be either synthetic fibres or natural fibres. Natural fibres constituents are primarily of cellulose fibres, comprising of helically wound cellulose small scale fibrils, bound together by a formless lignin matrix. Lignin keeps the water in fibres; goes about as an assurance against biological attack and as a stiffener to give stem its resistance against gravity powers and wind. Hemicellulose found in the characteristic filaments is accepted to be a compatibilizer in the middle of cellulose and lignin [1]. The utilization of lignocellulose fibres as reinforcement for polymeric materials has been developing amid the most recent decade or thereabouts to supplant engineered filaments, particularly glass filaments in composites, for distinctive modern areas, for example, bundling, autos and even in the building division. This is principally because of their special attributes, for example, accessibility, biodegradability, and low thickness, non-dangerous nature, less abrasiveness to plastic handling hardware, valuable mechanical properties and minimal effort [2]. The substance arrangement of common fibres may contrast with the developing condition and test techniques notwithstanding for the same sort of fibre. The physical mechanical properties of natural fibres are incredibly affected by their chemical compositions.

Natural fibres generally can be characterized taking into account their beginning, and the plant-based fibres can be further arranged in light of a piece of the plant they are recouped from. An outline of common fibres is shown in figure 2.1.

Epoxy resins (ER) are a standout amongst the most imperative classes of thermosetting polymers which are generally utilized as matrix for fibre-reinforced composite materials and as structural adhesives. They are amorphous, exceedingly cross-connected polymers and this structure brings about these materials having different alluring properties, for example, high rigidity and modulus, uncomplicated transforming, good thermal and chemical resistance, and dimensional strength [3]. In any case, it likewise prompts low toughness and poor crack

resistance, which ought to be updated before they can be considered for some end-use applications. A standout amongst the best systems for enhancing the durability of epoxy pitch is to consolidate a second period of scattered rubbery particles into the cross-connected polymer.



**Figure 2.1** Overview of Natural fibres

## 2.2 Related Work

Items produced from carbon are essential in our ordinary life. The creation of carbon black request high cost courses of action and energy utilization. Hence, an alternative option for growing new elementary materials for carbon material is required keeping in mind the end goal to lessen the expense and satisfy each need of the carbon black consumer. Numerous

scientists have assessed the by-products of rural waste in another path for the following carbon black era.

Carbon black is industrially utilized as filler and has its own evaluations and qualities. The properties of carbon utilized as a part of the composites principally rely on upon the source, preparing conditions and chemical treatments. The molecule size, surface action, level of interactions with polymer, substance piece, and level of abnormality of filler shape was the variables influencing the conduct of the composites.

In India there are numerous potential natural resources, Most of it originates from the woods and farming. Among every single regular fibre, Orange peel shell particles have high quality and modulus properties alongside the included focal point of high lignin content [4]. The high lignin substance makes the fibre suitable for assembling composites. Orange peel flour is additionally widely used to make items like outfitting materials, rope and so on. The shells likewise ingest less dampness because of its low cellulose content. R.D.T. Filo et al. [5] while contemplating on the adequacy of Orange peel particles as a wellspring of characteristic material for fortifying epoxy gums towards their flexural properties.

Jain, S et al. (6) in their work have picked bamboo (a biomass waste) as the crude material for arrangement of carbon black and initiated carbon and utilized the same as a filler material in polyester composites. Their outcomes indicate great mechanical properties, high stiffness and high porosity of the came about composite.

In another paper Abdul Khalil et al. (7) created a composite from carbon black and enacted carbon from bamboo with polyester as grid material. Their outcome shows a poor strength in tensile and flexural quality while the elastic and flexural module demonstrates an opposite phenomenon.

## **2.3 Objectives of the Present Work**

The objectives of the present work are:

- To prepare the orange peel particulates of desired particle size.
- To carbonize the orange peel particulate at two temperature (500°c, 700 °c).
- To calculate the density of orange peel char (500°c, 700 °c) using pycnometer.
- To fabricate the particulate with different weight percentage in the epoxy matrix.
- To perform the erosive wear rate tests on the composite samples

# Chapter 3

## MECHANICAL CHARACTERIZATION

## CHAPTER 3

### Materials and Method

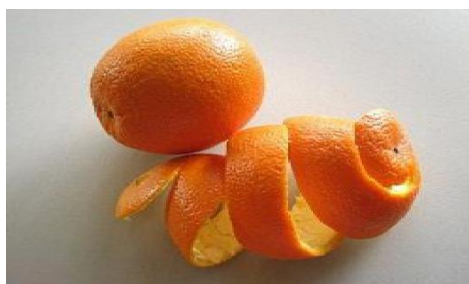
#### 3.1 Materials and Method

Raw materials used in this experimental work are listed below

1. Natural fibre (Orange peel)
2. Epoxy Resin
3. Hardener

##### 3.1.1 Orange peel:

Orange is a citrus natural product mostly started in Southeast Asia. It is the most ordinarily developed tree natural product on the planet. Like all citrus natural products, the orange is acidic having pH range 2.9-4.0.



(a) Orange peels



(b) Sun dried orange peels

(c) Powdered orange peels

**Figure 3.1** Different phases of orange peel

Orange peel, the external cover piece of an orange, principally comprises of cellulose, fundamental oils, proteins and some basic carbs.

The orange peels were gathered locally from local markets and were kept in sun to dry for 5 days. Sun drying was imperative to eliminate any moisture content from the peels. Before sun drying the peels are washed in distilled water to remove any impurities. The fibres were then

grinded into fine powder by a grinding machine or manually as shown.

### 3.1.2 Epoxy Resin

Epoxy sap Araldite LY 556 an unmodified epoxy resin taking into account Biphenyl-A supplied by (CIBA GUGYE restricted) having the accompanying exceptional properties has been utilized as the matrix material.

- Excellent grip to distinctive materials.
- Highly impervious to chemical and atmospheric corrosion.
- High dimensional stability.
- Free from inside stress.
- Excellent mechanical and electrical properties.
- Odourless, tasteless and totally nontoxic.
- Negligible shrinkage.

### 3.1.3 Hardener

Hardener HY951, aliphatic Primary amines which has a consistency of 10-20 MPa at 250 c is utilized alongside the matrix material.

### 3.1.4 Preparation of Orange peel char (500° and 700°C)

The carburisation temperature chose was 500°C and 700°C. The obliged amounts of Orange peel powder were taken in cauldrons and were set in the heater. It took around three to four hours to achieve the obliged temperature. The rate of augmentation of temperature is situated at around 5°C every minute. When this temperature is reached, one hour soaking time was permitted. After 24 hours cooling was permitted so that the furnace comes to room temperature. At that point the charred Orange peel powders were taken out from the heater for further utilization. Figure demonstrates the method of making Orange peel char.



**Figure.3.2 procedure of making carburized Orange peel char**

### 3.2 PREPARATION OF COMPOSITES:

A wooden mold of 140x60x5 mm Figure-3.3(a) was employed for casting the composite sheet. For quick and convenient detachment of the composite sheet from the surface a mold release sheet was kept over the glass plate. Mold release spray was also used and directed at the inner surface of the mold wall after it was fixed on the glass plate. Different weight percent of Orange peel char (ie.5, 10, 20 and 30 wt. %), were mixed with the matrix material consisting of epoxy resin and hardener in the ratio of 10:1 by weight. Pouring has to be done meticulously and with utmost care to avoid the formation of air bubbles, as it decreases the stiffness and rigidity of the composites. Slight stirring is done to ensure uniform thickness. A transparent per-pex sheet is put on the top carefully to minimize any air bubbles formation. Weights are kept on top of the arrangement to apply pressure, it increases the stiffness and rigidity of the composites. Then the arrangement is kept undisturbed for 72 hours to solidify. During the application of pressure some polymer squeezes out from the mould. For this, care has already been taken during pouring. While applying pressure some amount of mixture squeezes out. Care has to be taken to annul this affect by taking extra material. After it has solidified the samples are taken out of the mold by certain process, after removing the laminate, the composite was cut into desired size required for erosive wear rate test. In this situation it is 30x30x3 cm. The density of epoxy resin, Orange peel fibre char is found by using pycnometer respectively.



**Figure 3.3** Mould used for making the composite



# Chapter 4

## STUDY OF EROSIVE WEAR RATE

## **CHAPTER 4**

### **STUDY OF EROSIVE WEAR RATE**

#### **4.1 INTRODUCTION**

Since many years solid particle erosion has been deemed as problematic because it leads to many engineering applications, components failure which is seriously undesirable and is a wastage of money and resources. Solid particle erosion has a massive role to play in machinery parts thinning, roughening of components surfaces, degrading it, and scooping appearance in macroscopic level all the while diminishing the effective longevity of the components. Since the advent of the 20<sup>th</sup> century many research and attempts were made to understand and grasp the basic mechanism of erosion and these research have continued till the present. Finnie, a research scholar published an article citing the past and future of erosion technologies in the year 1995. Finnie reviewed the variables that affects erosion rate and Finnie also gave emphasis to dominating mechanism in erosion process of metals and certain materials made of ceramic minerals. Meng et al, another research scholar, also published an article whose sole purpose was to shed some lights on existing models, prototypes of wear, erosion and predictions equations.

#### **4.2 DEFINITION:**

When a congregation of particulates entrained in fluid system impinges on the surface of the material impacting at a very high speed and pressure, material damage occurs leading to loss of materials, this process is called erosion according to Bitter. According to Hutchings's erosion process is an abrasive wear process which incorporates collection of small minute particles moving in a fluidic environment when impacts on the material surfaces, it leads to the removal of material from the surface. Different people have proposed different definitions of erosion over the years. But it is both constructive and destructive process. Due to the impingement of solid particles it leads to material; removal which is sometimes desired as in case of machining and sometimes nuisance as in case of corrosion in fast moving components. So depending on the application and the situation erosion is maximized or minimized. Sand-blasting, high speed water jet cutting, blast stripping of paints from automobiles, adhesive flash removal from bonded parts, hard materials drilling through erosion. Erosion is undesirable in industrial application of machine components, turbine

blades surface degradations, pipelines erosion carrying slurries and erosion in combustion system in fluidized bed. Generally in erosive process large number of regular or irregular particles usually carries in a fluidized system are made to impinge on the material surface.

### **4.3 SOLID PARTICLE EROSION OF POLYMER COMPOSITES**

The subject of polymer composite erosion wear has always been of paramount importance in the past years. This area has received the undivided attention of mankind to cope up with the ever booming application of polymer composite in aerospace field, transportation industries and processing factories. In these areas the machine is subjected to impingement of solid or liquid particulate. Some of the basic examples of the applications are in petroleum refineries in pipelines carryings and slurries, rotor blades in helicopter, fast automobiles and aircrafts operating in arid areas where there is a high chance of the components encountering heavy impaction of the particles like dust, splinters of materials, slurry material particles and as a result the material undergoes erosion.

Variety of composites like nylon, polypropylene, epoxy, bismilemide etc. and their various applications are evaluated by many researchers and put to solid erosion test to gain some insight into their working. Work done by some of the researchers has been integrated by Harsha et al. on erosion of solid particle. Roy et al. while researching on this subject revealed that in comparison to metals composite materials have rather a poor resistance to erosion.

The parameters that affects rate of erosive wear of the composite materials can be categorized into broadly four categories:

1. Properties of the material that undergoes erosion (properties of the matrix material reinforcement, amount and orientation, properties of interface between the matrix and reinforcement material).

2. Condition of the testing and environmental surrounding (temperature, chemical reactivity erosive particles with the work piece).

3. Parameters of operations (impingement angle, impingement velocity, air pressure).

4. Properties of the abrasive particles (abrasive size, abrasive shape, hardness etc.)

Therefore it is evident the rate of erosive wear rate of the subject material can be calculated

by taking into account the combination of the above parameters. When the rate of erosion is computed on the basis of impingement angle, the erosive behaviour of materials can be subdivided into two categories: ductile and brittle. In case of ductile materials the maximum erosion rate occurs at an angle in the range  $15^{\circ}$ - $30^{\circ}$ . But if the maximum erosion rate occurs at  $90^{\circ}$  then subject material has brittle properties. Composites reinforced with polymer have been found to exhibit intermediary properties between ductile and semi ductile. In this type of subject materials the maximum erosion rate occurs at an angle in the range  $45^{\circ}$ - $60^{\circ}$ . Be that as it may, as the erosive wear behaviour of material has strong reliance on parameters of erosion this classification is not absolute.

To evaluate the true importance and utility of polymer reinforced composites a lot of advanced research has to be done in this field. Many researchers have dabbled with a wide range of thermosets and thermoplastic PMCs composed of glass, graphite and Kevlar's fibres as reinforcement. Very limited amount of information is available on erosive wear behaviour of carbonised orange peel. So in this work, an effort has been made to shed some light into this topic, to give information about the erosive wear behaviour of orange peel carbon black.

## **4.4 EXPERIMENT:**

### **4.4.1 Preparation of the test specimens:**

Test samples needed for this experiment has to be of certain dimension. The procedure for the preparation of the samples has been discussed in chapter 3. Test samples of particular dimension  $25 \times 25 \times 3$  is required, cut from the composite slab by hack saw. Adequate care has to be taken to maintain constant thickness.

### **4.4.2 Test apparatus & Experiment:**

The test apparatus employed for the erosion test is shown in the figure-4.1. ASTM-G76 is the standard according to which the erosion test apparatus is designed. It is designed and manufactured by the Magnum engineers, Bangalore. The equipment is user-friendly, offers one-piece control panel and aesthetically well designed. It can be employed for testing polymers, coatings, steels and organic materials. The assembly consist of compressor, a particle feeder, mixer, sand hopper, nozzle, and indexing system. A compressor provides compressed air at a certain pressure to the system, and this compressed air is mixed with the

erodent particles of certain shape and size, which is fed by the conveyor belt at a constant rate and then sped up by the nozzle arrangement. The nozzle is made up of Tungsten Carbide of 4mm diameter. These particles or erodent which is accelerated, when impinges on the specimen, kept fixed in a constant position by the indexing system. The specimen can be held at various angles by the adjustable sample holder. The velocity of the erodent particles is measured by double disc arrangement provided. The erodent particles velocity of impact is measured using the double disc method developed by Ives and Ruff. Experimental condition for the erosion test is shown in Table 4.1. The velocities obtained from this method for various pressures are given in Table-4.1.



**Figure-4.1** Details of erosion test rig. (1) Sand hopper, (2) Conveyor belt system for sand flow, (3) Pressure transducer, (4) Particle-air mixing chamber, (5) Nozzle, (6) X- Y and h axes assembly, (7) Sample holder

**Table-4.1 Experimental conditions for solid erosion test**

<b>Test parameters</b>	
Erodent:	Silica sand
Erodent size ( $\mu$ m):	200 $\pm$ 50
Erodent shape:	Angular
Hardness of silica particles (HV):	1420 $\pm$ 50
Impingement angle ( $\alpha^0$ ):	30, 45, 60 and 90
Impact velocity (m/s):	70
Erodent feed rate (gm/min):	2.567 $\pm$ 0.05
Test temperature:	(27 <sup>0</sup> C)
Nozzle to sample distance (mm):	10

Depending on the air pressure supplied by the compressor the particle velocity differs. More the compressed air pressure, more is the particle velocity. The erodent particles velocity for different pressure is shown in table 4.2.

**Table-4.2 Particle velocity under different air pressure**

<b>Sl. No.</b>	<b>Air Pressure (Bar)</b>	<b>Particle velocity (m/s)</b>
1	1	48
2	2	70
3	3	82

A particular method is executed each time the erosion test is done. Major parts of the solid erosion test rig are as follows:

1. Sand hopper.
2. Sand-nozzle-height adjustment.
3. Vibrator pad-Pneumatic type.
4. Conveyor belt.
5. Mixing chamber.

6. Specimen holding and indexing system.
7. Dust collecting unit.
8. Display system.
9. Double disc arrangement.

Procedure for the solid erosion test rig is as follows:

1. Clean the test rig and check all the valves, switches, knobs are in closed position.
2. Connect the test rig to 230V supply and start the compressor.
3. Switch on the mains.
4. Before placing the specimen clean it with acetone and weigh it. Place the specimen on the heater block and set it to the desired angle.
5. Set the timer for the desired period.
6. Set the conveyor motor of the desired speed.
7. Adjust the sand nozzle for the required by adjusting the nut.
8. Close all the doors and press the start button.
9. Once test is completed the specimen is removed and cleaned and weighed.
10. Difference in weight is noted ( $\Delta w$ ).
11. The erosion rate is calculated by using the following equation:

$$E_r = \frac{W_s}{W_e} \quad (1)$$

$\Delta w$  – mass loss of samples (Initial weight-final weight)

$W_e$  – Mass of the abrasive particles (erodent's).

$W_e = \text{Testing time} \times \text{Particle feed rate}$

#### 4.5 RESULT AND DISCUSSION:

Graphs were plotted based on the calculated results and shown in table 4.3 to 4.10 and in figure 4.2 and 4.3 for different test parameters and reinforcement percentage. In figure 4.2, the wear rate behaviour of Orange peel carbon black at a carbonisation temperature of 500°C reinforced epoxy composites is shown at a pressure of 2 bar and at an impact velocity of 70 m/s, keeping all other parameters such as stand-off distance at a constant value of 1cm, particle feed rate at 2.5 gm/minute, testing time at 3 minutes. From the plotted figure 4.2 it is clearly conclusive that the maximum erosion wear rate occurs at an angle of impingement of 45°, which depicts its semi-ductile nature. In general, all polymer composites reinforced with

filler show this trend. Moreover, the composites with fibre reinforcement maintain this semi-ductile nature more or less. But this behaviour is slightly different for carbon black reinforced composites. Due to the presence of substantial amount of carbon, the properties of carbon black reinforced composites are slightly different from the fibre reinforced composites. With increasing carbonisation temperature of the Orange peel particulates, the carbon content increases, as carbon is a natural hardener, it leads to a brittle composite. In a nutshell, increasing carbon content leads to a more brittle nature of the composites, which only happens if we increase the carbonisation temperature.

In figure 4.3, the erosion wear rate of Orange peel carbon black at a carbonisation temperature of 700°C reinforced epoxy composites is shown at a pressure of 2 bar and at an impact velocity of 70 m/s. The stand-off distance remains at a constant value of 1cm, particle feed rate at 2.5 gm/minute, testing time at 3 minutes. From the shown figure 4.3, it is clearly evident that the maximum erosion wear rate occurs at an angle of impingement occurs at 60°, which shows a transition from semi-ductile to semi-brittle nature. As mentioned above, this transition occurs because of the increase of carbon content due to increase in carbonisation temperature.

In tables 4.3 to 4.10, weight loss and erosion wear rate of composites with certain percentage by weight of filler, in this case Orange peel carbon black, and a particular carbonisation temperature.



**Table-4.3** Weight loss and Erosion rate of 5% carbonized Orange peel char at 500°C epoxy composites with respect to impingement angle due to erosion for a period of 3min

Sl. No.	Impact Angle (°)	Initial Weight (gm)	Final Weight (gm)	Weight Loss 'Δw' (gm)	Wear Rate (gm/gm)
1	30	2.775	2.771	0.004	0.00053333
2	45	3.363	3.355	0.008	0.00106667
3	60	3.153	3.146	0.007	0.000933333
4	90	3.223	3.217	0.006	0.0008

**Table-4.4** Weight loss and Erosion rate of 10% carbonized Orange peel char at 500°C epoxy composites with respect to impingement angle due to erosion for a period of 3min

Sl. No.	Impact Angle (°)	Initial Weight (gm)	Final Weight (gm)	Weight Loss 'Δw' (gm)	Wear Rate (gm/gm)
1	30	3.496	3.491	0.005	0.00066667
2	45	3.506	3.498	0.008	0.00116667
3	60	2.45	2.432	0.018	0.0011667
4	90	3.223	3.216	0.007	0.000933

**Table-4.5** Weight loss and Erosion rate of 15% carbonized Orange peel char at 500°C epoxy composites with respect to impingement angle due to erosion for a period of 3min

Sl. No.	Impact Angle (°)	Initial Weight (gm)	Final Weight (gm)	Weight Loss 'Δw' (gm)	Wear Rate (gm/gm)
1	30	3.115	3.108	0.007	0.000933333
2	45	3.87	3.853	0.017	0.002266667
3	60	2.499	2.492	0.007	0.0016333
4	90	2.77	2.761	0.009	0.001333

**Table-4.6** Weight loss and Erosion rate of 20% carbonized Orange peel char at 500°C epoxy composites with respect to impingement angle due to erosion for a period of 3min

Sl. No.	Impact Angle (°)	Initial Weight (gm)	Final Weight (gm)	Weight Loss 'Δw' (gm)	Wear Rate (gm/gm)
1	30	2.434	2.426	0.008	0.001066667
2	45	2.597	2.585	0.012	0.0016
3	60	3.109	3.098	0.011	0.001466667
4	90	3.199	3.19	0.009	0.0012

**Table-4.7** Weight loss and Erosion rate of 5% carbonized Orange peel char at 700°C epoxy composites with respect to impingement angle due to erosion for a period of 3min

Sl. No.	Impact Angle (°)	Initial Weight (gm)	Final Weight (gm)	Weight Loss 'Δw' (gm)	Wear Rate (gm/gm)
1	30	4.211	4.203	0.008	0.001066667
2	45	3.783	3.77	0.013	0.00136667
3	60	2.856	2.839	0.017	0.001733333
4	90	3.934	3.923	0.011	0.001167

**Table-4.8** Weight loss and Erosion rate of 10% carbonized Orange peel char at 700°C epoxy composites with respect to impingement angle due to erosion for a period of 3min

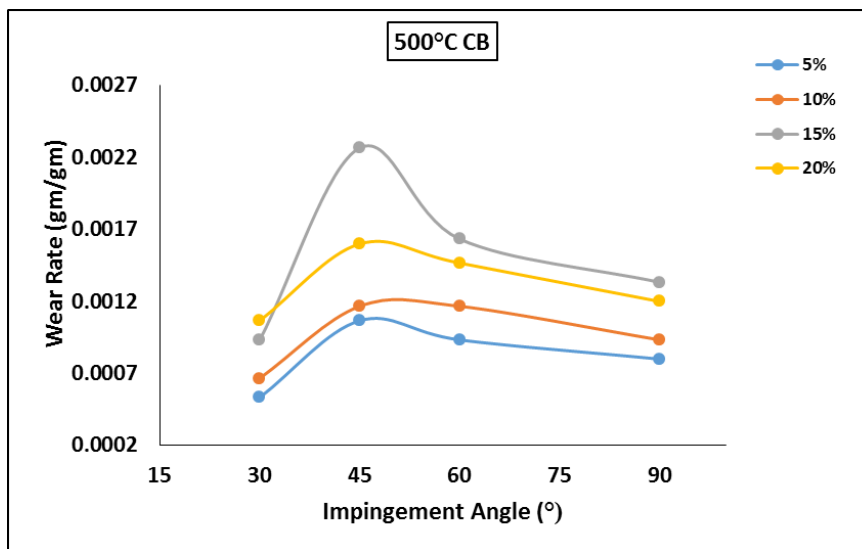
Sl. No.	Impact Angle (°)	Initial Weight (gm)	Final Weight (gm)	Weight Loss 'Δw' (gm)	Wear Rate (gm/gm)
1	30	3.164	3.157	0.007	0.0002333
2	45	3.723	3.715	0.008	0.00063333
3	60	3.496	3.486	0.01	0.000906667
4	90	2.595	2.589	0.006	0.000333

**Table-4.9** Weight loss and Erosion rate of 15% carbonized Orange peel char at 700°C epoxy composites with respect to impingement angle due to erosion for a period of 3min

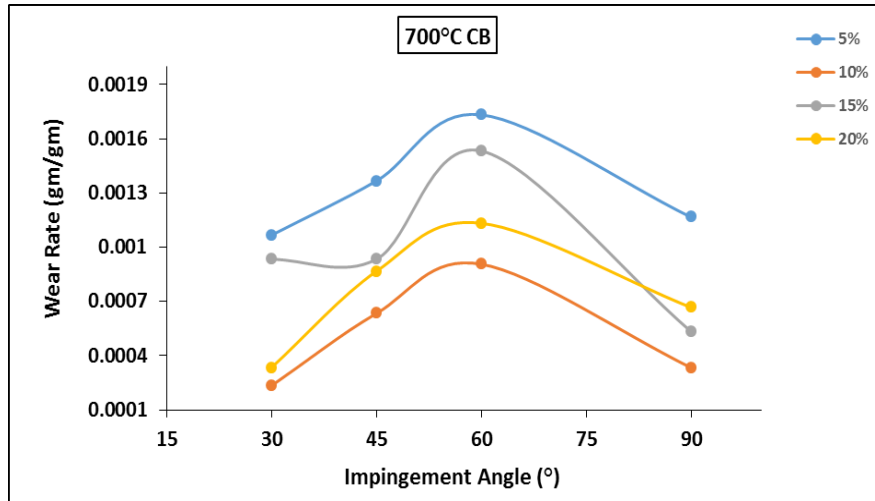
Sl. No.	Impact Angle (°)	Initial Weight (gm)	Final Weight (gm)	Weight Loss 'Δw' (gm)	Wear Rate (gm/gm)
1	30	3.499	3.492	0.007	0.00093333
2	45	2.531	2.518	0.013	0.00093333
3	60	3.337	3.327	0.01	0.00153333
4	90	3.557	3.549	0.008	0.000533

**Table-4.10** Weight loss and Erosion rate of 20% carbonized Orange peel char at 700°C epoxy composites with respect to impingement angle due to erosion for a period of 3min

Sl. No.	Impact Angle (°)	Initial Weight (gm)	Final Weight (gm)	Weight Loss 'Δw' (gm)	Wear Rate (gm/gm)
1	30	3.343	3.338	0.005	0.00033
2	45	2.901	2.885	0.016	0.00086
3	60	3.621	3.61	0.011	0.00113
4	90	2.638	2.63	0.008	0.00066



**Figure.4.2** Variation of erosion rate with impingement angle of various at 500°C carburized Orange peel char epoxy composite at impact velocity of 70 m/s



**Figure.4.3** Variation of erosion rate with impingement angle of various at 700°C carburized Orange peel char epoxy composite at impact velocity of 70 m/s

## 4.6 CONCLUSIONS

The erosive wear behaviour study of orange peel carbon black reinforced composites as a function of various parameters such as impingement angle, impact velocities of the abrasive sand particulates at different percentage by weight of the fillers leads to many definite conclusions. The conclusions derived from this study are as follows:

- The composite prepared with Orange peel carbon black carbonised at 500°C clearly and evidently shows maximum erosion rate at an impingement angle of 45° under the fixed experimental condition which depicts its semi-ductile behaviour. As mentioned earlier, because of the less amount of carbon content, carbon being a natural hardener, the composites are on ductile side more or less.
- Composites prepared with Orange peel carbon black carbonised at 700°C under the same experimental conditions when undergoes sand erosion test, at different weight fraction of the filler, shows maximum wear rate at an angle 60°, which shows a transition from semi-ductile to semi-brittle nature. That's because of the increase in carbon content due to increase in carbonisation temperature. It leads to hardening of the composites, which leads to its brittle behaviour.
- Weight fraction of fibre in the composites and velocity of impact of the sand abrasive particles plays a pivotal role in erosion wear rate of the composites and its behaviour.
- Increase in the weight fraction of fibre in the composite, also leads to void formation which fluctuates the composites behaviour. A balanced composite results in less wear rate in comparison to unbalanced composites.

# Chapter 5

## CONCLUSIONS

## Chapter-5

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- Composites prepared with Orange peel carbon black carbonised at 700°C under the same experimental conditions when undergoes sand erosion test, at different weight fraction of the filler, shows maximum wear rate at an angle 60°, which shows a transition from semi-ductile to semi-brittle nature. That's because of the increase in carbon content due to increase in carbonisation temperature. It leads to hardening of the composites, which leads to its brittle behaviour.
- Weight fraction of fibre in the composites and velocity of impact of the sand abrasive particles plays a pivotal role in erosion wear rate of the composites and its behaviour.
- Increase in the weight fraction of fibre in the composite, also leads to void formation which fluctuates the composites behaviour. A balanced composite results in less wear rate in comparison to unbalanced composites.
- The density of the orange peel carbon black decreases with the increase in carbonisation temperature. With increase in carbonising temperature, the behaviour of the orange peel char reinforced epoxy composites undergoes transition from semi-ductile to semi-brittle nature.

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## REFERENCES

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