Static Structural Analysis of a Four-Wheeler Disc Brake using Different Materials on ANSYS- A Review Study

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Abstract— Braking system is an important component in any automobile. Whenever any automobile is in moving condition we need some system to stop or decelerate the vehicle as & when rush appears or pits appear in the road. Braking system is employed for this vary role. Brakes of different types but for study I have considered disc brake rotor here. Vehicle to be selected is an Audi TT Mk3 Coupe. Conventionally Gray cast iron has been used for manufacturing the disc brake rotors but it is accompanied by a large weight which in turn increases the overall weight of vehicle. This increased weight increases the losses occurring in the vehicle during movement. It also reduces the brake efficiency. To counter these two problems we must go for some other materials which can have lower weight & higher tensile strength, compressive strength etc. In this particular study six different materials have been tried & tested. These materials are Aluminium wrought, Aluminium alloy, aluminium alloy NL, carbon fibre, carbon epoxy UD, Carbon E-Glass epoxy UD. These materials have been analysed for equivalent (von-Mises) stress, total deformation, maximum principal stress & stress intensity. In the end a comparative analysis has been presented. In order to develop the model of disc brake rotor for conducting analytical solution in software, CATIA V5-6 R2017 software will be used to develop the model & ANSYS 19.2 will be used to analyse the model.

Keywords: Four-Wheeler Disc Brake, ANSYS, Aluminium alloy

I. INTRODUCTION

A brake is a mechanical device which inhibits motion by means of soaking up strength from a transferring machine. It is used for slowing or stopping a transferring car, wheel, axle, or to prevent its motion, most customarily completed by using friction. Most brakes typically use friction among two surfaces pressed together to transform the kinetic power of the shifting object into warmth, although different techniques of electricity conversion can be hired. For example, regenerative braking converts much of the energy to electric power, which can be saved for later use. Other methods convert kinetic strength into ability power in such stored forms as pressurized air or pressurized oil. Eddy cutting-edge brakes use magnetic fields to transform kinetic power into electric powered modern-day inside the brake disc, fin, or rail, which is converted into warmth. Still different braking methods even transform kinetic strength into specific paperwork, for instance by using moving the strength to a rotating flywheel. Brakes are commonly applied to rotating axles or wheels, however may take different kinds consisting of the surface of a moving fluid (flaps deployed into water or air). Some vehicles use a combination of braking mechanisms, along with drag racing vehicles with both wheel brakes and a parachute, or airplanes with each wheel brakes and drag flaps raised into the air at some stage in landing.

A. Disc Brake

A disc brake is a form of brake that uses calipers to squeeze pairs of pads towards a disc or "rotor" to create friction. This action slows the rotation of a shaft, which includes a automobile axle, both to reduce its rotational pace or to preserve it stationary. The strength of motion is transformed into waste warmness which needs to be dispersed. Hydraulically actuated disc brakes are the maximum normally used form of brake for motor, but the ideas of a disc brake are applicable to almost any rotating shaft.

B. Composites

Composite material (additionally known as a composition fabric or shortened to composite that is the commonplace name) is a material made from two or more constituent substances with considerably considered one of kind physical or chemical residences that, even as mixed, produce a material with characteristics precise from the individual components. The character components remain separate and wonderful in the finished form, differentiating composites from combinations and strong solutions. The new fabric may be favored for plenty motives. Common examples encompass substances which is probably stronger, lighter, or much less expensive while in comparison to traditional materials.

More currently, researchers have additionally all commenced to actively encompass sensing, actuation, computation and communication into composites, which might be referred to as Robotic Materials.

II. LITERATURE SURVEY

Deepansh Mathur et al. [1] Studied about the layout & optimization of a disc brake rotor. They studied approximately the strategies to lessen the friction generated in the course of braking procedure due to the fact it can purpose major energy wastage. Results of their take a look at showed that the fabric caused a weight reduction of approximately 50% & they also achieved development in preventing distance due to modern layout. They hired this disc on SAE BAJA's ATV to complete the brake take a look at. All the calculations had been based at the ATV.

Santosh kumar Kallepalli et al. [2] Studied about the enhancement in layout & thermal evaluation of a disc brake rotor. According to them the contributions of composite materials are appreciable however solid iron is normally used material for disc brake. Composite substances are much less in weight and have more power to weight ratio which can be chosen as an exchange fabric for disc brake. The substances used are Cast Iron, Aluminium and

Aluminium Composite. Actual disc brake rotor has no extrusions over the brake rotor. Modelling is achieved in Catia V5 and Thermal Analysis is completed in FEA using ANSYS.

Sarip [3] studied about the design development of a light weight disc brake for regenerative braking. According to this study the automotive industry has for many years identified weight reduction as a way of improving product competitiveness and thus the ability to make profits. One area that has been examined for weight reduction is vehicle with regenerative braking system (RBS). Ultimately a design method for lightweight brakes suitable for use on any car-sized hybrid vehicle was used from previous analysis.

Akshay Pophale et al. [4] conducted an ANSYS analysis of a disc brake rotor of a two wheeler. According to his statement Noise and vibration associated with the braking process in passenger automobiles has become an important economic and technological problem in the industry. The knowledge of natural frequencies of components is of great interest in the study of response of structures to various excitations. FEM software package is used for vibration analysis of brake discs the disc brake is modeled using commercial computer aided design (CAD) software, Ansys.

Ali Belhocine et al. [5] studied about the Effects of material properties on generation of brake squeal noise using finite element method. According to his study this work is concerned with the disc brake squeal problem for passenger cars. The aim of the present research is developing a finite element model of the disc brake assembly in order to improve understanding of the influence of Young's modulus on squeal generation. A parametric study is carried to look into the effect of changing Young's modulus of each brake components on squeal generation. The results of simulation indicated that Young's modulus of disc brake components play a substantial role in generating the squeal noise.

Avinash Singh thakur et al. [6] Studied about the thermal analysis of a disc brake using ANSYS workbench. He stated that the disc brake is a mechanism that used for reducing speed or discontinuing the cycle of the vehicle. Many times using the brake for vehicle starts to heat producing during braking process, such that disc brake undergoes breakage due to high Temperature. A comparison between the two materials for the Thermal values and material properties obtained from the Thermal analysis low thermal gradient material is preferred. Hence best appropriate design, low thermal gradient material cast iron is chosen for the Disc Brakes for better result.

Amr M. M. Rabia et al. [7] studied about the vibrations being generated in a disc brake system of an automobile. He revealed that Friction-induced vibration of disc brakes is a topic of major interest and concern for the automotive industry. Customer complaints result in significant warranty costs yearly. In the present paper, a detailed experimental study of the disc brake vibration is performed on a simplified brake dynamometer. The preliminary brake dynamometer consists of three subsystems, namely driving unit, braking unit and measurement facilities. There are approximately twenty seven vibration tests are conducted at various operating conditions such as different brake-line pressure and disc speeds.

A. Belhocine et al. [8] Studied about the numerical modeling of a disc brake rotor in frictional contact. He stated that safety aspect in automotive engineering has been considered as a number one priority in development of new vehicle. Each single system has been studied and developed in order to meet safety requirement. Instead of having air bag, good suspension systems, good handling and safe cornering, there is one most critical system in the vehicle which is brake systems. The objective of this work is to investigate and analyze the temperature distribution of rotor disc during braking operation using ANSYS Multiphysics.

Manjunath T V et al. [9] studied about the structural & thermal analysis of rotor disc of disc brake and he stated that the disc brake is a device for slowing or stopping the rotation of a wheel. Repetitive braking of the vehicle leads to heat generation during each braking event. A comparison between analytical and results obtained from FEM is done and all the values obtained from the analysis are less than their allowable values. Hence best suitable design, material and rotor disc is suggested based on the performance, strength and rigidity criteria.

Hui Lu et al. [10] studied about the stability optimization of a disc brake with hybrid uncertainties of squeal reductions. He introduced a hybrid uncertain model to deal with the uncertainties existing in a disc brake system in this paper. The combinational algorithm of Genetic Algorithm and Monte-Carlo method is employed to perform the optimization. The results of a numerical example demonstrate the effectiveness of the proposed optimization on improving system stability and reducing squeal propensity of a disc brake under hybrid uncertainties.

Peter Futas et al. [11] Studied about the failure analysis of a railway disc brake system with the use of casting process simulation. They stated that Software for modeling of industry processes is an integral part of production involving many segments of industry. Based on the results of these simulations, the shape of gating system and position of casting in mould was modified and the number of feeders has been reduced from 6 to 1. This technology modifications saves the liquid metal and the casting has been without shrinkages.

Ying Wu et al. [12] studied about the failure mechanism of severe abrasion of a high-speed railway brake on snowy days. Study tells us that the brake discs of high-speed trains undergo severe abrasion on snowy days, which damages the safety of railway transportation. In the present paper, the mechanism leading to severe abrasion failure of brake discs in snowy days was determined. To demonstrate the model, reduced scale dynamo tests were carried out to simulate the severe abrasion according to speculation of the model, and similar results consistent with the actual situation were obtained.

Riva Gabriele et al. [13] Studied about the simulation of disc brake wear & airborne particle emissions. This study stated that Emissions from disc brake wear adversely affect the air quality in cities. Finite Element Analysis (FEA) approaches focusing on the macroscopic wear of pads and rotors can be found in the literature, but none of these take the wear and emission dependence of the

local contact pressure and sliding speed into account. Results from a dyno bench test are compared with simulated results. The simulated rotor and pads wear, and airborne emissions are in line with the measured values.

G. X. Chen et al. [14] et al. studied about the effects of the braking pressure variation on disc brake squeal of a railway vehicle through test measurement & finite element analysis. Study shows us that In order to suppress or eliminate brake squeal of light rail trains, a field test measurement and a finite element analysis of disc brake squeal were carried out. In the field test measurement, the braking air pressure, speed of the axle, vibration accelerations of a backplate were measured. A transient dynamics of the model was also studied using the measured braking air pressure data as an input of the model. The squeal frequency measured in the field test is in a good agreement with the finite element prediction result.

A. Belhocine et al. [15] studied about the thermal analysis of both ventilated & full disc brake rotors with frictional heat generation. Study revealed that in automotive engineering, the safety aspect has been considered as a number one priority in development of a new vehicle. Each single system has been studied and developed in order to meet safety requirements. Instead of having air bags, good suspension systems, good handling and safe cornering, one of the most critical systems in a vehicle is the brake system. The objective of this work is to investigate and analyze the temperature distribution of rotor disc during braking operation using ANSYS Multiphysics. The work uses the finite element analysis techniques to predict the temperature distribution on the full and ventilated brake discs and to identify the critical temperature of the rotor. The analysis also gives us the heat flux distribution for the two discs.

M. D. Rajkamal et al. [16] studied about the structural & thermal analysis of the disc brake rotor. They stated that Disc brakes have been failing for quite a lot of times during extreme conditions of braking which eventually brings down the efficiency and performance of the disc rotor. Three existing materials that are Stainless Steel, Cast Iron and Carbon-Carbon Composite are being compared with Vanadium Steel to check for the maximum deformation, stress and temperature. The disc brake is modeled using Creo Parametric 3.0 and the analysis is done in ANSYS Workbench 15.0. By finishing the analysis, it is proved that Vanadium Steel has better strength and temperature distribution factors than the other three materials.

Jean Gabriel Bauzin et al. [17] studied about the analytical model developed to determine the 3D temperature distribution in a brake disc of a high-speed train. In this system, the brake pad is composed from multiple pins. A compensation term due to the fact that the surface of the spots is not negligible compared to the surface of the disc is introducing in the model. Indeed, the fact that the analytical model assumes a convection term on the friction surfaces, which is not the case, must be fixed. Then the analytical model is validated by comparing the results with those of a numerical simulation.

Deekshith Ch et al. [18] studied that a Brake is a mechanical device which is used to slowing or stopping a moving object or preventing its motion. Present work deals with structural and thermal analysis of disc brake rotor of a vehicle. CATIA V5R20 is used for the design and ANSYS 15.0 is used for the analysis of disc brake rotor. The objective of this work is to compare temperature distribution and heat flux of disc brake rotor of two different materials. After obtaining the analyzed results the manufacturing of the rotor for the best results is carried out using CNC machine.

Tanuj Joshi et al. [19] revealed that in today's era, brake designers of the greatest automotive companies are being pushed to their limits in search of an innovative design that leads to better safety of passengers, increased driver comfort and an ergonomically designed quick response system. Important parameters which decide the braking performance of a vehicle are deceleration, stopping distance, stopping time. For both static structural and thermal stress analysis. Temperature load was applied on the rotors and the temperature distribution was analyzed considering cooling parameters (convection). An attempt is also made to suggest a best combination of material and thickness used for disc brake rotor, which yields a low temperature variation across the rotor, less deformation, and minimum von mises stress.

Mahmood Hasan Dakhil et al. [20] studied about an optimized design for performance of disc brake using finite element analysis. Cast iron and stainless steel are used as disc brake materials. ANSYS 12.0 is a dedicated Finite element package used for determining the temperature distribution, variation of stresses and deformation across the disc brake. Further structural analysis is also carried out by Coupled Field Analysis. An attempt is also made to suggest a best combustion of material, flange width and wall thickness used for disc brake rotor, which yields a low temperature variation across the rotor, less deformation and minimum Von-misses stress possible.

Swapnil Umale et al. [21] Studied that these days' technologies go beyond us. For automotive field, the technology of engine develops very fast even the system of the car, luxury or comforts everything that develops by the innovation of engineer. Although the engineer gives priority for safety measure, but most consumers still have inadequate of knowledge in safety system. Thus safety is the first important thing we must focus. Hopefully this paper will help everyone to understand action force and friction force on the disc brake and how disc brake works more efficiently, which can help to reduce the accident that may happen in each day. Profile 3 is selected for further work as it gives better result.

C. Venkatesh et al. [22] stated that Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. The disc brake is a device for de-accelerating or stopping the rotation of a wheel. A brake disc (or rotor) usually made of cast iron or ceramic composites, is connected to the wheel and/or the axle. Friction material In structural analysis displacement, ultimate stress limit for the design is found and in thermal analysis thermal gradients, heat flow rates, and heat fluxes to be calculated by varying the different cross sections, materials of the disc. Comparison can be done for displacement, stresses, nodal

temperatures, etc. for the three materials to suggest the best material for FSAE car.

Yogesh h Mishra et al. [23] stated that these day technologies go beyond us. For automotive field, the technology of engine develops very fast even the system of the car, luxury or comforts everything that develops by the innovation of engineer. Therefore, we can estimate the efficiency of the disc brake. Hopefully this project will help everyone to understand action force and friction force on the disc brake and how disc brake works more efficiently, which can help to reduce the accident that may happen in each day.

B. Subbarayudu et al. [24] stated that Braking is a technique which converts the kinetic energy of an automobile into mechanical energy, which must dissolute in the form of heat A brake disc usually made of cast iron or ceramic composites, is attached to the wheel. Rubbing material in the form of brake pads is enforced mechanically, hydraulically, pneumatically or electromagnetically in opposition to both sides of the disc and prevents the wheel to rotate. The design is found and in thermal analysis, heat flow rates, and heat fluxes are considered by varying the dissimilar cross sections and materials of the disc brake rotor.

Mit Patel et al. [25] studied that Consideration for optimization of technical aspects in automobile is very important and necessary as there are large numbers of vehicles running on road today, so that part or product will be durable, safe and affordable to the users. The coupled thermal-structural analysis is used to determine the deformation and the Von Mises stress established in the disc to enhance performance of the rotor disc. A comparison between analytical and results obtained from FEA is done and all the values obtained from the analysis are less than their allowable values. Hence best suitable design will be suggested based on the performance, strength and rigidity criteria.

Swapnil R Abhang et al. [26] stated that each every single system has been studied and developed in order to meet safety requirement. Instead of having air bag, good suspension systems, good handling and safe cornering, there is one most critical system in the vehicle which is brake systems. The standard disc brake two wheelers model using in ANSYS and done the Thermal analysis and Modal analysis also calculate the deflection and Heat flux, Temperature of disc brake model. This is important to understand action force and friction force on the disc brake new material, how disc brake works more efficiently, which can help to reduce the accident that may happen in each day.

Hemraj Nimhal et al. [27] studied that the objective of this study is to analysis the thermal behaviour of the non-vented (solid) disc using ANSYS software. The Reliable and effectual braking is an imperative requirement of safe transportation. The disk brake generally has a high braking ratio and alleviates the thermal load of the wheels; therefore it has been extensively used in vehicles. Comparison study has been made between two different materials used for solid type disc brake and the best material for making disc brake have been suggested on the basis of magnitude of temperature distribution and total heat flux. The computational results are presented for the temperature distribution and heat flux on each friction surface between the disc and pad. After the investigation result of temperature distribution and heat flux of the Ceramic material was found excellent.

Sumit Satope et al. [28] studied that each single system of automotive along with brake system has come a long way in past years. In two wheeler brake system the material used for disc brake mostly is, alloy martensitic stainless steel and sometimes in high end bikes is carbon – carbon composite and grey cast iron. But when brakes is subjected to structural and wear issues it is important to study analytical calculation in order to obtain temperature, heat flux, heat generated etc. In this paper mathematical inputs, and thermal loads of brake rotor, calculations of different parameters required for thermal analysis is done by taking suitable assumptions. The design of brake rotor is done on solid works 15 and analysis is done with the help of ANSYS 14.5.

III. Conclusion

Disk brakes are important components now days for any automobile component. A lot has been done for the research work in case of disc brake. Several researchers have analysed disc brakes of trains, ATVs, Bikes etc. This research has been confined in just the structural analysis of disc brake. Here only stress & deformation analysis has been performed which has led to the introduction of some new materials for development of disc brake. These materials are basically composite materials. Now numerous researchers are working on these composite materials.

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