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Experimental Investigation on Mechanical Properties of Marble Dust Powder and Al_2O_3 Reinforced Composites for Brake Pad

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ABSTRACT

Asbestos poses a high risk to health, such as being carcinogenic and hazardous to the environment, it should not be used in brake pads. Natural ceramics are therefore of interest to researchers because of their excellent properties, affordability, availability, non-toxicity, etc. The mechanical and tribological properties of a non-asbestos brake pad were compared to those of an asbestos brake pad in this study. The brake pads can be replaced by natural ceramics such as marble dust powder, with additives such as aluminium oxide. Epoxy resin is utilized as a binding agent. For increased strength, marble dust powder is used. Abrasive materials are aluminium oxide. This helps to make brake pads with a high friction coefficient and less wear rate with low noise pollution. Catia v5 software the structural model of the brake pad is developed. The objective of the project is natural ceramics as an alternative to asbestos. The outcomes are what matter due to the varying filler compositions' effects on the mechanical and physical qualities. Hardness tests have been performed, and the behavior of materials with various compositions has been researched. The resulting marble slabs' properties regarding water absorption have also been evaluated.

KEYWORDS: *Composite Material, Marble Dust Powder, Aluminium Oxide, Hand Layup Process*

1. INTRODUCTION

The brake pad is one of the most important parts of the braking system which is mounted on a brake disc rotor on each wheel. The braking system also contains many other parts like cylinders (master cylinders, wheel cylinders, tandem cylinders) and a control system which may be operated by the hydraulic system or pneumatic system. In different types of braking systems varieties of materials are used for brake pads. Binders, fillers, friction modifiers and reinforcement are four important classes of ingredients into which they are often categorized. Asbestos is the most frequently used brake pad material in which asbestos is embedded in matrix of polymer along with other several ingredients.

Many research works have been carried out for the Asbestos free brake pad utilization of composite brake pad materials which provide more economic benefits and also the preservation of the environment. For the fulfilment of the above requirement. Due to the carcinogenic nature of asbestos use of as behave shave has been reduced day by day. The brake pad is most important part of an automobile disk brake system is the brake pad. The brake pad serves as a component to decelerate the vehicle by converting the kinetic energy of the vehicle to heat energy through the friction occurring between the brake disc and the brake pad. Disc brakes require less effort to stop the vehicle. It generates less heat. Disc brakes are that the wheels must be built strongly and they must be able to take high torque stresses between the rim and the hub conditions.

2. LITERATURE REVIEW

Oisik Das et.al [1]: The usefulness of natural and industrial wastes in the creation of bio composites is summarized in this review paper. The current comprehensive review has shown the following significant characteristics. The majority of research found that particles with lower sizes led to considerable property change and improved performance compared to bigger particles.

T Naveen kumara et.al [2]: Epoxy matrix composites supplemented with marble powder can be easily made in a variety of weight fractions of bolstering. This technique helps high-performance epoxy composites be tailored to have the appropriate mechanical properties.

Abhinay Singh Rajawat et.al [3]: In this study, epoxy composites with fixed basalt fiber (20 wt. %) and changing marble dust filler (0, 2.5, 5, 7.5, and 10 wt. %) were developed, manufactured, and tested for mechanical and wear behavior. WMP due to the collection of particles of WMP resulting in a higher stress Concentration at the fractured section. In the context of sliding wear, specific wear at different Speeds and normal loads was steadily observed.

R Balaji et.al [4]: Wear resistance and other tribo-ability of materials such as AlAl2O3 Ceramic Composite/C/Sic-Carbon Matrix Composite/Cr-Ni-Mo-V steel were analyzed with ANSYS software. This paper also stated the comparison impacts of the tribological behavior of disk brake materials with the polymer composites.

Tej Singh et.al [5]: In this study, the applicability of MD was investigated as a filler in polymer composites. Common thermoplastic techniques, namely extrusion, and injection molding were applied to prepare suitable specimens for the characterization of the composites. A constantly increasing stiffness was observed both during the tensile and flexural tests with increasing MD concentration.

D Swapnil gat et.al [6]: Study the tribology behavior of natural fibers in normal and hot conditions. Percentage in brake pad composite and their capability to withstand at evaluating temperature. The agro waste might be efficiently used as a replacement for toxic ingredients in brake pad manufacturing when appropriately united with some other additives to fit a good performance of brake pad.

R. Karthikeyan et.al [7]: It has been discovered that the amount of filler affects the compressive and tensile properties of the created composites, which show that tamarind shell powder at a weight percentage of 35 wt % and waste marble dust at a weight percentage of 15 wt %, respectively, are the ideal filler weight percentages. The composites that have been created can be applied to packing medium sized mechanical components.

A.H. Awad et.al [8]: Marble dust particles which are waste materials from industry are suitable for reinforcing the PP matrix to produce a novel PP composite. The presence of marble dust particles influences the thermal properties of PP by reducing the entropy and the crystallization of the PP composites. The addition of marble dust into the PP matrix was found to increase the flexural strength up to 40 wt%.

Pujari Satish et.al [9]: These brake pads can be replaced by natural fibers like Palm kernel (0- 50%), Nile roses (0-15%), and Wheat (0 -10%) with additives like aluminum oxide (5%-20%) and graphite powder (10%-35%). The maximum value of hardness occurred in Type-2 composites at 10% wheat and 15% Nile rose added to 25% palm kernel, which is nearer to the value of 50% of palm kernel in Type-1 composites.

Sandip Kumar Nayak et.al [10]: Waste marble dust-filled polyester composites are possible by polymer solution casting technique. The dry sliding wear characterization of the composites has been gainfully analyzed using Taguchi's experimental model. The influence of factors like sliding distance and normal load is found to be marginal. The prediction and simulation of the wear response of these composites for different test conditions within and beyond the experimental boundary are conducted by the successful implementation of a model based on artificial neural networks.

Sandip Kumar Nayak et.al [11]: This paper shows the successful fabrication of polyesterbased composites filled with micro-sized waste marble dust through the solution casting technique. While the tensile and flexural strengths decrease with the increase in marble dust content, improvements are noticed in the values of compressive and impact strength of the composites. It reveals that the composite Shore hardness improves with the incorporation of marble dust.

Juana Abenojar et.al [12]: Marble leads to a change in impact and wears properties, increasing both resilience and wear resistance. Wear resistance rises due to the third-body effect of the marble, promoting high friction coefficients. However, compression strength decreases by around 15%. With the addition of short glass fibers, resilience is increased, but wear properties decrease since the loss of fibers is associated with higher weight loss. If the short fibers are replaced by mesh, both resilience and wear resistance increase.

Raffi Mohammed et.al [13]: The experimental investigation on the effect of fiber loading and filler content on the mechanical behavior of fiber-reinforced epoxy composites was conducted. Properties such as the Tensile strength, flexural strength, and Impact energy were evaluated in various experiments. Mechanical characterization has been done and Tensile strength and tensile modulus are more for 5wt% marble powder-filled epoxy composites when compared with the other composites.

Mahavir Choudhary et.al [14]: In this study, the influence of various percentages of waste marble dust loading in glass fiber- reinforced epoxy composites on physical, thermomechanical, and erosive wear properties was Studied. The maximum value of erosive wear rate for glass fiber composite (without marble dust) was found at 450 showing a semiductile mode of erosion, whereas the maximum value of erosive wear rate for waste marble dust--filled composites was found at 600 semis brittle mode of erosion.

Ajith Gopinath et.al [15]: The jute-epoxy and jute-polyester composite specimens were prepared as per ASTM standards and subjected to mechanical characterization. The tensile strength for jute-epoxy and jute-polyester composites was found to be 12.46 N/mm2 and 9.23N/mm2. The 5% NaOH-treated jute fiber-reinforced composites seemed to have a higher tensile strength than the 10% NaOH-treated fiber-reinforced epoxy composite by 18.67 % and for polyester composites, it was found to be an increase of 16.67 %.

Cheng-Ho Chen et.al [16]: The epoxy/c-Al2O3 nanocomposites were prepared by a solution blending process with a homogenizer and followed by a step thermal curing process. It also revealed that cAl2O3 nanoparticles were effective to enhance both the stiffness and toughness of epoxy resin. When the c-Al2O3 content in the nanocomposite was increased up to 7phr or 9phr, not only the coagulation phenomena of c-Al2O3 nanoparticles were significantly observed, but also resulted in decreasing of thermal stability of the epoxy nanocomposites.

T. Narendiranath Babu et.al [17]: The fiber used in this experimental study is Aloe fibers. Samples are made by taking specified percentages of fibers with Epoxy resin, Aluminum Oxide (Al2O3), and Silicon Carbide (SiC) powder. The reduction in the coefficient of friction and increase in wear resistance, which is demonstrated by the two filler-incorporated fibers are positive traits, which can allow the reinforced composite to be used for several applications, such as liners in coal handling equipment.

Tej Singh et.al [18]: Fiber-reinforced and marble dust-filled epoxy composites were carried out. The tensile strength and hardness results increased until 7.5 wt. % bagasse fiber loading; however, above this amount, a slight decrease was observed. Glass transition temperature for all the composites remained almost 690C as determined from the peak of the damping factor. A remarkable improvement in damping properties was observed for 10 wt% bagasse fiberloaded composites. The wear analysis exposes that the sliding distance emerges as the most critical control factor affecting the volumetric abrasive wear of the manufactured composites with a contribution of 58.70. The work demonstrates the use of some waste materials such as marble dust and bagasse fiber.

Ashiwani Kumar et.al [19]: The experimental investigation of physical and mechanical and dry sliding wear resistance of marble dust particulate reinforced Al-7075 metal matrix composite has been developed and investigated. It has been studied and observed that the void content of the fabricated alloy composite is increased with the addition of 6% marble dust particulate in Al-7075 alloy composite. The maximum value of hardness is obtained for 6 wt% marble dust and the maximum value of compressive strength is obtained at 2 wt% marble dust Al-7075 composite. The maximum value of flexural strength and impact strength are obtained at 6 wt% marble dust Al-7075 composite. The maximum value is obtained for 6 wt% M D mixed Al-7075 composite and the minimum for 0 wt% M D mixed Al-7075 composite.

M. Kok et.al [20]: The wear resistance of the composites increased with an increase in the Al_2O_3 particle content and size within the range studied, but the effect of Al_2O_3 particle content on the wear resistance of the composites was less than that of Al_2O_3 particle size. The wear resistance of the composites increased with an increase in the applied load and the SiC abrasive grit size within the range studied. The excellent wear resistance of the composites was mainly dependent on the effective resistance of Al_2O_3 particles to penetration, cutting, and grinding by the SiC abrasive papers. The improvement in wear resistance of the 16μm Al_2O_3 particles reinforced composites was mainly attributed to the matrix.

3. METHODOLOGY

Initial preparation of all the materials and tools that are going to be used is a fundamental standard procedure when working with composites. This is mainly because once the resin and the hardener are mixed, the working time (before the resin mix gelling) is limited by the speed of the hardener chemically reacting with the epoxy producing an exothermic reaction. Each group of students must prepare all materials and supplies available and set up before proceeding. Also, as part of the initial preparation, the woven cloth must be cut according to the shape of the part. Once all the materials are prepared, the workstation is ready and the mold preparation is done; the students can start with the layup process. The first step is to mix the resin and the hardener as shown in figure 1.

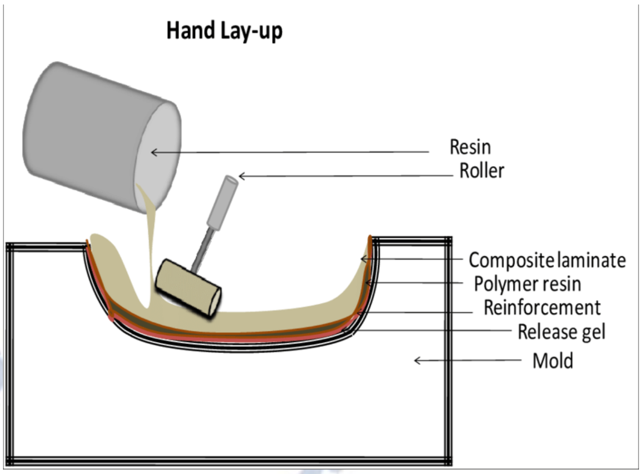

Fig 1: Hand layup method

The portions can be either measured by weight or by volume but it is important to follow these proportions exactly as this is a complete chemical reaction and all components must react completely for maximum strength of the matrix. These pumps can be purchased along with containers of resin and hardener. Make sure to keep the resin pump and container top separate from the pump and container top of the hardener because any contamination will initiate the chemical reaction and cause the resulting blend to harder. The mixing is performed in the mixing containers with the mixing stick and should be done slowly to not entrain any excess air bubbles in the resin. Be careful to mix completely and deliberately for a full two minutes before applying. If it is not completely wet, more resin can be added over the top and spread around. It is best to use a “flat” stick- such as a tongue depressor; a round stick does not work well as it does not ‘paddle’ the mixture to blend it properly. Note: Plastic mixing containers may melt during the exothermic reaction, so it is best to use containers that are specifically made to mix the epoxy resin. These are typically available from the resin vendor. Next, an adequate quantity of mixed resin & hardener is deposited in the mold and a brush or roller is used to spread it around all surfaces.

4. DEVELOPMENT OF COMPOSITE MATERIAL

The process for this study involved several important steps, starting with the Literature review: Technical paper, research of composite materials Study and analysis of various types of ceramics and their properties, Selection of ceramic materials, 4-D Modelling of specimens of composite, and Preparation of making samples or specimen.

- Marble dust powder
- Aluminium oxide powder (Al2O4)
- Epoxy resin (LY 556)

Marble dust powder:

Marble waste as a by-product is a very important material that requires adequate environmental disposal effort. In addition, recycling waste without proper management can result in environmental problems greater than the waste itself. Marble dust is a waste product formed during the production of marble. A large quantity of powder is generated during the cutting process. Such as the increase in soil alkalinity, which affects the plants, Marble powder can be used as an admixture in concrete.

Fig 2: Marble dust powder

Marble dust is a waste product formed during the production of marble. A large quantity of powder is generated during the cutting process. Such as the increase in soil alkalinity, which affects the plants, affects the human body, etc. Marble dust is shown in figure 2 a solid waste material generated from marble processing that can be used either as a filler material in cement or fine aggregates while preparing concrete. Marble powder can be used as an admixture in concrete so that the strength.

Aluminum oxide powder (Al_2O_4):

Aluminum Oxide powder is a white, odorless, crystalline (sand-like) powder. It is used in abrasive and refractory materials, ceramics, laboratory ware, and paper, and as an adsorbent for gases. Alumina powder, also known as aluminum oxide or activated alumina as shown in fig 3, is a chemical compound that is mainly used to produce aluminum – one of the most important metals in the advance of a low-carbon economy. Aluminum oxide is used for its hardness and strength.

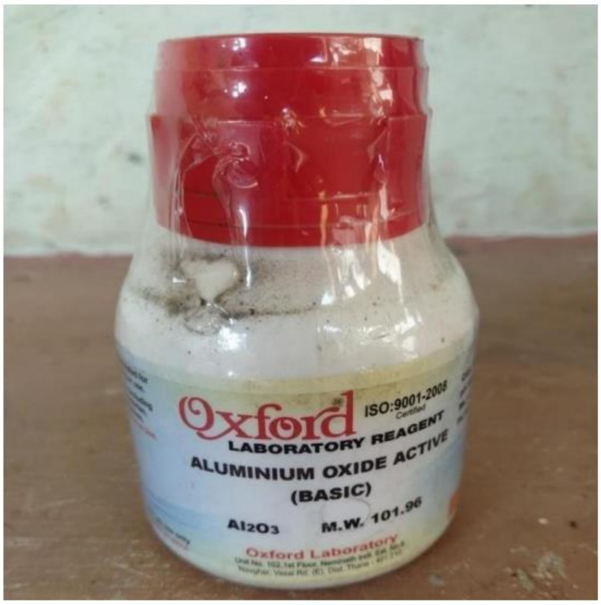

Fig 3: Aluminum oxide powder

Epoxy resin (LY 556) and Harder (HY951):

On the other hand, the weaknesses of this material include long curing time, difficult installation process, and its possible slipperiness when wet or oily. Epoxy is the family of basic components or cured end products of epoxy resins. Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. Adour HY941 is a Low viscosity, unfilled epoxy casting resin system, curing at room Temperature. Epoxy resin (LY 556) and Harder (HY951) as shown in figure 4. Its naturally occurring form, corundum, is a 9 on the Mohs scale of mineral hardness (just below diamond). It is widely used as an abrasive, including as a much less expensive substitute for industrial diamonds. Many types of sandpaper use aluminum oxide crystals.

Fig 4: Epoxy resin (LY 449) and Harder (HY914)

Banvar sheet:

Banvar sheet most popular use of rubber sheets in the industry. Rubber provides good resistance to substances like oil and petroleum, ultraviolet lights, and oxidizing elements. Furthermore, it can maintain flexibility even in cold temperatures.is preparing mold or cutting standard shapes as shown in figure 5.

Fig 5: Banvar sheet

Beakers:

Beakers are tools used to measure the volume of liquids. Beakers are graduated. The liquid can be poured directly into the beaker and measured with the help of markings on the beaker. Two beakers are 100ml, 60ml is shown in fig 6.

Fig 6: Beakers

5. DESIGN

This chapter discusses the design of the brake pad in Catia software and the experimentation of the brake pad.

Fig 7: CATIA software

We can draw a model of a brake pad in CATIA V5 software. Figure 7 shows the CATIA software app.

Step 1: Open the Catia software fig 8 shows it.

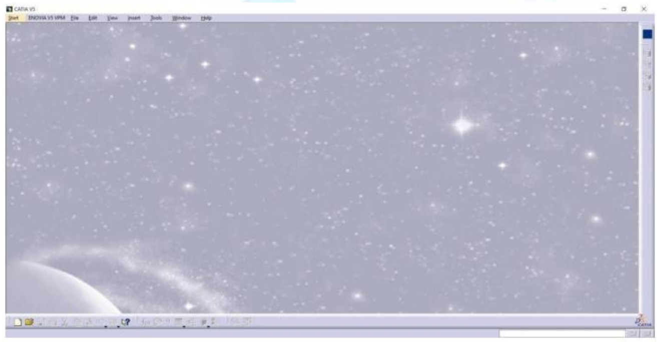

Fig 8: Open the Catia software

Step 2: Click on the "start" menu bar and select "mechanical design" so that we can select "Part design". Figure 9 say about it.

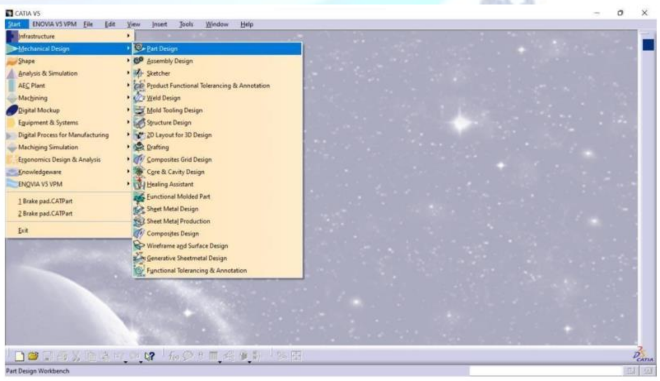

Fig 9: A process of opening the software

Step 3: Click on "ok" and we can get the drawing window and select the reference plane. Figure 10 says about it.

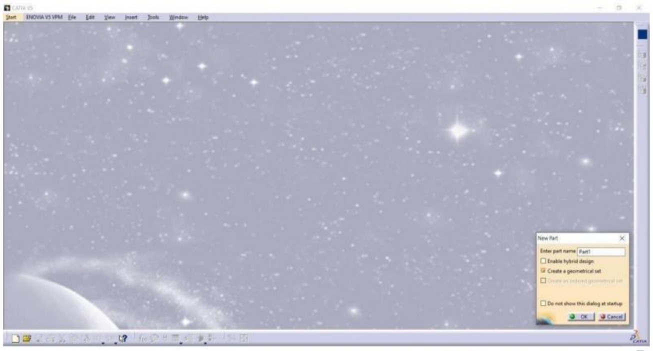

Fig 10: The process of opening the software

Step 4: Their few commands are used to draw the brake pad. Figure 11 is explained below the fig.

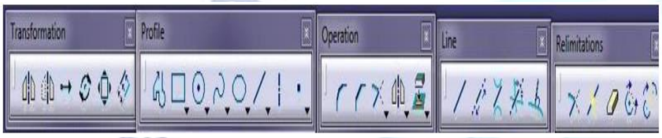

Fig 11: Draw commands in CATIA software

Modelling of brake pad:

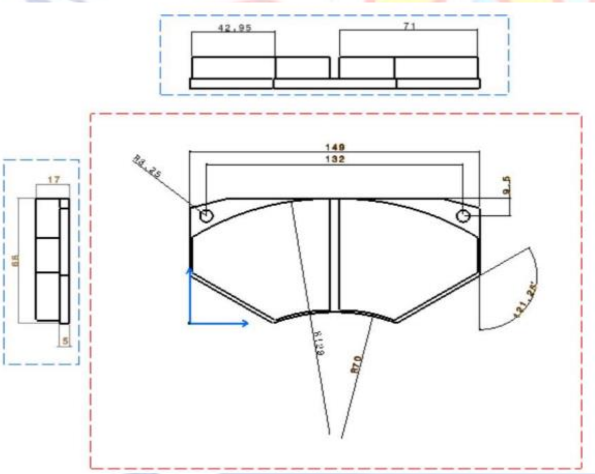

Fig 12: Dimensions of brake pad

Draw the base part concerning dimensions by using a profile, rectangle, arc, and trim commands shown in figure 12 and pad it for 5mm.

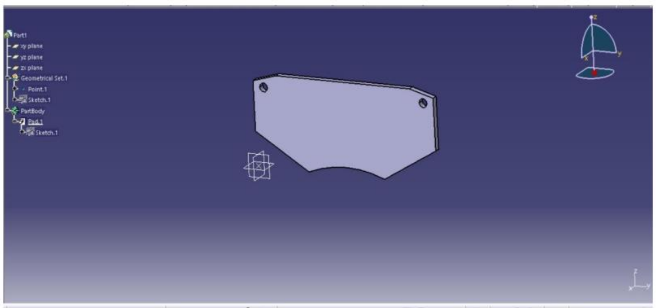

Fig 13: Base part

Take a Y-axis for reference and draw a line at 5mm length. Draw brake pad material as shown in figure 13 and mirror its opposite side.

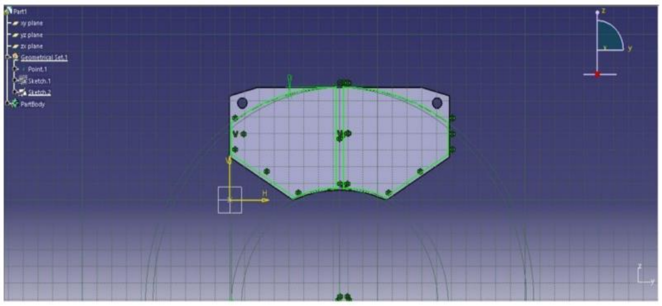

Fig 14: Brake pad material

Padding it 15mm is shown in fig 5.10. Before padding check, the sketchers are iso-constrained in figure 14. Figure 15 shows M.

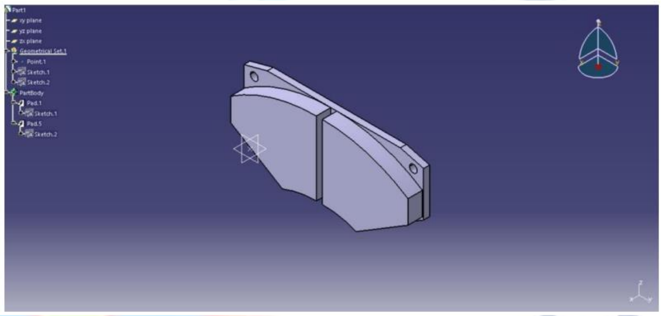

Fig 15: Modeling of brake pad

6. EXPERIMENTATION

Universal Testing Machine (UTM):

The equipment used for tensile testing ranges from simple devices to complicated controlled systems. The so-called universal testing machines are commonly used, which are driven by mechanical screws or hydraulic systems. This illustrates a relatively simple screw-driven machine using large two screws to apply the load whereas shows a hydraulic testing machine uses the pressure of oil in a piston for load supply. These types of machines can be used not only for tension but also for compression, bending, and torsion tests. A more modernized closed-loop servo-hydraulic machine provides variations of load, strain, or testing machine motion (stroke) using a combination of actuator rods and pistons. Most of the machines used nowadays are linked to a computer-controlled system in which the load and extension data can be graphic as shown in figure 16 and figure 17 displayed together with the calculations of stress and strain. General techniques utilized for measuring loads and displacements employ sensors providing electrical signals. Load cells are used for measuring the load applied while strain gauges are used for strain measurement.

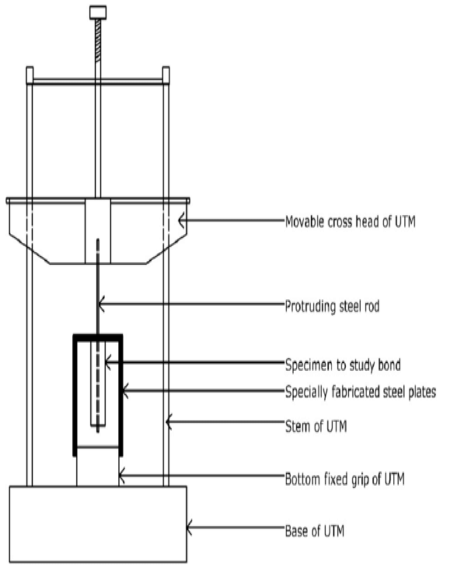

Fig 16: Line diagram of UTM

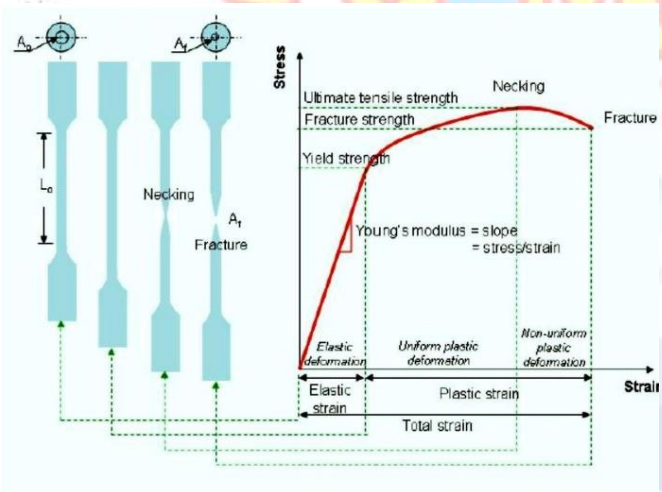

Fig 17: Stress and strain relationship

Steps to involve in testing the specimens:

- The specimens provided are made of composite materials.
- Measure and record specimen dimensions (diameter and gauge length) in a table proto calculate the engineering stress and ring strain.
- Marking the location of the gauge length along the parallel length of each specimen for subsequent observation of necking and strain measurement as shown in figure 17.
- Fit the specimen onto the universal Testing Machine (UTM) and carry on testing.
- Calculate the tensile strength of each specimen.

Brinell hardness:

The Brinell Hardness Test is used to determine the Hardness Number of hard, moderately hard, and soft materials E.g.: Brass, Bronze, Aluminum, Gold, and Copper. Very hard material and Brittle materials cannot be tested by a Brinell hardness tester. Brinell hardness number (BHN) is obtained by the ratio of the calculated load and the spherical area of the Indentation or Impression made on the specimen by the foreshowing Indenter Ball as shows in figure 17. In the Brinell hardness test, a steel ball of diameter (D) is forced under a load (F) onto the surface of the test specimen. The mean diameter (d) of indentation is measured after the removal of the load (P). The Brinell Hardness Number (BHN) is obtained by dividing the applied force P, in kg-F; by the curved surface area of the indentation, which is a segment of a sphere. Since the deformations caused by an indenter are of similar magnitude to those occurring at the ultimate tensile strength in a tension test, some empirical relationships have been established between hardness and engineering the ultimate tensile strength of metals and alloys.

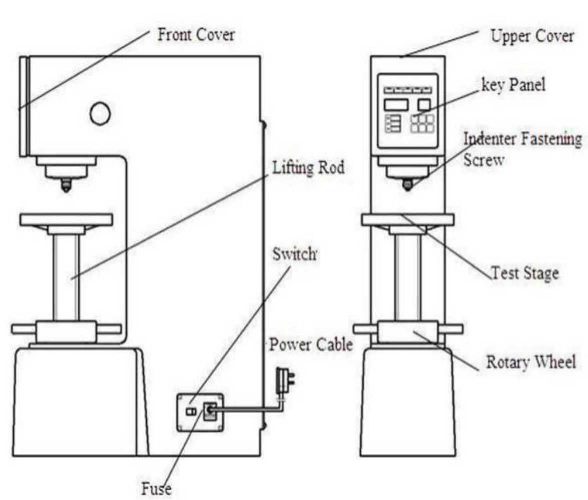

Fig 18: Line diagram of Brinell hardness

Steps to involve in testing the specimens:

- Keep the loading and unloading lever at position "A" which is the unloading position.
- Place the specimen on the testing table anvil as shown in fig 18.
- Turn the hand wheel to raise a job until it makes contact with the indenter & continue turning till the longer pointer at the dial gauge makes 2 ½ rotations. Turn the lever position "A" to "B" i.e. that the unloading to the loading position. So that the total load will act.
- When the longer pointer of the dial gal ever touches a steady position, take back the lever to the unloading position "A". [Avoid sudden release at the lever].
- Remove the job from indentation using note down the diameter of the indentation using a Brinell microscope.
- Using the appropriate formula calculate BHN.
- Similarly, repeat the step from 'a-h' for different trials and different materials.

7. RESULT

1. Tensile test:

Table 1.1: Aluminium oxide powder of tensile test

S.no		WT%	Ultimate Tensile strength(Mpa)
1	Aluminium+ oxide powder	2.5	3.208
2		5.0	3.724
3		7.5	4.186

Table 1.1 shows the ultimate tensile strength with different weights % of Aluminum oxide powder.

Table 1.2: Marble powder of tensile test

S.no		WT%	Ultimate Tensile strength (Mpa)
1	Marble dust powder	2.5	3.218
2		5.0	3.556
3		7.5	3.90

Table 1.2 shows the ultimate tensile strength with different weights % of marble dust powder.

2 Hardness test:

Table 2.1: Aluminum oxide powder of hardness test

S.no		WT %	Hardness load(Kgf)	Indentation(mm)	(BHN)
1	Aluminium oxide powder	2.5	52	0.95	211.15
2		5.0	42.86	0.97	202.14
3		7.5	44.66	0.99	194.38

Table 2.1 shows the hardness load with different weights %, indented on and Brinell hardness of Aluminum oxide powder.

Table 2.2: Marble powder of hardness test

S.no		WT%	Hardness load(Kgf)	Indentation (mm)	(BHN)
1	Marble Dust powder	2.5	22	0.94	215.66
2		5.0	36	0.96	206.75
3		7.5	35.16	0.98	198.38

Table 2.2 shows the hardness test with different weights % of marble dust powder.

8. GRAPHS

Increasing of Aluminum oxide powder as reinforcement as well as tensile strength gth also increased is shown below graph 1.

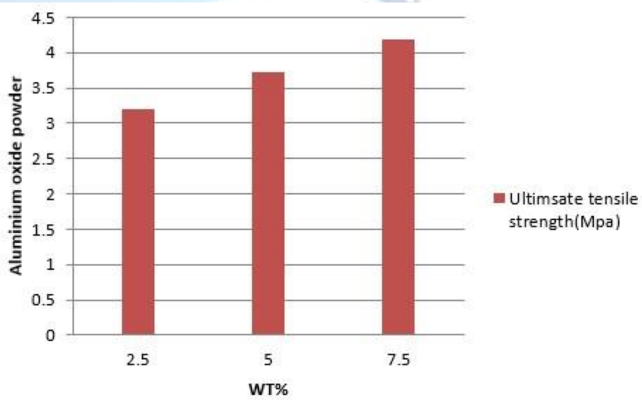

Fig 1: Aluminium oxide powder of tensile test

Increasing of Marble dust powder as reinforcement as well asasensileas sensible they also increased is shown below graph 2.

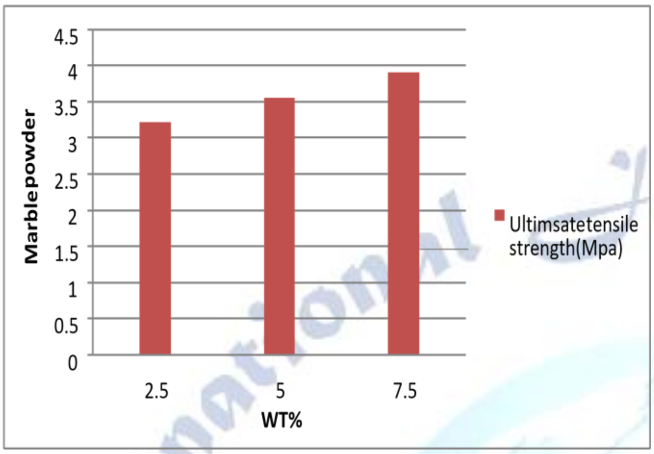

Fig 2: Marble dust powder of tensile test

Increasing of Aluminum oxide powder as reinforcement as well as hardness althea o increased is shown below graph 3.

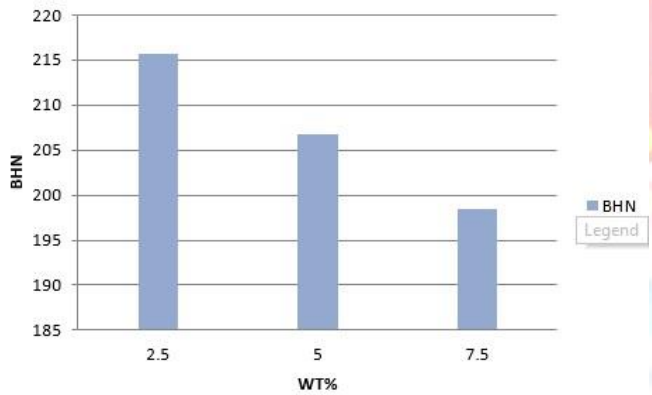

Fig 3: Aluminium oxide powder of Hardness test

Increasing of Marble powder as reinforcement as well as hardness also the increased is shown below graph 4.

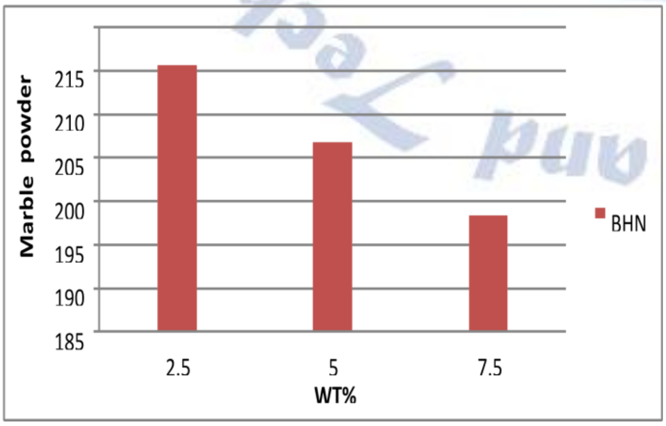

Fig 4: Marble Dust Powder of Hardness Test

9. CONCLUSION

This chapter gives the conclusion of the tests which were conducted on the brake pad.

The experimental investigation on the effect of ceramics loading and filler content on the mechanical behavior of ceramics-reinforced epoxy composites was conducted. Properties such as the Tensile strength, Brinell hardness, and Wear rate were evaluated from various experiments. The experiments lead us to the following conclusions obtained from this study:

- The successful fabrications of a new class of epoxy-based composites reinforced with marble powder and aluminium oxide powder with varying compositions have been done.
- The maximum tensile strength among all specimens is 4.186Mpa whose composition is epoxy resin and 7.5wt% of aluminium oxide powder.
- The maximum hardness among all specimens is BHN 215.66 whose composition is epoxy resin and.
- The maximum wear rate among all specimens whose composition is epoxy resin and. From the above data we have concluded that the composition which contains Resin, Coarse fly ash, and glass fiber shows a better result when compared to the remaining 3 compositions most of the mechanical and wear properties are highest.
- The material developed in this experimental process can be used in the automobile brake pad.

FUTURE SCOPE

Composite materials have attractive aspects like relatively high compressive strength, good adaptability in fabricating thick composite shells, low weight, low density, and corrosion resistance. Composite materials have good mechanical, electrical, and chemical properties, due to which we can use composite materials in many various industries. Various parts of automobiles and aerospace are manufactured with composite materials due to their good properties. Composite materials are used for domestic purposes like furniture, window, door, mating, civil construction, etc. In the marine, chemical industries, sports, we can use composite material for better performance of the parts. With the help of a review, we conclude that composite materials have wide advantages & applications in various industries; we can make better lifestyles with the help of composite materials. Possible use of these composites such as pipes carrying coal dust, low-cost housing, etc. is recommended. However, this study can be further extended in the future to new types of composites using other inorganic materials/fillers and the resulting experimental findings can be similarly analyzed. There are several types of fabrication techniques for brake pad preparation. In this work, the hand layup technique is used for preparing the brake pad. There is a wide scope of composite material in automotive, aerospace, wind energy, electrical, sports, domestic purpose, civil construction, medical chemical industries, etc. Composite materials have a great potential for application in structures subjected primarily to compressive loads.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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