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Fabrication of Disc Brake Rotor using Metal MatrixComposite.

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ABSTRACT

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction. The brakes are very important aspects of a vehicle as it fulfils all the stopping functions and requirements. The following work is about the disc or rotor of disc brake. A disc brake is a type of brake that uses callipers to squeeze pairs of pads against a disc or "rotor" to create friction. The disc is usually made of cast iron but may in some cases be made of Stainless steels Due to these causes Weight of the disc was high, and another important Disadvantage was wearing because of Friction was higher these leads to heat generation over the rotor, corrosiveness. The objective of this project is to reduce rotor weight and reduce the thermal gradient by replacing the conventional material to metal matrix composite. The MMC selected for rotor was AA6061+12%RHC which is compared to the existing material it can reduce the weight and also have high heat conductivity. The Modelling of Rotor has been done in Autodesk fusion 360, and Analysis in an ANSYS workbench. And thereafter the final stage the Material should been cast by using the Stir casting method.

Keywords: Disc Brake Rotor, Metal Matrix Composites, AA6061, Rice Husk Ash.

I. INTRODUCTION

Disc Brake:

Brake system of automobiles is an important part of the safety feature. Brakes help in controlling the speed of the vehicle, either slowing down or stopping within a safe distance to provide both safety and control. There are many types of brakes based on their operating mechanism like pneumatic brakes, mechanical brakes, magnetic brakes, etc. Mechanical brakes work by converting the kinetic and potential energy possessed by the vehicle into thermal energy and dissipating it to the surrounding. Due to braking, friction forces are developed which opposes the relative motion between the stationarypart, i.e., the brake pads and the rotating part, i.e., the disc or the drum. In braking, kinetic friction comes into play as the relative motion is there between the pads and the disc. Kinetic friction is a non- conservative friction resulting in generation of heat. Disc brakes are one of the mechanical brakes mostly in use today. Disc brakes are known for their ease of application, ease of maintenance, reliability, better time response, better cooling, and their ability to with-stand higher temperatures than the drum brakes.

When the brakes are applied, the brake fluid is pressurized to move from the master cylinder to the slave cylinder through the hoses and pushes the pistons of the slave cylinder. The pistons of the slave cylinder move the friction pads axially into contact with the disc retarding the motion of the vehicle.

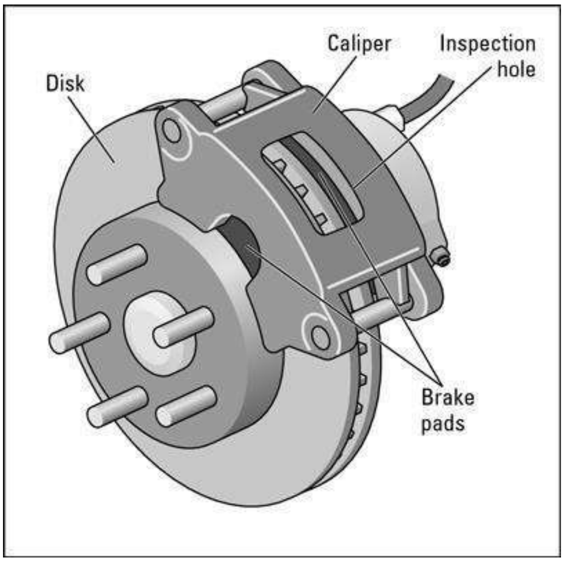

Figure 1.1

AA6061:

Aluminium 6061 is one of the most used and versatile alloys. Because it possesses such significant strength for many structural applications, it is often called structural aluminium. When designing a custom extruded shape for a structural application, it is best to include generous corner radii both to increase the strength of the design and ease of extrudability. The chemical properties of these 6061 alloys enable its effective use in wide-ranging applications including specially designed custom extrusion shapes**.**

Rice Husk Ash:

Rice husk ash (RHA) is formed as a byproduct when rice husks are burned or exposed to high temperatures under controlled conditions. Rice husks are the outermost layer of rice grains and are rich in silica ($SiO2$), making them a valuable source of this material.

II. LITERATURE REVIEW:

Mit Patel.et al, has been investigated of thermo mechanical behaviour of break disc was carried out. The Coupled thermo Structural analysis determined Von misses stress and hence the performance of life of rotor disc was calculated. Experiment wit0h different disc geometries and analysis through Ansyswere compared. 18 different models are modelled by using Orthogonal Array in Taguchi method and their thermo-structural behaviours investigated. The FEA analysis is carried out and compared with Taguchi result. Among all set, 10 mm diameter of hole having 5 mm of circular pitch and 9 mm of radial pitch give best 20 % of weight reduction.

Anurag Parag Borse, has been investigated with the help of the calculation procedure the disc was designed as per the assumed weight of the bike. The below table represents the result out of the calculation of the disc. The Thermal analysis was performed on the disc rotor with the help of the Ansyssoftware.

Akshay Naikwadi.et al, has been investigated Maximum stress and displacement is within control andyielding a factor of safety around 1.5 necessary for Disc brake. Existing brake disc weight 1.746kg. The Von mises stress and the maximum displacement are found 364.7MPa and 0.9mm. which is less than the yield strength of disc material so disc will be safe against load. Shape optimization brake disc weight1.528kg hence up to 14% optimization possible than brake disc. The Max. Von mises stress and the maximum displacement is found 421MPa.and.1.28mm. which is less than the yield strength of disc material so disc will be safe against load.

Anjali Ashok Shinde.et al, has been investigated Modal analysis of hydraulic brake is performed to getdifferent mode shapes and natural frequency of existing 4-wheeler hydraulic brake. Static structural analysis of hydraulic brake is performed to see deformation and equivalent stress. It is observed around maximum deformation is 0.0108 mm and equivalent stress is 16.76 MPa.It's concluded that the region indicated in the pit in topology optimization provides information regarding removal of material from that area it is about 55.53% to original mass.

S.R. Durgavad.et al, has been investigated for derived result from the modification and analysis of disc brake, we can conclude that modification shape 5 is the best outcome for using as rotor disc in a disc brake. Also, the weight of the disc is reduced by 0.11265 kg.

Hovorun T. P.et al, has been investigated Thus, we can conclude that the automotive industry is not standing still and developing to the satisfaction of the consumer who wants a fast and safe car. At the expense of innovative development of automobile industry, it is possible to realize competitive products both on the national and international markets, which will ensure the country's entry into the international economic community. This leads to the fact that in the production of cars used increasingly new materials that meet modern requirements.

Kenneth Kanayo Alaneme.et al, has been investigated in this research that the results show that Hardness decreases with increase in the weight ratio of RHA and graphite in the composites; and with RHA content greater than 50%, the effect of graphite on the hardness becomes less significant. The tensile strength for the composites containing o.5wt% graphite and up to 50% RHAwas observed to behigher than that of the composites without graphite. The toughness values for the composites containing 0.5wt% graphite was in all cases higher than that of the composites without graphite. The %Elongation for all composites produced was within the range of 10e13% and the values were invariant to the RHA and graphite content.

Hammar Ilham Akbar.et al, has been investigated Studies on composite reinforcement using industrialand agricultural wastes show that the waste has high economic potential due to its use as reinforcementfor metal composites. The addition of reinforcement from industrial and agricultural wastes shows an increase in mechanical properties. In addition to improving mechanical properties, another advantage is the reduction of industrial and agricultural waste. Especially for agricultural waste, the release of oxides into the atmosphere due to decay or combustion processes will be reduced. This paper review suggests that researchers utilize waste from local potential as raw material, development, and production of metal matrix composites.

Lü Hui.et al, has been investigated in an engineering application, uncertainties with and without sufficient information may exist simultaneously. For this case, a hybrid uncertain model with probabilistic and interval variables is introduced to deal with the optimization problem of squeal reduction for a disc brake system in this paper. To explore the optimal design of a disc brake system for squeal reduction, a model of the optimization design based on reliability and confidence interval is constructed by using the methods of RSM.

Avinash Bhat.et al, has been investigated the results of the newly developed composite of Al6061 and 5% SiC (silicon carbide) has shown better wear characteristics as compared to Al6061. Also, there is an appreciable enhancement in hardness value of the new composite. The knowledge base is enhanced with the insight that both RPM and load has a greater influence on the specific wear rate at constant load, as the RPM increases wear also increases. Similarly, at constant RPM, as the load increases wear increases. At constant RPM, with the increase in load the wear was found greater in the case of Al6061than it was for Al6061- SiC.At constant load, with the increase in RPM the wear was also found greater in the case of Al6061 than Al6061-SiC. It is therefore concluded that a reinforced SiC Metal Matrix Composite has better characteristics than an unreinforced Al6061 alloy.

Ji-Peng Chen has been Reviewed that in recent years, an increasing number of SiCp/Al composites withhigh-SiC fraction, e.g., 50%, 55%, and 65% (volume fraction), have attracted the attention of investigators. For these high- SiC fraction SiCp/Al composites, turning and milling processes are adopted, and nonconventional processes such as EDM, BEAM, and Jet- ECM are also preferred by researchers. It is concluded that there will be more machining methods and investigations regarding high-SiC fraction SiCp/Al composites in the future.

III. METHODOLOGY:

The methodology involves the technology utilized for performing the designing and analysis of the object.

CAD process:

- Define the geometric parametric of rotor.
- Draw the model of rotor using cad software.
- Analysing of cad model.
- Compute the numerical result.

CAM process:

- Selection of material and reinforcement.
- Experimental setup and fabrication.
- Mechanical testing.
- Result discussion.

IV. CAD PROCESS:

Defining the geometric parametric of rotor:

PARAMETERS	DIMENSIONS(MM)
outer diameter	240mm
inner diameter	180mm
hole diameter	5mm
number of holes	36
pitch diameter	5mm

Table 4.1

Drawing the model of rotor using cad software:

The model of disc brake in designing software Autodesk Fusion 360.

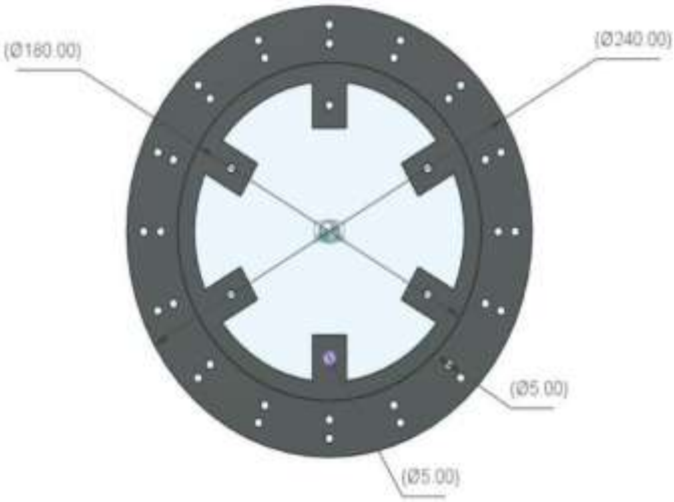

Figure 4.1

Analysing of cad model:

1. Static Structural Analysis

In this analysis we applied braking pressure at the one surface, and we got two outputs.

- Equivalent Stress (von-Mises)
- Total Deformation 2.Steady state thermal analysis

In this analysis braking pressure is applied with boundary condition like ambient temperature (100 ˚C), convective heat transfer coefficient (22˚C W/m2 K) based on Assumption. Output from this analysisis,

- Temperature

As above properties the Disc Rotor Was modelled and by using Analysis software Ansys2023 R1 Resultwas Obtained and compare with existing material stainless steel is shown as follows,

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1. **Static Structural Analysis:**
- **Equivalent Stress (von-Mises)**

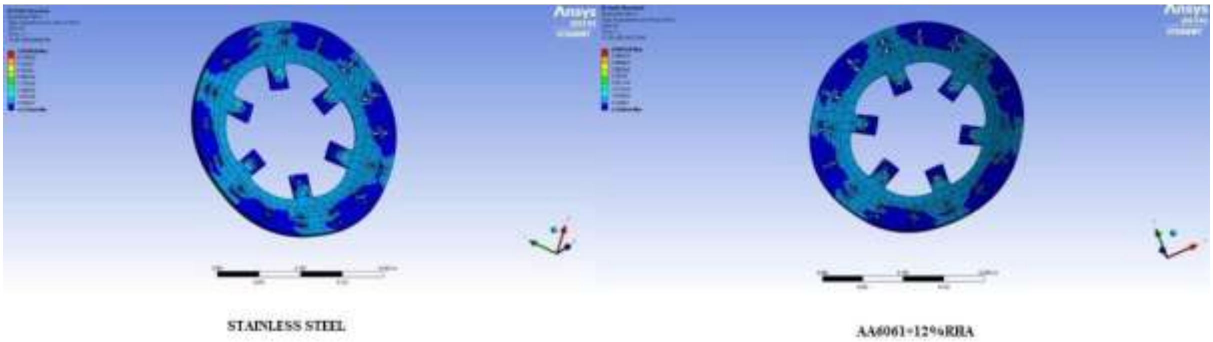
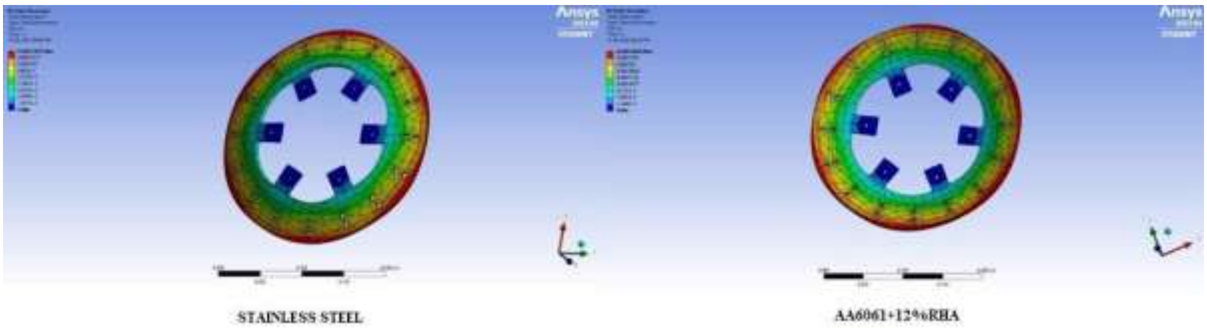


Figure 4.2

- **Total Deformation**

Figure 4.3



2. **Steady state thermal analysis:**
- **Temperature**

Figure 4.4

COMPUTING THE NUMERICAL RESULT:

1. **Static Structural Analysis:**

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Equivalent stress

Disc Material	Max (pa)	Min(pa)
Stainless steel	7.09838E8	4.7334E6
AA6061+12% RHA	4.4905E8	2.7609E6

Table 4.2

Total Deformation

Disc Material	Max (m)	Min(m)
Stainless steel	0.00013025	0
AA6061+12% RHA	0.00024699	0

Table 4.3

2. **Steady state thermal analysis:**
Temperature

Disc Material	Max (˚C)	Min (˚C)
Stainless steel	100.1	98.197
AA6061+12% RHA	100	99.44

Table 4.4

V. CAM PROCESS:

Selection of material and reinforcement:

AA6061

RICE HUSK ASH

Table 5.1

Properties of aluminium 6061:

PROPERTIES	VALUE
Density	2.70g.cm 3
Ultimate tensile strength	241 Mpa
Yield tensile strength	145 Mpa
Modulus of elasticity	68Mpa

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Thermal Conductivity	154 W/m-K | 1070 BTU-in/hr- ft²-°F
Poisson Ratio	0.28
Coefficient of Thermal Expansion @ 20.0 – 100 °C Temp	23.6 µm/m-°C

Table 5.1

Chemical properties of rice husk ash:

SI.NO	PARTICULARS	PERCENTAGE (%)
1.	Silicon dioxide	86.94
2.	Aluminum oxide	0.2
3.	Iron Oxide	0.1
4.	Calcium oxide	0.3-2.2
5.	Sodium oxide	0.1-0.8
6.	Potassium oxide	2.15-2.30
7.	Magnesium oxide	0.2-0.6
8.	Loss on Ignition	3.15-4.4

Table 5.2

EXPERIMENTAL SETUP AND FABRICATION

Die designing and fabrication:

Designing of model:

Sketch and development of 3D Model,
In this step we made the model of die was designed in MASTERCAM software.

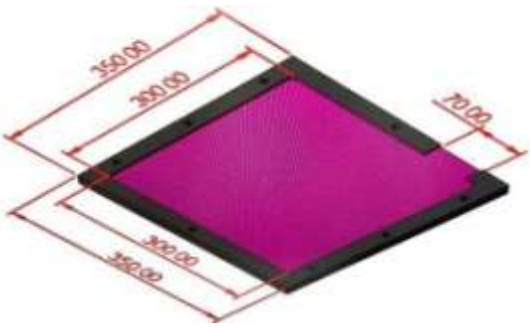

Figure 5.2 die design

Fabricated die:
The Fabrication of the Die was Done by the HURCO VMX30 4-Axis CNC Milling MACHINE shown in Figure

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Figure 5.3 Fabricated die

Casting process:

A weighted quantity of the AA6061 Al alloy was melted in Teflon coated crucible of 1.2 Kg capacity using a small electrical furnace and the melt was preheated by about 250oC metal was stirred using a mild steel impeller at a speed of 60 RPM to create the vortex. The impeller blades were designed such that it creates a vortex to achieve the particle mixing. The impeller blades were coated with a zirconium-based coating to minimize blade dissolution in molten metal. The stir casting setup and stirring processis shown in Figure 8.3.

Figure 5.4 stir casting setup.

During the process, the molten metal was well agitated by a mechanical stirrer to create turbulent motion. The depth of the immersed impeller was approximately two-thirds of the height of the molten metal from the bottom of the crucible and the speed of the stirrer was maintained at 60 RPM. The reinforcement particles were artificially oxidized in air at 800oC for 120 minutes to form an oxide layer on them and thereby improve their wettability with molten aluminum. Preheated reinforcement particleswere then added into molten metal by using metal funnel and spoon. The stirring action was continued during the addition of reinforcement particles. The stirring action continued for around 20 minutes. The composites have been 11 percent weight fraction of reinforcements. The composite slurry was then poured into the mild steel die, which was preheated to about 300oC. The MMCs (Metal Matrix Composites) were fabricated for the combination of AA6061+12%RHA. The combination for MMC (Metal Matrix Composites) fabrication was selected based on wear testing samples requirements, Characterization is important for ensuring quality of composite after its fabrication through conventional stir casting process. The uniform distribution of particles on soft matrix is the most important problem in stir cast composites. By evaluating micro hardness and Tensile along the length of casted composites and microstructure analysis helps to verify the reinforcement distribution on composites.

Table 5.3

Aluminium 6061(%)	Rice husk Ash (%)
88	12

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Figure 5.5

Disc plate fabrication process:
MasterCAM is a Three-dimensional geometry creation engine along with features to aid in tool path generation and verification. MasterCAM allows tool path planning and NC code generation for given part. The part which Drawn in MasterCAM 2022 was shown in Figure 8.6.

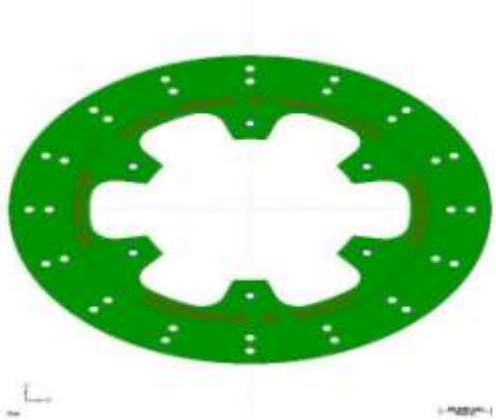

Figure 5.6

Tool path generation:
The generation of Tool Path Was generated by using MasterCAM, following notes should be created,

- Extensive Tool Library
- Machining Parameter Selection
- NC Program Generator
- Animation to visualize machining Operation.

A set of tool Paths and Positions can be Automatically generated, These Paths Can be edited and modified. The paths and instructions can then be 'Posted' to a Specific Machine.

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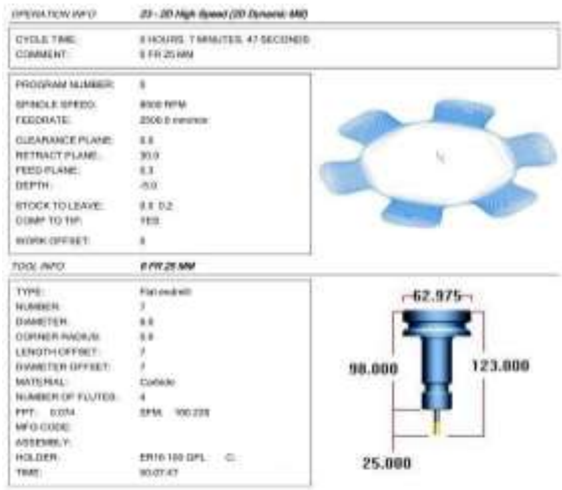

Figure 5.7 Tool Path generation sample **Figure 5.8 Operation sequence order**

Verification of cad model:

The verification of cad model was verified by using MasterCAM simulator, this interface helped us to clear idea about Machining Process. A Verification Process is final stage of CAD Process.

The CAD model was Fed into the interface and simulation process was shown in figure

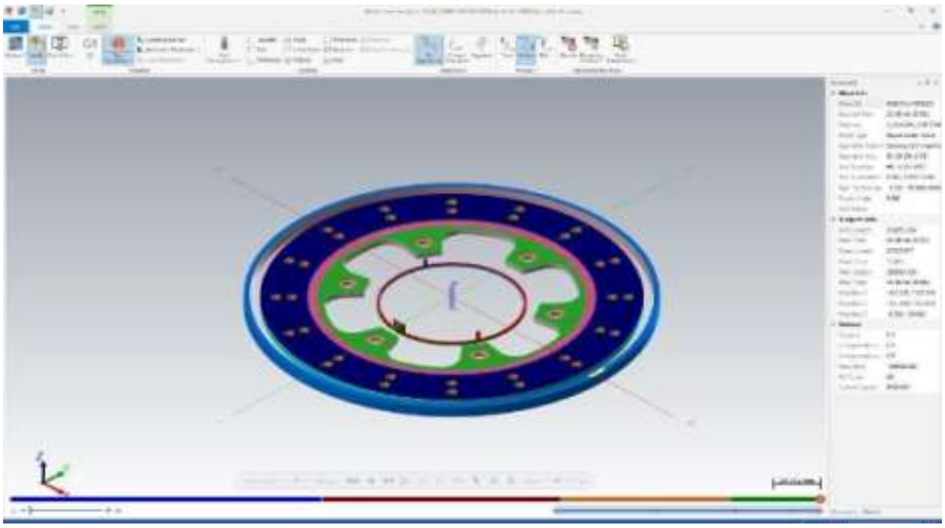

Figure 5.9 Verification of CAD Model

NC code generation for cad model:

The NC CODE was generated for the Disc plate was shown in figure 5.10A and 5.10B.

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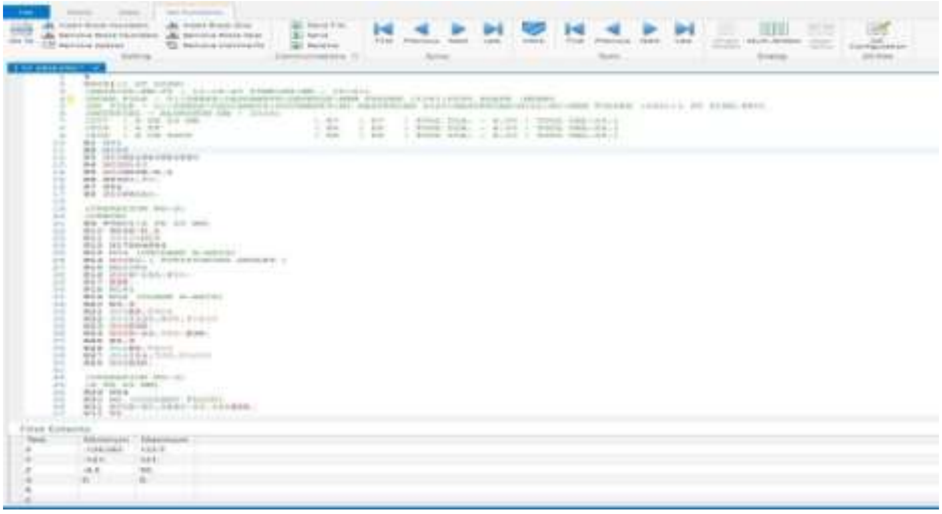

Figure 5.10A

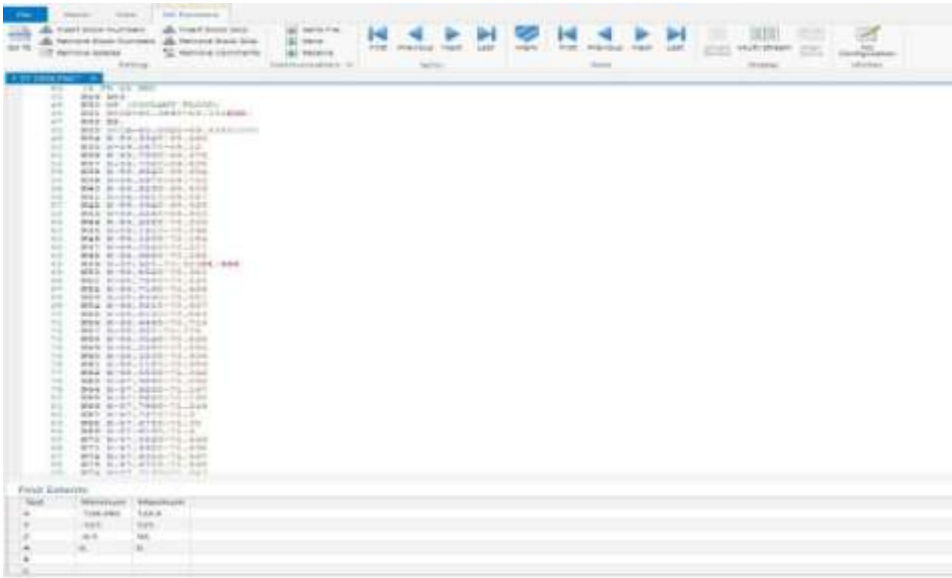

Figure 5.10B

Machining process:

The Machining process of the Casted material was Done by the HURCO VMX30 CNC 4-AXIS MILLING MACHINE at Decimal Engineering Pvt Ltd. Chennai, shown in Figure 5.11.

Figure 5.11

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When the NC Program was generated, it was feed into a CNC milling machine the Casted Material wasFixed on Bed of CNC milling machine is shown in Figure 5.12.

Figure 5.12

After the Machining Process, The Milling was done successfully as per CAD model is shown inFigure 8.13.

Figure 5.13

MECHANICAL TESTING

Hardness test:

Hardness is a surface property and can be defined as. the resistance to scratch or penetration or indentation. From the literature, it is seen that the addition of reinforcements enhances microhardness and the wear resistance of the composites. The AA6061+12%RHA composites were evaluated on a Rockwell Hardness with a Dimond indenter. ASTM E10 standard was followed, and the load applied for test was 100 kgf.

Tensile test:

The tensile test is often performed on the material to assess the yield strength, tensile strength, and % elongation. Tensile samples were prepared as per the ASTM E8 standard and the tests were performed on the universal testing machine (Make: FIE, model: UTN) with a strain rateof 1 mm/min and a maximum load of 40 KN.

Wear test

Wear is the progressive loss of material that occurs due to the interaction of materials themselves or interaction with the hard particles. A computerized pin-on-disc sliding wear testing machine (Model TR-20LE- CHM400) was used. In this work, the drysliding wear tests were performed as per the ASTM G99 standard on the fabricated composite of pins featuring hemispherical tips with a load of 30 N. The sliding distance and velocity were maintained at 1500 m and 7.5 m/s, respectively. The pin specimen issecurely clamped in place while in contact with a rotating disc made ofEN-31 steel.

Stopping distance test

The braking distance is one of two

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principal components of the total stopping distance. The other component is the reaction distance which is the Product of The Speed and the perception-reaction time of the driver rider. This Test Was performed by Disc Brake Test Rig.

Figure 5.14 Disc Brake test Rig

Scanned electronic Microscope (SEM)

SEM (Scanning Electron Microscopy) is a powerful imaging technique used to visualize the surface morphology and microstructure of materials at a high resolution**.** The SEM Analysis was performed in the Sample only for a Proof of the RHA reinforcement was Added in the AA6061 and Distribution Of reinforcement in a Metal Matrix Composite.

VI. RESULT DISCUSSION

Effect of reinforcements on the hardness

The composite materials are often said to have higher hardness than the base alloy owing to their two-phase structure i.e., ductile matrix and hard reinforcement phase. The addition of reinforcements impedes the dislocation motion which in turn increases the hardness of the composite. The Rockwell Hardness Test was performed on the given sample and the value was observed in "C" scale by thrice thus the average value was noted. The Test shows that the Depth of Dimond indenter was decreased in a AA6061+12%RHA sample Compared to the Existing AA6061, Due to this case the Hardness of the Material was increased against Exist material. The average value of Rockwell hardness number (HRC) was shown in below Table 5.4.

SI.NO	SPECIMEN	HRC 1	HRC 2	HRC3	AVERAGE HRC
1.	AA6061	83	88	84	85
2.	AA6061+12% RHA	57	55	59	57

Table 5.4

Effect of reinforcements on Tensile Test:

The Interpret the tensile test results and discuss the implications of incorporating RHA into the AA6061 alloy. Assess whether the addition of RHA has resulted in improvements in the composite's mechanical performance compared to the base alloy. When the addition of 12% RHA in a AA6061 the ultimate tensile Strength was increased about 11% and the Ultimate yield Strength was also increased up to 33%. The tensile test report was tabulated below Table 5.5.

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SI.NO	SPECIMEN	ULTIMATE TENSILE STRENGTH (Mpa)	ULTIMATE YEILD STRENGTH (Mpa)
1.	AA6061	325	234
2.	AA6061+12%RHA	361	312

Table 5.5

Wear resistance analysis:

In my project the Wear Test was compared with existing material of Disc Plate, which is Stainless steel, basically the stainless steel have quit good compare to AA6061 in nature of densityand hardness, but Addition of 12%RHA the wear behavior was increased about 65% The comparison of Wear Percentage is shown in Table 5.6.

WEAR % OF STAINLESS STEEL	WEAR % OF AA6061+12%RHA
0.42%	0.29%

Table 5.6

Effect of Stopping Distance Test:

The stopping distance was the important Parameter for the disc brake system. While in this test full braking was applied on Disc plate by using Test rig the Distance that obtained in Fabricated disc brake was about 3.26m during the test disc was rotated about 1330RPM , when This result was compared to existing Disc plate which is comparatively excellent performance have been gathered, because the stopping distance stainless steel disc was about 6m only.

SEM analysis result:

The Scanned Electron Microscope (SEM) was performed on the surface of the Given sample it shows that the 12%RHA was Distributed properly and The SEM image figure 10.1 Shows the evidence that the RICE HUSK ASH (RHA) was Added on Base metal AA6061, respectively.

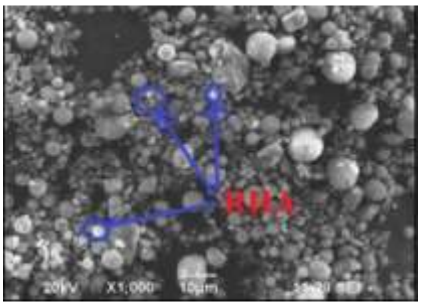

Figure 5.15.

VII. CONCLUSION

The weight of the Fabricated brake disc was 4XTIMES of Existing disc Brake, That the Existing Disc Weight was About 1200g, but the Fabricated Disc was weighing at 300g hence major Weight was Decreased in Braking System of vehicle helps to increase the Full economy and suitable for Electric Vehicle. This Project Results concluded that the Adding of 12% RHA in AA6061 mechanical Behaviors was increased such as ultimate Tensile strength about 11% and ultimate yield strength was also increased about 33%. The Hardness of the AA6061 was also increased while the addition of RHA in MMC. The Stopping

Distance of the fabricated disc was reduced comparatively to existing disc brakeby 6m to 3.2m at 1330 while applying the full Braking. The Rice husk ash is agricultural waste generated by paddy milling and can be used for reinforcing a material to produce aluminum Metal matrix composite. It can be successfully used in place of conventional aluminum intensive material.

The use of rice husk ash for the production of metal matrix can turn agricultural waste into the profitable wealth of industry. This can also solve the problem of storage and disposal of rise husk ash. From the work it can be concluded that RHA can be successfully incorporated into pure aluminum matrix to produce composites.

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