

FABRICATION OF COMPOSITE BRAKE PADS

Submitted in partial fulfillment of the
requirements for the award of

Bachelor of Engineering degree in

Automobile Engineering

By

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(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of AJAY SHIVSHARAN REDDY (37860025) and SURAJ RAMESH DAVANAPALLI (37860038), who carried out the project, entitled **“FABRICATION OF COMPOSITE BRAKE PADS”** under my supervision from December 2020 to April 2020.

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DECLARATION

I, AJAY SHIVSHARAN REDDY (37860025) hereby declare that the Project Report entitled “**FABRICATION OF COMPOSITE BRAKE PADS**” done by me under the guidance of **Mrs. K.R. KAVITHA, M.E., (Ph.D).**, at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Automobile Engineering.

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ABSTRACT

Composites are turning out to be a new growth in the material science industry, mainly automobile and aircraft industry. The search for materials for low cost, less weight but should have high strength to increase the efficiency is increasing. Therefore, the solution for the above problems is composite materials only. The project focuses on the study of microstructure studies of Chopped Basalt fiber and steel slag reinforced with phenolic resin and frictional additives.

Phenolic resin is used as a binder for holding the composition of other components together and maintaining structural integrity. Further, the SEM analysis with EDAX was performed to see the micro-structures. From the study it was observed that Basalt fiber and steel slag composites are not more effective than the current materials. Although the basalt fiber is environmental friendly material the composite did not survive the mechanical tests.

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CHAPTER 1

INTRODUCTION

1.1 FIBER REINFORCED COMPOSITE

Fabrication of frictional materials for brake pads has been claimed as multi-staged work since long. It needs enhancements in every stage. Various tests are needed to be carried out for appropriate performance and operation. The biodegradability has helped the transportation, automotive and aeronautical industries. Basalt fiber is made from basalt composed of plagioclase, pyroxene, and olivine. Compared to glass fiber, carbon fiber and aramid fiber, basalt fiber has better mechanical properties, acid-alkali resistance, non-conductive, sound insulator. In recent times, many vehicles are using disc brakes instead of drum brakes as they dissipate heat better than drum brakes, that is why the braking system are more efficient than older systems. However, the formulation composite brake pads are a multistage process which requires multiple optimizations at different stages. The brake pads materials should meet the minimum friction coefficient, wear rate. Resin is one of the most important ingredients used in composite preparation as it binds the other materials. The current work investigates the characteristics of modified fiber on friction and wear of disc brake pad material. The objective is to develop new brake pad material. Formerly, the brake pads were made using asbestos which is now no longer in use because environmental problem and health problems. The current brake pad material consists of metal fibers bonded with a resin and additives. The two materials under investigation are basalt fiber and steel slag. The samples are prepared at high temperature compression. The study was conducted for patents and literature search. No patents exist for basalt fiber and steel slag composite. The most similar patents include basalt fiber with other ingredients or steel slag with other ingredients. The literature survey confirmed the potential properties of the materials for the brake pads. The test results will be used to determine the viability of using new materials for brake pads. Also, it will help recognize whether the new materials provide better properties than the current materials. In case the composite is determined as useful for brake pad material then the last goal of the project is to conduct the field test on a two-wheeler vehicle to find out the on-ground performances under different conditions.

1.2 EXISTING BRAKE PAD MATERIALS

There are majorly three types of brake pads which are currently sustaining in the market those are

- Ceramic brake pads
- Semi metallic brake pads
- Non asbestos organic brake pads

1.2.1 Ceramic brake pads

Ceramic can find a small amount of metal in this brake pad type, but they are mainly made of ceramic fibres, bonding agents, and nonferrous filler materials. They create less noise, wear down slowly in comparison to other brake pad types, and create less dust. Ceramic brake pads are designed to come as close as possible to the braking performance of semi-metallic brake pads, without the noise, dust, and worn brake rotor issues. A large percentage of new cars come equipped with ceramic brake pads right from the factory. But shopping for ceramic brake pads can be difficult because every manufacturer uses a different formula. When shopping for ceramic brake pads, a higher-priced ceramic brake pad is an indication of its quality. In other words, don't replace a factory ceramic brake pad with an economy model and expect to get the same braking performance. Ceramic pads, yes, made of similar materials to what we would find in ceramic pottery and plates, but far more durable. These pads are made of stacked glass ceramic fibres, filler material, bonding agents, and bits of varying metals. Ceramic has gained popularity in recent years and is widely used among many manufacturers. They were developed after semi-metallic pads in an attempt to reduce noise, heat, and brake dust. The difference between ceramic and metallic brake pads is that ceramic pads are quieter and cleaner in comparison to organic and semi-metallic pads, less abrasive on rotors, and often last longer than others. Drawbacks of ceramic pads include cost, as they are the most expensive brake pad option and are not designed to be used on performance vehicles or heavy-duty trucks. The ceramic material does not absorb heat as well, which means our brake system temperatures can be consistently hotter when managing steep terrain. If we adjust our driving style to shift down in our gearbox to reduce speeds that we can manage this disadvantage a little bit, but we'll notice that our car tends to run

hotter with the brakes using this product almost all of the time.

1.2.2 Semi metallic brake pads

Semi metallic brake pads have long-term durability and excellent heat transfer capability, semi-metallic is the most common brake pad type used widely in different vehicles. It is made of steel wire or wool, graphite or copper, and friction modifiers. Such a brake pad contains nearly 30%-65% metal. Called “semi-mets” by the pros, semi-metallic brake pads are filled with metal fibres. The fibres pull heat away from the rotor and transfer it to the metal backing plate to reduce overheating and brake fade. That’s why semi-metallic brake pads provide ultimate stopping power. The drawbacks of the semi metallic brake pads are they are not perfect. Since they’re the hardest of all pad materials, semi-metallic brake pads tend to chew up rotors faster. They also make the most noise. In fact, semi-metallic brake pads are notorious for squealing during stops. And, they produce rusty, brown brake dust that’s guaranteed to dirty up fancy, aluminium rims.

1.2.3 Non asbestos organic brake pads

Organic brake pads very peculiar properties than that of the others. Advantages are more than the drawbacks. Non-Asbestos Organic fibres are made of high-temperature resins, and filler materials are used in the making of this brake pad type. If compared to the semi-metallic type, they are softer and create less noise; but deteriorate faster and create more dust. Pros of Non-Asbestos Organic brake pads are made, they are inexpensive and quiet and the cons are they wear quickly because it is made with organic fillers like carbon, rubber, and Kevlar. The fillers dissipate heat and dampen vibrations. NAO brake pads are still standard on many vehicles because they work well, are inexpensive, and quiet. The major drawback is that they are soft in nature and doesn’t last long when compared to other expensive formulation of the brake pads.

1.3 COMPOSITES

A composite is a material made from two or more different materials that, when combined, are stronger than those individual materials by themselves. Simply put, composites are a combination of components.

1.4 TYPES OF COMPOSITES

1. Polymer Matrix Composite (PMCs)
2. Metal Matrix Composite (MMCs)
3. Ceramic Matrix Composite (CMCs)
4. Particulate Reinforced Composites.
5. Flake composites.
6. Fiber Reinforced Composites (Fibrous Composites)
7. Laminated Composites.

1.5 BASALT FIBRE

Basalt fiber is a material made from fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene and olivine. It is similar to fiberglass, having better physic mechanical properties than fiberglass, but being significantly cheaper than carbon fiber. These are woven using yams form the filament basalt so as to make the fabrics non-combustible, fire resistant and have high resistance tensile strength.

1.5.1 Applications of Basalt Fibre

Basalt Fibre is ecofriendly material which does not produce any toxic emissions during production and processing. It is used with carbon, ceramic or various types of metals to develop new composites. Basalt fibers surpass and thus replace E-glass, R-glass, and S-glass in almost all the applications. At the moment it is being used in production of automobile, airplanes, ships, and household appliances. Other possible applications include printing press, vacuum forming, and winding. Structural basalt composites are used making rods and pipes using unidirectional basalt fiber reinforcements. In high voltage wires and underground wires, it is used as insulator.

1.5.2 Insulator and Construction Sector

Compared with carbon fiber, basalt fiber has better non-conductive and electromagnetic properties. They are used in military radar and power systems. It used as electromagnetic inference shielding. Basalt fiber high temperature filter bag with high tensile strength, with temperature resistance, oxidation resistance, and acid-alkali corrosion, has high efficiency in dedusting process and improves

the life and efficiency of dust removal filter. Alkali resistant sizing's (KV-13, KV-42 and KV-41) basalt fiber was developed specifically for construction. They provide good compatibility and alkali resistance with concrete.

1.5.3 Sound Absorption and Heat Dissipation

Basalt fiber with specific size and density can help basalt fiber a low thermal conductivity. It is used in making composite materials for thermal insulation. Due to the irregularity in the structure and porosity it absorbs sound properly. It is also used in clothing of high and ultra-low ambient temperature protective clothing and equipment.

1.6 STEEL SLAG

As a result of growing environmental awareness, iron and steel slag is highly regarded as a recycled material that can reduce impacts on the environment due to its resource-conservation and energy-saving effects. Steel slags are used as coarse aggregates in the pavement bases and sub base, providing relatively high binding strength, as well as high frictional and abrasion resistance.

1.7 ALUMINIUM OXIDE

Alumina is often used in industrial applications which are odourless and white amorphous material. Its outstanding properties has contributed in society enhancing applications such brake lining materials, brake pad and brake shoe materials etc., Also due to its excellent mechanical and thermal properties stands for un comparable materials by providing better solutions for low-production and manufacturing.

Alumina has 2072°C and 2977°C as its highest melting point and boiling point respectively.

1.8 GRAPHITE POWDER

Graphite is a form of element occurs naturally and mostly available in the carbon form. It is used in lubricants because of its better thermal and mechanical properties.

1.9 APPLICATIONS OF GRAPHITE POWDER

Graphite powder has variety of applications in many industrials fields. Graphite powders are used linings or brake shoes for heavier (nonautomotive) vehicles, and became important as a substitute material for asbestos.

CHAPTER 2

LITERATURE SURVEY

1. Amar Patnaik et al. in his paper has investigated the wear properties of palm kernel reinforced composites for brake pad applications. Asbestos is toxic in nature and also leads to various health problems. Therefore, it is no more used for manufacturing of brake pads. Various investigations are being made on composite materials for brake pads using natural fibers. Various natural fibers like palm kernel, Nile roses, wheat with additives like aluminium oxide and graphite powder. Phenolic resin was used as binder as it has good binding nature with fiber. Aluminium oxide and graphite help in increasing friction coefficient and reduce wear rate. Various mechanical tests were conducted like wear test on pin-on-disc apparatus, hardness test on Rockwell hardness apparatus and oil absorption test.
2. Satish Pujari, S. Srikanth in their paper have friction and wear behaviour of disc brake pad materials. Brake pad material is diverse material and is composed of few elements. The ideal brake friction material should have a constant coefficient of friction under different operating conditions. During sudden braking excessive heat is produced and hence coefficient of friction falls abruptly. So, to maintain the coefficient of friction new composites have been developed so that the resin regains its binding ability at high temperature. Here in all 13 ingredients have been used including binding material and modified binder. A reciprocating friction monitor was used to conduct wear and friction tests at different loads and temperatures was conducted for around 10 minutes. The results displayed that the coefficient of friction augmented at higher temperature range and wear characteristics show that banana peel powder is an effective alternative to improve the binding ability of phenolic resin at higher temperatures.
3. I.D.G Ary Subagia et al. explains the wear properties of composites of phenolic resin and basalt powder reinforced on brake pads linings. Composite brake sample have been manufactured using compaction and sintering process. His research aimed to test the wear properties of composite on pin-on-disc apparatus. The weight fraction ratios are 30:70%wt; 60:40%wt, and 80:20%wt were done. The characteristics of basalt were compared with and without treatment of 5%

NaOH. The results showed that the durability was 10.9% and 11.38% of specimens of each composition. They concluded saying that basalt has better environmental characteristics than asbestos does.

4. R.J. Talib et al. in his paper has discussed the effects of phenolic resin on the friction behaviours with respect to temperature and operating speed. He said brake friction consist of four different components. Phenolic resin was used as the binding material to maintain the structural integrity during braking. Three semi-metallic samples were prepared and then each of them was tested using inertia dynamometer in accordance with the standard test SAE J2522 test procedures.

5. C. Colombo et al. has discussed the static and fatigue characteristics of basalt fibre composites. These are valid alternatives for carbon fibre as they are amorphous mineral fibre and are available at cheaper price stronger than glass fibre. To use the basalt reinforced composites for structural applications there few mechanical tests carried out. Two polymeric matrices were considered to assess their influence on their work. Thermal results were evaluated to mechanical loads using thermography. The experimental method allows defining the composite local heating during the application.

CHAPTER 3

AIM AND SCOPE OF PRESENT WORK

3.1 AIM AND OBJECTIVE

This study aims to develop alternative eco-friendly composite brake pad materials and to investigate the microstructure study of basalt fiber, slag steel, aluminium oxide, graphite powder and phenolic resin for brake pads composite materials.

This article presents a metallurgical review of basalt fibers used as reinforcement material composites and discusses them as an alternative to the use of brake pad materials. The objective of the study is to reveal the extensive usage of basalt fibers as stable, inert, eco-friendly and non-reactive reinforcement material used as light-weight composites with highly improved mechanical properties.

3.2 SCOPE OF PRESENT WORK:

Basalt fibers are almost as favorable as carbon fibers, but have an edge as they are ecofriendly, non-toxic, and green. Further, basalt is chemically inert, highly resistant to corrosion, and possesses very low thermal conductivity making it superior to any other reinforcement available today.

CHAPTER 4

MATERIALS AND METHODS.

4.1 BASALT FIBER:

Basalt fiber is material made by extraction of fibers from basalt. The basalt rock is crushed, washed, and melted at 1500°C . Now it is melted and passed through small nozzles to get filaments. The diameter of this fiber is between 10 and 20 μm . This makes it a suitable replacement for asbestos. To produce fiber, basalt of low iron content and high acidity (i.e., 46% of silica) is considered. Basalt fiber is newcomer to fiber reinforced polymers and structural composites and has wider application of temperature range from -269°C to $+650^{\circ}\text{C}$. It has advantages like excellent electrical properties, acid-alkali resistance, good mechanical properties, high wave permeability, non-conductive and excellent sound insulation, insulation performance.



Fig:4.1: Basalt Fibre

Table 4.1: Basalt fiber properties.

PROPERTY	VALUE
Tensile strength	2.8 – 3.1 GPa
Elastic Modulus	85-87 GPa
Elongation at break	3.15%
Density	2.67g/cm^3

Table 1.1 describes the various property of basalt fiber.

4.2 STEEL SLAG

Steel slag

Steel slag raw powder was purchased from the market which has the silicates and oxides as its composition which is playing vital role in increasing the mechanical properties of the components.



Fig: 4.2: Steel Slag

4.3 ALUMINIUM OXIDE

Aluminium oxide is an inert, odourless, white amorphous powder which is generally used for making industrial ceramics. Due to the excellent properties aluminium oxide has helped in life-extending and society enhancing applications. When aluminium combines with oxygen it forms aluminium oxide, a protective layer is formed to stop the further oxidation.

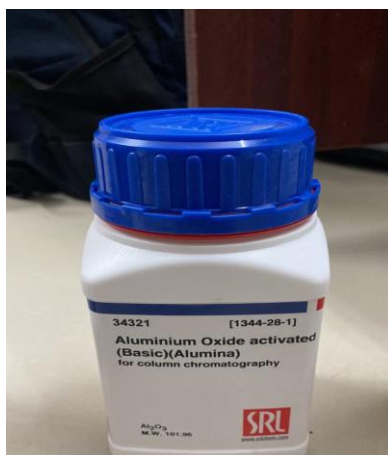


Fig:4.3: Aluminium Oxide

This increases the strength of material and makes it less vulnerable to wear. Aluminium oxide wide range of applications across medical industry, military and protective equipment, gem industry, electrical and electronics industry, and industrial applications.

4.4 GRAPHITE POWDER

Graphite is crystalline allotrope of carbon. It is most stable form carbon. It is conductor of heat and electricity. The two most common crystalline allotropes of carbon are diamond and graphite. In diamond the bonds are sp^3 the atoms form tetrahedral structure with nearest neighbors, whereas in graphite there are sp^2 bonds. The atoms form bonds with three neighbors at 120° . Graphite and graphite powder are known for their self-lubricating and dry lubrication properties.

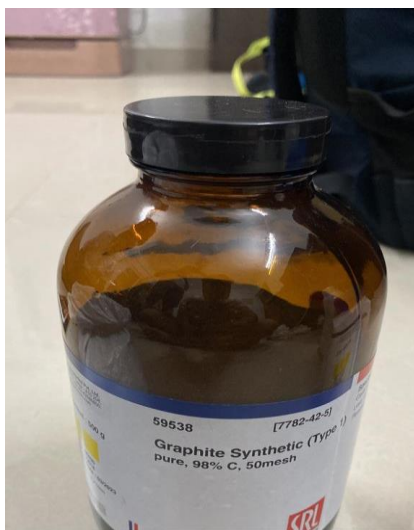


Fig:4.4: Graphite powder

4.5 PHENOLIC RESIN

Resin is one of the most important ingredients in friction materials because it binds the ingredients firmly and allows them to contribute effectively to the desired performance

Basalt fibre, Steel slag, Aluminium oxide, Graphite powder and phenolic resin were used as binder. Four samples were prepared in total. The amount of materials was different in each specimen. The below given table demonstrates the amount of materials used in each specimen.

Table 4.2 Sample Preparation

S. No	Materials	S1	S2	S3	S4
1	Basalt fibre (reinforcement)	35	15	35	35
2	Steel Slag (reinforcement)	5	33	15	20
3	Graphite powder (friction modifier)	35	19	15	5
4	Aluminium oxide (friction modifier)	15	25	5	5
5	Phenolic resin (binder)	10	8	30	35

The above-mentioned percentages of materials are blended for each sample. The amounts were taken in terms of weight. Each material was measured separately and then added to mixture.



Fig: 4.5: Weighing machine

4.6 MATERIAL PROCESSING

The processing of new composite material was done by using heat press method. This process is followed in the following way.

- I. A mould was made from waste metal piece with help of lathe machine; its inner diameter was 20mm.
- II. Then the upper covering was made using turning method

on lathe with the extruded length of 3mm and its diameter was 19.5mm

- III. Now the slag was prepared with the raw materials after taking them in specific ratios by weight.
- IV. Now the slag is mixed with the binder material and then allowed to dry it of naturally for 28 days.
- V. Once the composite is dried, Compaction was carried out using hydraulic heat pressing machine.
- VI. Now again the specimen was allowed to cool down at room temperature for overnight.
- VII. Now the specimen was ready in smaller biscuits form.

There were in total four different samples fabricated. The ingredients were taken in different quantity by weight. There mixture was prepared of powder earlier, when the powders were mixed properly then phenolic resin was added to it. Now the paste was once hot pressed during which due to the high temperature the phenolic resin melted and came outside. In second round the percentage of phenolic resin was reduced, and then hot pressed, same problem was seen after a while. Now the composite paste was prepared and then allowed it to dry naturally for 28 days. After which some amount was used to hot press it and some was used to cold press by adding 1% of zinc in it. The hot compaction was carried out at 200⁰C. The samples were allowed to cool down to room temperature for a night. Due to the weather conditions the samples had held a small amount of moisture during overnight cool down process. Due to which the samples could not survive the mechanical tests.

4.7 MOULD PREPARATION.

Mould preparation was carried using a waste piece of solid metal rod. Two pieces of rod were taken and then facing was carried out on it to make the surface even using lathe machine. Once the turning was over, drilling was carried out. The depth of the mould was 10mm and inner diameter was 20mm.



Fig.:4.6: Lathe Machine

Once the pocket was made the upper cap was made using lathe machine. The extruded part was of 3 mm height and the diameter was 19.5mm.



Fig:4.7: DIE

Figure 4.3 shows the die fabricated using machining process as per. As mentioned above the process of mixture preparation was carried out and it was heat pressed.



Fig: 4.8: Composite preparation

Fig 4.4 shows the preparation of sample with various compositions. Four different samples like S1, S2, S3 & S4 were prepared by varying the basalt fiber, steel slag, aluminium oxide, graphite powder, phenolic resin.



Fig:4.9: Composite Mixture

Fig 4.5 shows the blended samples prepared. This blended samples prepared constitute of basalt fiber, steel slag, aluminium oxide, graphite powder, phenolic resin. Basalt fiber and steel slag is used as composites by reinforcing with aluminium oxide and graphites are used for enhancing mechanical properties, phenolic resin is used for better binding.



Fig:4.10: Heat pressing

Fig 4.6 shows the processes of heat pressing of the samples. The samples prepared was pressed under a certain pressure for better bonding purpose. This was done for all the four samples by varying the composition of basalt fiber, steel slag, aluminium oxide, graphite powder, phenolic resin



Fig:4.11: Composite material in die After heat press.

Figure 4.7 shows the pressed samples in a pressing machine with a suitable pressure. This procedure was repeated for all the samples prepared



Fig:4.12: Sample for natural drying

The samples were left for natural drying for more than two days as shown in figure 4.8. After complete drying samples were taken for testing and analysis purposes.

CHAPTER 5

RESULTS, DISCUSSIONS AND ANALYSIS

5.1 BASALT FIBRE

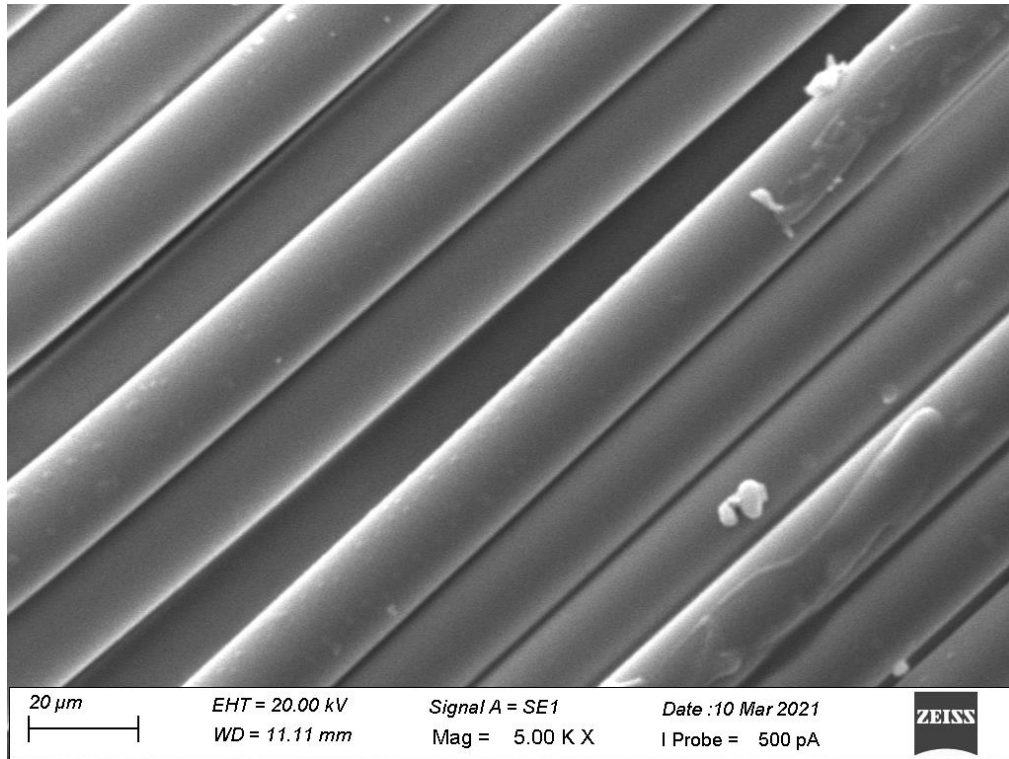


Fig:5.1: SEM image of raw basalt fibre

The uni-directional basalt fibre was used for fabrication of composite material. The properties of unidirectional basalt fibre reinforced composites are similar to or better than E-glass fibre reinforced composite. Elongation and stress at break are comparable while the Young's Modulus are higher by upto 35%. As fibre is extracted from basalt rock as mentioned in introduction, due to the procedure followed during this there are some micro level layers formed on this. The image was taken at 20 µm zoom.

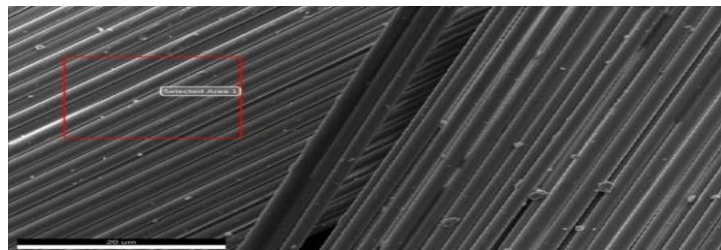


Fig:5.2: SEM image Basalt fiber after heat press

The sem analysis of basalt fiber is shown in figure 5.2. From the fig it is clear that

the fiber is arranged in uni directional. Also it is better arranged than the fiber glass. In the image few pores are observed. It is because of heat press done using machining processes. This pores leads to reduce properties of the composites.

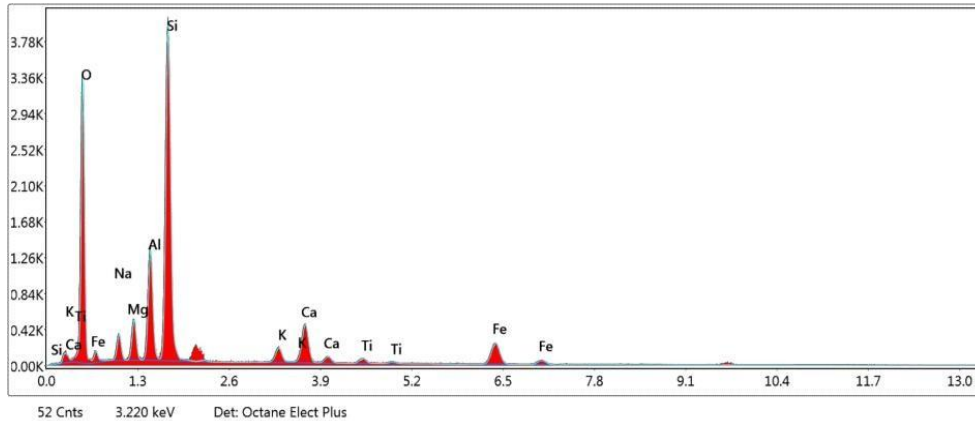


Fig. 5.3 EDAX reports

The EDAX report is shown in figure 5.3. From the EDAX report the various elements present in the composites is observed along with its peak point. The elements are represented in weight percentage in the report. The Silicon and oxides level seems to be high than the other elements.

Table 5.1 EDAX reports.

Elements	Weight %
O K	43.24
NaK	3.54
MgK	3.55
AlK	8.52
SiK	25.18
K K	1.88
CaK	5.95
TiK	0.89
FeK	7.25

The table 5.1 graph and table display the number of different components in the material. The table demonstrates the percentage of those components. There are 9 components in total. Each of them is present in different quantities by weight

percentage

5.2 GRAPHITE POWDER

Graphite powder is used as an abrasive in composite materials for brake pads. Melting point of graphite powder is $3652^{\circ} - 3697^{\circ}\text{C}$. Due this it improves the composite survival at higher temperature range. It is used in brake linings, foundry facings, lubricants, etc.

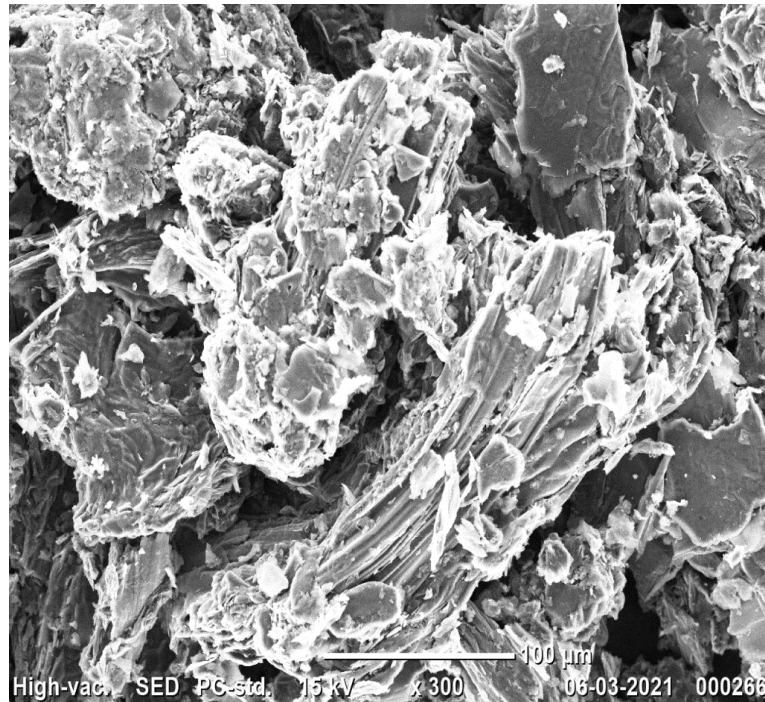


Fig. 5.4 SEM image of Graphite

Figure 5.4 shows the sem image of Raw Graphite powder. From the report it is observed that the arrangement of powder is cluster is in format. Also from the image it is observed that the grain boundaries are in dendrite regions. But the there is no uniform distribution of of the elements.

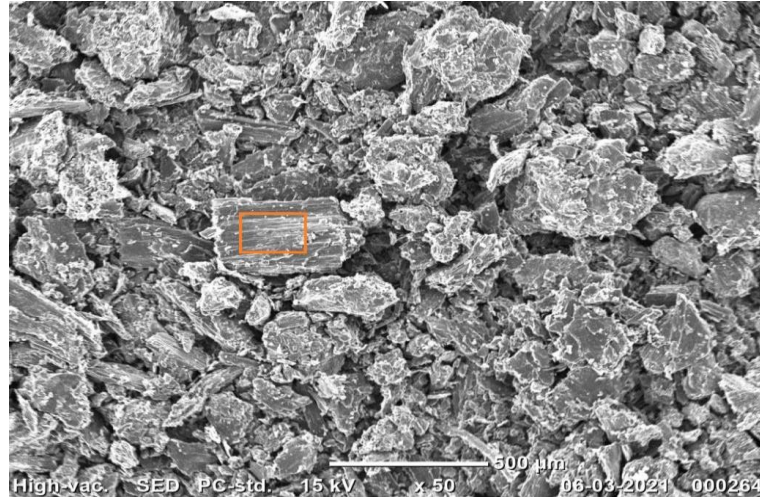


Fig. 5.5 SEM image of Graphite after heat press

Figures 5.5 are SEM images of graphite powder after heat press. The image clarifies that there is uniform distribution of the reinforcement is observed. Also minimum porosity is observed which proves for better bonding. But when the reinforcements are done with all composites, more porosity is observed which reduces the hardness and bonding strength. This weak bonding strength does not stabilize for going to mechanical testing as the composites are cracking during the testing. It is used as friction coefficient stabilizer. Both noise performance and thermal conductivity are highly effected by graphite. Graphite is important element used in brake linings and clutch linings. It also helps in improving brake comfort.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

The work carried out with the preparation of composites materials for brake pad. The composites were prepared by reinforcing the following the composites at various composition. Basalt fiber, Steel glass, Aluminium Oxide, Graphite powder and Phenolic resin are the composites materials used for reinforcement by varying weight percentage. For the preparation of samples first die was fabricated through machining processes with the required dimensions. Then the samples are blended and heat pressed. The prepared samples were left for natural drying for two days. Then the samples were taken for microstructure study and mechanical characterization. After the microstructural study it was observed that as there is no uniform distribution of composites and due to more porosity, the samples were failed to for mechanical testing. Even though tried one sample for testing which leads to cracking as it is not able to with stand the hardness.

6.2 Conclusion.

The primary objective of the investigation is to develop a composite material for automotive brake pads used for two wheeler braking system and has not been successful. These new fibre reinforced composites consist of graphite and aluminium oxide. Optical analysis of materials show that the results did not occur as expected.

The second objective was to conduct various mechanical tests required for the same. The specimens couldn't survive tests as they had some amount of moisture held in it. The composite samples were not hard and brittle as required to pass the compression test and wear test.

The third objective was to study material properties of the composite material prepared. The study showed deficiency of mechanical properties required for a brake pad material. Even though the basalt fibre is natural fibre with high thermal conductivity but the bonding of fibre with the help of phenolic could not take place. Zinc was added to composite material to increase hardness but alone Zinc was not sufficient. The testing helped us compare their mechanical properties and verify with the superior performance composites. Therefore, in conclusion the

basalt fibre and steel slag composite is not suitable for the brake pads material.

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