Design And Analysis Of Brake Disc With Prototype

By

K.Jaya Chakri[1], K.V.Venkata Ramana[2], M.M.Surya Vamsi[3], K.Guna Veera Swamy[4], M. Rambabu[5]

[1,2,3,4]B.Tech, [5]Assistant Professor, Aditya College of Engineering & Technology, Surampalem, A.P, India, 533437

Abstract

When a vehicle is in motion the only system which assists in stopping or retarding the motion is „brake system‟. Earlier block of wood wrapped in friction material such as leather, known as mechanical "scuff" brake were used. As the automotive technology ameliorated, they came across drum brakes. The working of drum brake is quiet simple, the effective function is the brake shoe pressure or force is applied against the drum which stops or retard the rotating moment of the drum. The next leap in brake system was the invention of Disc brake. Earlier disc brake where mostly made of cast iron, sandwiched between the stationary parts called as brake pads situated inside the brake calliper. In this paper we are presenting study of temperature distribution and stress distribution of brake rotor while brake is applied. 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 Catia V5 and analysis is done with the help of ansys 19. All the results are discussed thoroughly.

1. INTRODUCTION

Squeal noise generation during braking is an important economic and technical issue in the automotive industry. A re-evaluation of customers' requirements puts comfort high on the list of vehicle's major design considerations, in order to provide a competitive and attractive product to the public. Akay (2002) stated that the warranty claims due to the noise, vibration and harshness (NVH) issues including brake squeal in North America alone were up to one billion US dollars a year. Disc brake squeal noise is mainly due to friction-induced vibration caused by the dynamic instability of the brake system, which usually radiates noise in the audible frequency 1 kHz to 16 kHz. Various theories and methods have been proposed to explain and predict the brake squeal phenomenon. However, it seems quite obvious that none of them can explain all events related to the squeal noise. The theories related to squeal have presented challenging problems for researchers and engineers because of their complex nature, which involves multiple disciplines such as non-linear dynamics, contact mechanics, and tribology.

In the last few decades, a considerable amount of research has been done by many researchers on the possibility of eliminating brake squeal to improve vehicle users‟ comfort and reducing the overall environmental noise level. A good deal of progress has been made and a number of solutions have been suggested, for example, reducing the impulsive excitation, adding damping shims and shifting modal coupling. Despite these efforts, squeal still occurs frequently within the audible frequency range. Therefore, it is one of the most important issues that require a detailed and in-depth study for prediction as well as eliminating brake squeal.

1.2 BACKGROUND ON AUTOMOTIVE DISC BRAKE SYSTEMS

The most significant safety aspect of an automobile is its brake system, which must slow the vehicle quickly and reliably under varying conditions. There are many types of brake systems that have been used since the inception of the motor car, but in principle they are all similar. The main function of brake system is to retard the vehicle by transforming the kinetic energy of the vehicle into heat by friction, and this heat must be effectively and efficiently dissipating to the surroundings by the brake components. The principle of the disc brake was first patented by Frederick Lanchester in his Birmingham factory in 1902, but was not popular until the spectacular win by the Jaguar racing cars in 1957 that their advantages were visibly demonstrated to the motoring public. Since the early 1960s, disc brake systems have become more common form in the most passenger vehicles, although some of the passenger vehicles use drum brakes on the rear wheels to keep costs and weight down as well as to simplify the provisions for a parking brake. Since the front brakes perform most of the braking effort, this can be a sensible compromise. The present investigation is attempted to study squeal noise of the passenger cars, therefore disc brakes will be the focus of this work. There are two types of disc brakes, fixed calliper and floating

1.3 CALIPER

The fixed calliper usually contains two or more pistons that act directly on both the inner and outer pads. In order to increase the braking power two pistons or more can be used. The pistons attempt to stop the rotating disc by exerting an equal amount of pressure against 3 each side of the rotor as the each piston moves with equal pressure. The main limitation of the fixed caliper is requiring a rotor position which is not compatible with the geometric needs of the most modern front suspensions. Nowadays, the floating caliper is commonly used on the majority of automotive brake systems. Typical disc brake components are shown in Figure 1.1. It consists of a rotor that is rigidly mounted on the axle hub and therefore rotates with the automobile‟s wheel through drive axles, a floating caliper–piston assembly where the piston slides inside the caliper, which is attached to an anchor bracket on the vehicle suspension system, and a pair of brake pads. The caliper is free to float laterally on its mounting pins. When hydraulic line pressure is applied, the piston is pushed forward to press the inner pad against the disc and simultaneously the outer pad is pressed by the caliper against the disc. The hydraulic pressure is converting into an applied force that presses the pad against the rotor. This generates the friction forces needed for the braking.

Discbrakes

In a disc brake system, a set of pads is pressed against a rotating disc and due to friction, heat is generated at the disc-pad interface. This heat ultimately transfers to the vehicle and environment and the disc cools down. A simplified disc brake is shown in figure 1 with the terminology which is in common use. The pad which is nearer to the center of the vehicle is called the inboard pad while the one that is away is called the outboard pad. Similarly friction surface of the disc which faces towards vehicle is called inboard cheek and the one which faces away is called outboard cheek. The edge of the pad which comes into contact with a point on disc surface first is called leading edge while the edge which touches that point last is called trailing edge. The edge of the pad with smaller radius is called inner edge while the one with larger radius is called outer edge. A disc brake assembly consists of following major components: brake disc, pad, underlayer, back plate, shim and caliper. Now these components will be described in more detail.

Brake disc

Brake disc, also called brake rotor, is fixed to the axle, so it rotates with the same speed as the wheel. Braking power of a disc brake is determined by the rate at which kinetic energy is converted into heat due to frictional forces between the pad and the disc. For an efficient brake design, it is also important that heat is dissipated as quickly as possible otherwise the temperature of a disc might rise and affect the performance of a disc brake. So to get an optimum performance in demanding applications, ventilation is introduced in the brake discs which increases the cooling rate. Brake discs could be

1. Solidbrake discs
2. Ventilatedbrakediscs

A solid brake disc is the simplest form and consists of a single solid disc. In a ventilated disc, vanes or pillars or both separate two annular discs and provide a passage for the air to flow. Ventilated brake discs increase the cooling rate and result in lower surface temperature. This lower temperature reduces the risk of brake fade and also helps in reducing wear of the disc and pad. Both of these designs are constructed with or without a mounting bell. A mounting bell increases the distance from the friction surface to axle and the surface area of 4 the disc which improves cooling [3] and therefore it helps to protect the wheel bearings from the high temperature generated due to braking operation. A schematic description of these two types of discs is given in figure 2. When mounting bell is not a part of the brake disc then this multi-part disc configuration is called hybrid or composite brake disc. In this design, the disc is sometimes called the braking or friction ring. There are different ways to join a mounting bell and a friction ring mainly depending upon the material of the disc. In figure 3, two methods (patented [4, 5]) used for joining a friction ring and a mounting bell by using a connecting element are shown. In figure 3a the connecting element is a special threaded bolt which is screwed to the mounting bell and free to slide in radial direction inside the friction ring. This bolt is usually made of steel which could experience corrosion and heat could conduct quickly to the mounting bell. In figure 3b the connecting element is made of a ceramic material to avoid the corrosion problems and reduce the heat transfer to the bell. The head of the ceramic pin is cast into the mounting bell. In another design (patented [6]), shown in figure 4, several projecting teeth on the inner periphery of friction ring are finely machined and then mounting bell is casted so that these teeth are embedded into the bell material. In this design mounting bell is usually made of a light alloy e.g. aluminum or magnesium. One major advantage of the hybrid brake disc is the relative freedom of expansion of the friction ring which results in lower thermal distortion [7]. Different configurations of vanes and pillars are used in ventilated brake discs. Each configuration gives a unique airflow pattern. Some of the configurations used on the ventilated discs are the following: straight radial vanes, curved vanes, diamond and teardrop pillars (DTDP), and arcuate vanes. Figure 5 shows three different configurationsused for ventilation. In all of these, cooling air enters at the inner periphery and leaves the disc at outer periphery. One disadvantage with these configurations is that high stresses develop near the inner periphery primarily due to the inlets [8, 9]. This could be a problem when a disc is used in a demanding situation

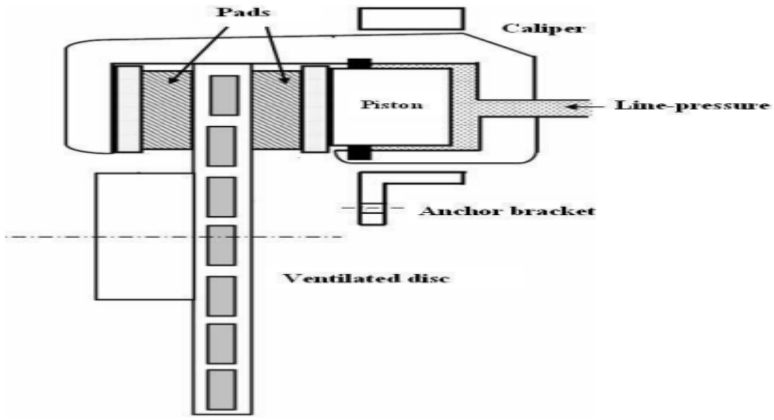


Figure 1 . Floating disc brake components

Figure 1.Floating disc brake components

Ever since the invention of the wheel, if there has been "go" there has been a need for "whoa." As the level of technology of human transportation has increased, the mechanical devices used to slow down and stop vehicles has also become more complex. In this I discuss the history of vehicular braking technology and possible future developments. Before there was a "horse-less carriage," wagons, and other animal drawn vehicles relied on the animal‟s power to both accelerate and decelerate the vehicle. Eventually there was the development of supplemental braking systems consisting of a hand lever to push a wooden friction pad directly against the metal tread of the wheels. In wet conditions these crude brakes would lose any effectiveness.

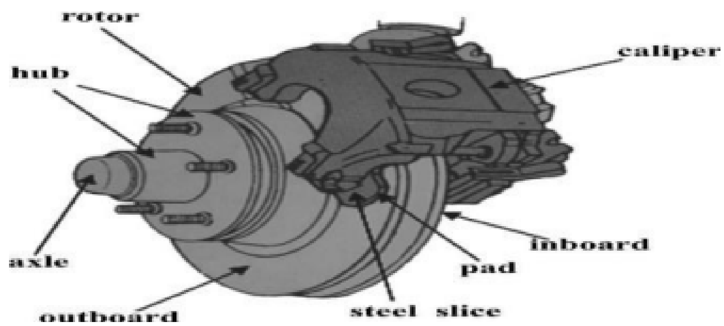


Figure 1.2

The early years of automotive development were an interesting time for the designing engineers, "a period of innovation when there was no established practice and virtually all ideas were new ones and worth trying. Quite rapidly, however, the design of many components stabilized in concept and so it was with brakes; the majority of vehicles soon adopted drum brakes, each consisting of two shoes which could be expanded inside a drum." In this chaotic era is the first record of the disk brake. Dr. F.W. Lanchester patented a design for a disk brake in 1902 in England. It was incorporated into the Lanchester car produced between 1906 through 1914. These early disk brakes were not as effective at stopping as the contemporary drum brakes of that time and were soon forgotten. Another important development occurred in the 1920‟s when drum brakes were used at all four wheels instead of a single brake to halt only the back axle and wheels such as on the Ford model T. The disk brake was again utilized during World War II in the landing gear of aircraft. The aircraft disk brake system was adapted for use in automotive applications, first in racing in 1952, then in production automobiles in 1956. United States auto manufacturers did not start to incorporate disk brakes in lower priced non-high-performance cars until the late 1960‟s.

Investigations into Brake Squeal Problem

Research on brake squeal noise has been conducted using theoretical, experimental and numerical approaches. In theoretical investigations, the complicated brake system has to be considerably simplified using lumped models to help in understanding the mechanism of brake squeal. Experimental approaches have been used to measure the brake frequencies and mode shapes for the system in squeal and to verify possible solutions that can eliminate or significantly reduce squeal.

PROBLEM OCCURRED IN DISC BRAKE

Discs are made up mainly gray cast iron, so discs are damaged in one of three ways: scarring, cracking, warping or excessive rusting. Service shops will sometimes respond to any disc problem by changing out the discs entirely. This is done mainly where the cost of a new disc may actually be lower than the cost of workers to resurface the original disc. Mechanically this is unnecessary unless the discs have reached manufacturer's minimum recommended thickness, which would make it unsafe to use them, or vane rusting. severe (ventilated discs only). Most leading vehicle manufacturers recommend brake disc skimming (US: turning) as a solution for lateral run-out, vibration issues and brake noises. The machining process is performed in a brake lathe, which removes a very thin layer off the disc surface to clean off minor damage and restore uniform thickness. Machining the disc as necessary will maximize the mileage out of the current discs on the vehicle. Braking systems rely on friction to bring the vehicle to a halt – hydraulic pressure pushes brake pads against a cast iron disc or brake shoes against the inside of a cast iron drum. When a vehicle is decelerated, load is transferred to the front wheels – this means that the front brakes do most of the work in stopping the vehicle. Scarring can occur if brake pads are not changed promptly when they reach the end of their service life and are considered worn out. Cracking is limited mostly to drilled discs, which may develop small cracks around edges of holes drilled near the edge of the disc due to the disc's uneven rate of expansion in severe duty environments. The discs are commonly made from cast iron and a certain amount of what is known as "surface rust" is normal. Sometimes a loud noise or high pitched squeal occurs when the brakes are applied. Most brake squeal is produced by vibration (resonance instability) of the brake components, especially the pads and discs (known as force-coupled excitation). This type of squeal should no negatively affect brake stopping performance.

Working of Disc Brakes

The caliper is the part that holds the brake shoes on each side of the disk. In the floating-caliper brake, two steel guide pins are threaded into the steering-knuckle adapter. The caliper floats on four rubber bushings which fit on the inner and outer ends of the two guide pins. The bushings allow the caliper to swing in or out slightly when the brakes are applied 9 When the brakes are applied, the brake fluid flows to the cylinder in the caliper and pushes the piston out. The piston then forces the shoe against the disk. At the same time, the pressure in the cylinder causes the caliper to pivot inward. This movement brings the other shoe into tight contact with the disk. As a result, the two shoes "pinch" the disk tightly to produce the braking action

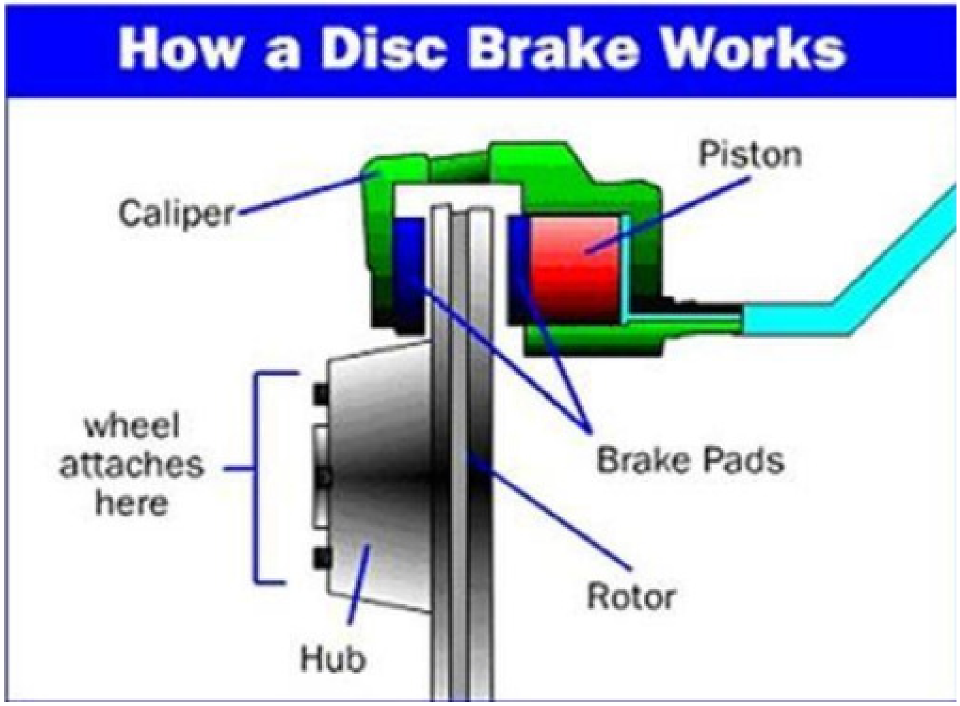
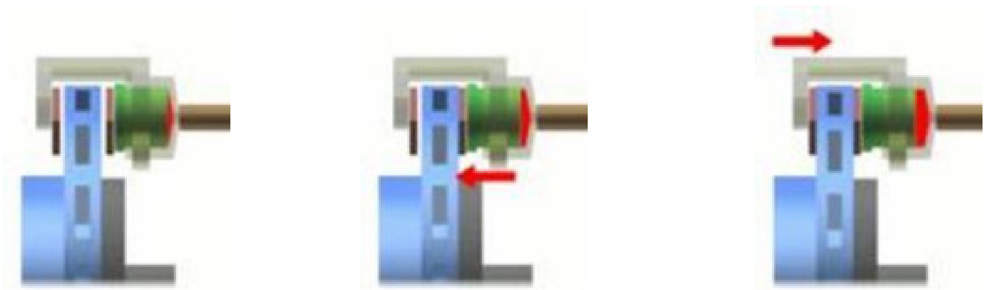

How a Disc Brake Works
Piston
Caliper
wheel
attaches
here
Brake Pads
Rotor
Hub

Figure 1.3

STAGES OF WORKING



The sliding-caliper disk brake is similar to the floating-caliper disk brake. The difference is that sliding-caliper is suspended from rubber bushings on bolts. This permits the caliper to slide on the bolts when the brakes are applied. Proper function of the brake depends on (1) The rotor must be straight and smooth, (2) The caliper mechanism must be properly aligned with the rotor, (3) The pads must be positioned correctly, (4) There must be enough "pad" left, and (5) The lever mechanism must push the pads tightly against the rotor, with "lever" to spare. Figure 1.3 10 Most modern cars have disc brakes on the front wheels, and some have disc brakes on all four wheels. This is the part of the brake system that does the actual work of stopping the car the most common type of disc brake on modern cars is the single-piston floating caliper. In this article, we will learn all about this type of disc brake design

2. LITERATUREREVIEW

TING-LONG HO Et al. (1974), Investigated on the effect of frictional heating on brake material (Aircraft) [1]. In this paper simplified analysis is conducted to determine most significant factors which affect surface temperature. Where there are size and weight restrictions the specific heat and maintaining the contact area appear a criterion is suggested for determining the number and thickness of brake disks, within the limited space available in a wheel. Frictional variations at high temperature could result from three different phenomenon‟s: softening of the material, formation of oxides and surface melting. Metallographic study approach is been used here. It was found that minimum surface temperature would result under material with minimum value of (1/ρc) and (1/kρc), when there is maximum contact

Masahiro Kubota et al. (2000), presented paper on development of a lightweight brake disc rotor: a design approach for achieving an optimum thermal, vibration and weight balance [2]. This paper presents a parametric study that was conducted on the basis of an analysis of airflow through the ventilation holes as well as a thermal stress analysis and a vibration analysis during braking. Based on the relationships obtained between rotor weight, shape and each performance requirement, a method is presented for designing a lightweight disc rotor. Computational fluid dynamics (CFD) analysis approach is used to visualize the actual process .Short and gourd shaped fins arrangement had been used and the results verified that anti squeal performance was improved, and also a substantial weight reduction was achieved compared with the baseline rotor shape without causing cooling performance and heat resistance to deteriorate.

Choi and Lee, (2004) presented a paper on Finite element analysis of transient thermo elastic behaviours in disk brakes [3]. A transient analysis for thermo elastic contact problem of disk brakes with frictional heat generation is performed using the finite element method. To analyse the thermo elastic phenomenon occurring in disk brakes, the coupled heat conduction and elastic equations (cylindrical coordinates) are solved with contact problem. Material used is carbon-carbon composite and wear is assumed negligible. The numerical simulation for the thermo elastic behaviour of disk brake is obtained in the repeated brake condition. The computational results are presented for the distributions of pressure and temperature on each friction surface between the contacting bodies. It is observed that the orthotropic disc brakes can provide better brake performance than the isotropic one because of uniform and mild pressure distribution

JIANG LAN et al. (2011), presented paper on thermal analysis for brake disk of Sci/6061 Al. Alloy cocontinuous composite for CRH3 during emergency braking considering air flow cooling [4]. The thermal and stress analyses of SiCn/Al brake disk during emergency braking at a speed of 300 km/h considering airflow cooling were investigated using finite element (FE) and computational fluid dynamics (CFD) methods. All three modes of heat transfer were analysed. The highest temperature after emergency braking was 461 °C and 359 °C without and with considering airflow cooling, respectively. The equivalent stress could reach 269 MPa and 164 MPa without and with considering airflow cooling, respectively. The airflow through and around the brake disk was analysed using the Solidwork2012 simulation software package. The results suggested that the higher convection coefficients achieved with airflow cooling will not only reduce the maximum temperature in the braking but also reduce the thermal gradients, since heat will be removed faster from hotter parts of the disk.

Oder G. et al. (2009), worked on thermal and stress analysis of brake discs in railway vehicles [5]. Performed analysis deals with two cases of braking; the first case considers braking to a standstill; the 12 second case considers braking on a hill and maintaining a constant speed. In both cases the main boundary condition is the heat flux on the braking surfaces and the holding force of the brake calipers. In addition the centrifugal load is considered. Finite element method (FEM) approach is been used, 3D model has been modelled for analysis. Brake disc material is rounded graphite; two types of disc considered for studies one without wear and one with 7mm wear on both sides. Maximum speed is 250 km/hr and the ambient and initial disc and surrounding temperature is 50 C Temperatures and stress in discs under different loads is very high. Although they are fulfilling the buyer‟s requirements for safety, this investigation not considered shearing forces, residual stress and the cyclic loads during brake discs lifespan. The results need to be compared with experimental results.

Talati and Jalalifar (2009), presented a paper on Analysis of heat conduction in a disk brake system [6]. In this paper, the governing heat equations for the disk and the pad are extracted in the form of transient heat equations with heat generation that is dependant to time and space. In the derivation of the heat equations, parameters such as the duration of braking, vehicle velocity, geometries and the dimensions of the brake components, materials of the disk brake rotor and the pad and contact pressure distribution have been taken into account. The problem is solved analytically using Green's function approach. It is concluded that the heat generated due to friction between the disk and the pad should be ideally dissipated to the environment to avoid decreasing the friction coefficient between the disk and the pad and to avoid the temperature rise of various brake components and brake fluid vaporization due to excessive heating.

Zaid, et al. (2009) presented a paper on an investigation of disc brake rotor by Finite element analysis. In this paper, the author has conducted a study on ventilated disc brake rotor of normal passenger vehicle with full load of capacity [7]. The study is more likely concern of heat and temperature distribution on disc brake rotor. In this study, finite element analysis approached has been conducted in order to identify the temperature distributions and behaviours of disc brake rotor in transient response. Modelling is done in CATIA & ABAQUS/CAE has been used as finite elements software to perform the thermal analysis on transient response. Material used is Grey cast iron, with maximum permissible temperature 550 C. For load analysis 10 cycles of breaking and 10 cycles without breaking (idle) operation is considered total of 350 seconds. Result provided during 1st , 5 th and during 10th cycle. Thus, this sure study provide better understanding on the thermal characteristic of disc brake rotor and assist the automotive industry in developing optimum and effective disc brake rotor.

Piotr Grzes & Adam Adamowicz (2011), presented paper on analysis of disc brake temperature distribution during single braking under non-axisymmetric load [8]. First step of the analysis based on the previously developed model where the intensity of heat flux was Assumed to be uniformly distributed on the friction surface of disc during braking process, and the heat is transferred exclusively in axial direction, whereas during the second, the three-dimensional rotor is subjected to the nonaxisymmetric thermal load to simulate realistic thermal behaviour of the brake action Operation conditions, thermo-physical properties of materials and dimensions of the brake system were adopted from the real representation of the braking process of the passenger vehicle. Arbitrarily selected four values of the velocities at the moment of brake engagement were applied to the models so as to investigate theirs influence on the obtained solutions of the temperature evolutions on the contact surface of the disc volume referring to two separated finite element analysis. Two- and threedimensional FE modelling techniques is used considering FEA approach. Finite element analysis and Fast Fourier transform been used to reduce computational time. Radiation heat transfer had been neglected and wear on the contact surface is negligible. We can conclude that the large amount of heat generated at the pad/disc interface during emergency braking indisputably evokes non-uniformtemperature distributions in the domain of the rotor, whereas the pad element is constantly heated during mutual sliding.

Ali Belchocine & Mostefa Bouchetara (2012), presented paper on thermal analysis of a solid brake disc [9]. The objective of this study is to analyse the thermal behaviour of the full and ventilated brake discs of the vehicles using computing code ANSYS. In this analysis approach is to create the model CFD which contains the fields to be studied in Ansys Workbench. Three different grade of cast iron is chosen (FG 25 AL, FG20, and FG15). The numerical simulation shows that radial ventilation plays a very significant role in cooling of the disc in the braking phase. The variation in temperature between a full and ventilated disc having same material is about 60 degree at the moment1.8839 s from application of brake The obtained results are very useful for the study of the thermo mechanical behavior of the disc brake (stress, deformations, efficiency and wear).

Haripal Singh and Harshdeep Shergill (2012), presented paper on thermal Analysis of Disc Brake Using Comsol [10], in these paper Finite element analysis techniques is used to predict the temperature distribution and identify the critical temperature of brake disc. Considering all three modes of heat transfer (conduction, convection and radiation) for three different materials of rotor disc are been used (cast iron, aluminium and ceramics). It is concluded that cast iron can be used in brake disc which will give moderate cooling at low temperature as compared to other. Ceramics has good cooling characteristics but it is costly, can be used in racing cars where high temperature is produced.

Zhang Jiang& Xia Changgao (2012), research of the transient temperature field and friction properties on disc brakes [11]. The 3D transient and cyclic symmetry finite element model of the temperature field of the ventilation caliper disc brake in a long downhill braking condition was established in this paper. The finite element modeling for three-dimensional transient cyclic symmetry during the long downhill braking is established. The variation of the friction factor combined with the temperature characteristics of the friction factor during the braking are analyzed. Analysis is done by using finite element software ANSYS. During the braking, the temperature of the brake rises increasingly and reaches the top temperature of 316.04℃ at the end of braking process; the high temperature section concentrates in the far area of the friction surface. The maximum rate of recession is 8.16%, friction coefficient is always stable within a reasonable range, and the obvious thermal recession is not happened.

K. Sowjanya & S.Suresh (2013), presented paper on Structural analysis of disk brake rotor [12]. Disc brake is usually made of Cast iron, so it is being selected for investigating the effect of strength variations on the predicted stress distributions. Aluminum Metal Matrix Composite materials are selected and analyzed. The domain is considered as axis-symmetric, inertia and body force effects are negligible during the analysis. The model of Disc brake is developed by using Solid modeling software Pro/E (Cero-Parametric 1.0).Further Static Analysis is done by using ANSYS Workbench. Thermal solution to the structural analysis and the maximum Von Misses stress was observed to be 50.334 M Pa for CI, 211.98 M Pa for AlMMC1, and 566.7 M Pa for AlMMC2, the Brake disc design is safe based on the Strength and Rigidity Criteria.

K. M. Muniswamy et al. (2013), heat transfer enhancement on ventilated brake disk with blade inclination angle variation [13]. The objective of the current study is to investigate the potential heat transfer enhancements in ventilated brake disk by varying the geometrical parameters of the blades 14 inside the flow passage. The thickness remains constant and only the length can be changed to fit the inner and outer radius. The computational model constructed in GAMBIT. The models are solved using ANSYS-FLUENT proprietary software package. The results show a tremendous increase in the heat transfer rate with blade inclination angle configurations as compared to conventional straight blade. The Nusselt number is found to be in a power-law relationship with the Reynolds number. Distinct relationship between laminar and turbulent condition is predicted. An improvement in total convective heat transfer coefficient of 51% was achieved with blade inclination angle of 40 C tilting towards clockwise direction and also recirculation was
also eliminated completely in 30 degree blade designs with heat dissipation 32%.

3.1 INTRODUCTION:

3. MODELING

There are various types of drawings required in the different fields of engineering and science. In earlier days, various drawing instruments like drafting machine, T-square, scale etc., are used to prepare drawings easily and accurately. But to obtain better ease in modifying the design and making calculations, the process of preparing a drawing is made in the computer using certain software. This use of computer systems is termed as computer aided design. It replaces manual drawing with an automated process.

Briefly, computed aided design (CAD) can be defined as the use of computer systems in conceptualizing the idea to create and modify the design. Computer aided design is a process in which interaction between designer and computer is made as simple and effective possible. Various engineering activities like planning, analysis, detailing, manufacturing, construction, modelling, process control and management can be improvised by CAD.

3.2 CATIA – INTRODUCTION:

CATIA which stands for Computer Aided Three Dimensional Interactive Application is CAD software owned and developed by Dassault Systems and marketed worldwide by IBM. It is the world"s leading CAD/CAM software for design and manufacturing. CATIA supports multiple stages of product development through conceptualization, design, engineering and manufacturing.

CATIA has a unique ability of modelling a product in the context of its real life behaviour. This design software became successful because of its technology which facilitates its customers to innovate a new robust, parametric, feature based model consistently. CATIA provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly, 17 electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly. Solid and surface modelling can be done easily.

3.3 GEOMETRIC MODELLING:

The computer compatible mathematical description of geometry of an object is called geometric modelling. The CAD software allows the mathematical description of the object to be displayed as an image on the computer. Various steps for creating a geometric modelling are: Creation of basic geometric elements by using commands like points, lines and circles.¬ Transformation of the basic elements based on requirements by using commands like¬ scaling, rotating and joining. Creation of geometric model by using various commands that cause the integration of¬ the elements into desired shape.

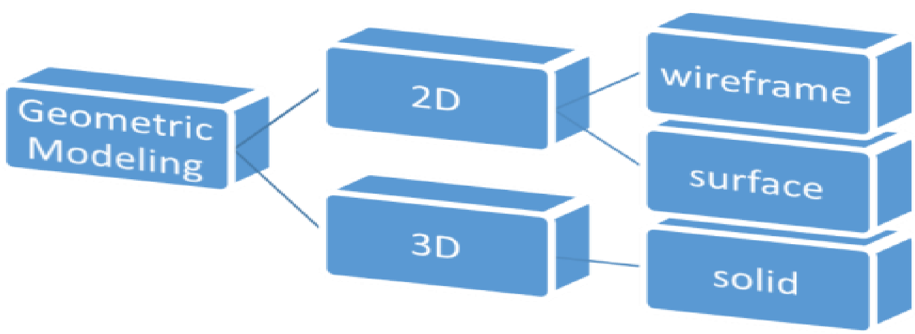


Fig: 3.1 Geometric modeling

3.4 SKETCHER TOOLBAR: Sketcher toolbar contains the tools that are required to select some elements. Some of the tools are: 1. Select 2. Selection trap 3. Intersecting trap 4. Polygon trap 5. Paint stroke selection 6. Outside trap selection 7. Intersecting outside trap selection A typical sketcher workbench looks in the following manner:

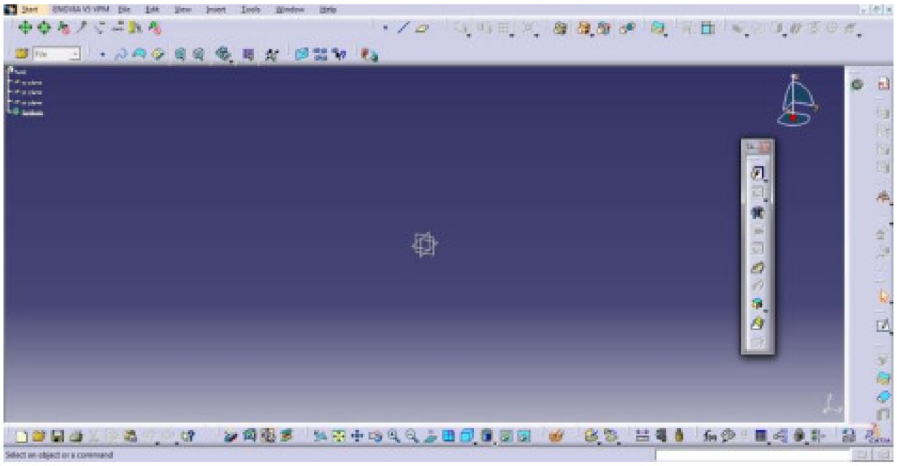


Fig: 3.2 Catia workspace

3.5 ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive 22 explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

4. RESULTS AND DISCUSSIONS

4.1 Solid model

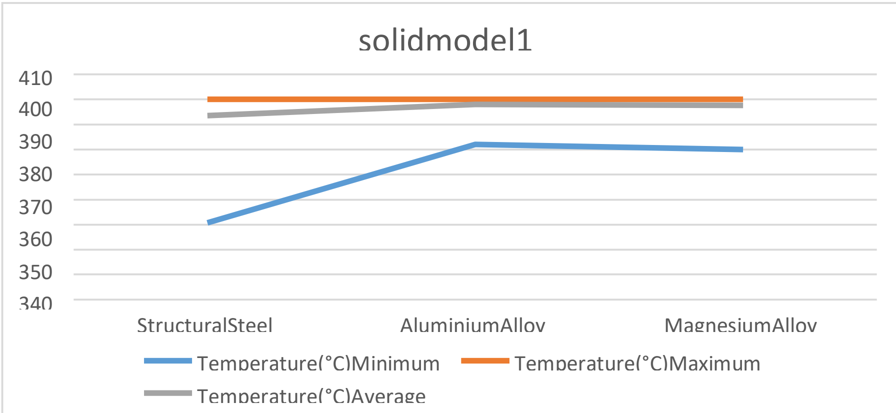
Thermal analysis

solidmodel1	Temperature(°C)			TotalHeatFlux(W/m²)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Structural Steel	350.68	400	393.43	7.6595	2.00E+05	14048
Aluminium Alloy	382.03	400	397.96	26.272	1.90E+05	8804.5
MagnesiumAlloy	379.94	400	397.72	26.249	1.89E+05	8778.8

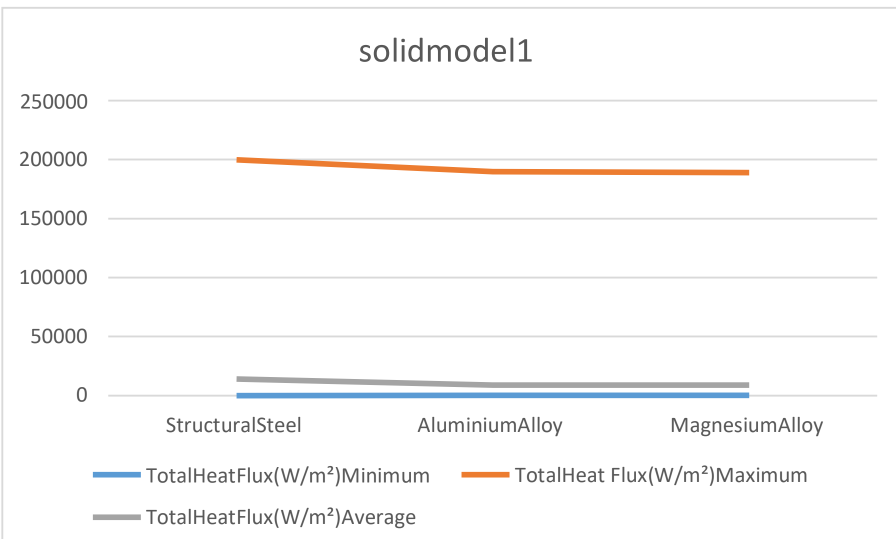
Structural analysis

solidmodel1	TotalDeformation(m)			EquivalentElasticStrain (m/m)			Equivalent(von-Mises) Stress(Pa)		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
StructuralSteel	0	6.89E-04	5.22E-04	7.35E-07	1.58E-02	5.73E-04	36993	3.15E+09	1.06E+08
AluminiumAlloy	0	1.33E-03	1.07E-03	8.94E-07	2.93E-02	1.34E-03	36920	2.08E+09	8.59E+07
MagnesiumAlloy	0	1.50E-03	1.21E-03	6.48E-07	3.36E-02	1.52E-03	27298	1.51E+09	6.15E+07

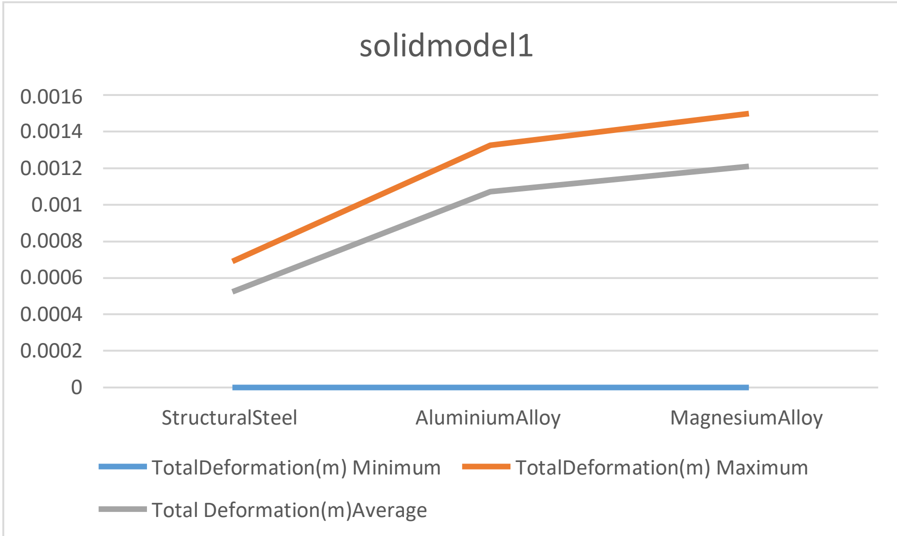
Graphs



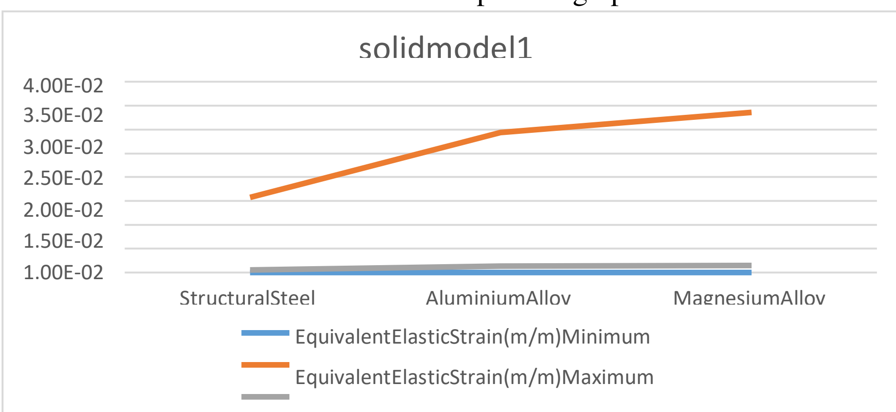
Temperature comparison graph for model 1



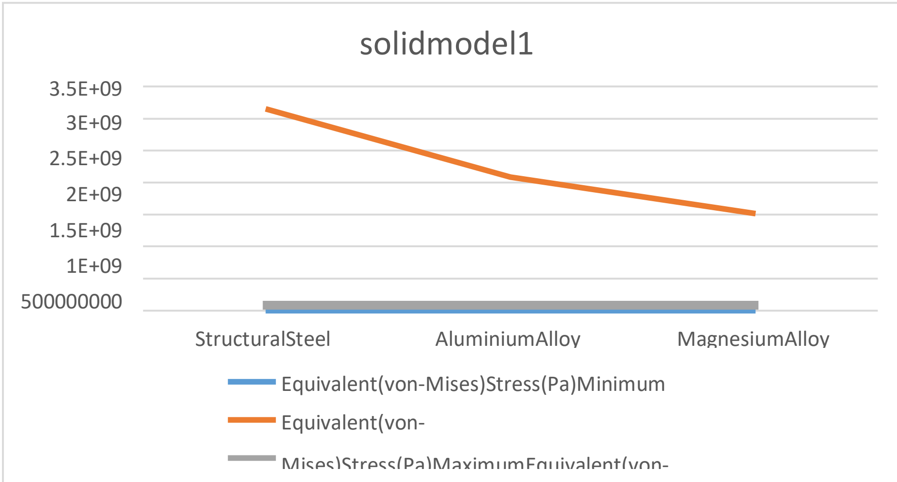
Total heat flux comparison graph for model 1



Total deformation comparison graph for model 1



Equivalent elastic strain comparison graph for model 1



Equivalent (von-Mises) stress comparison for model 1

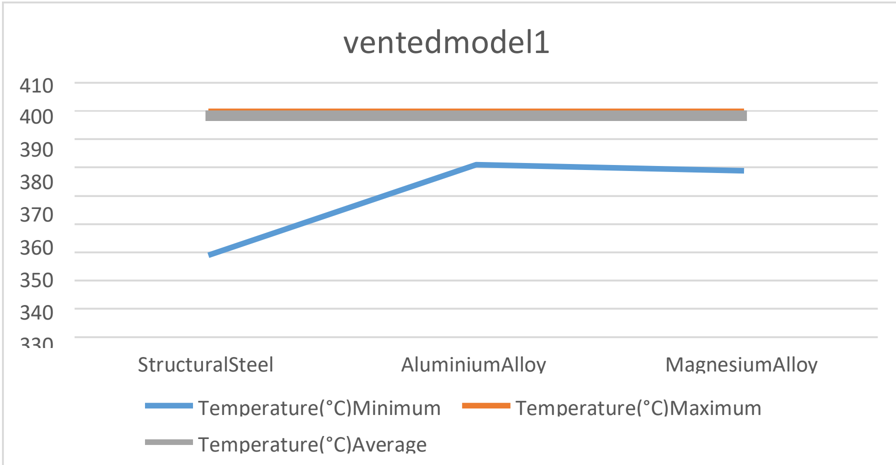
4.2 Ventedmodel1

Thermal analysis

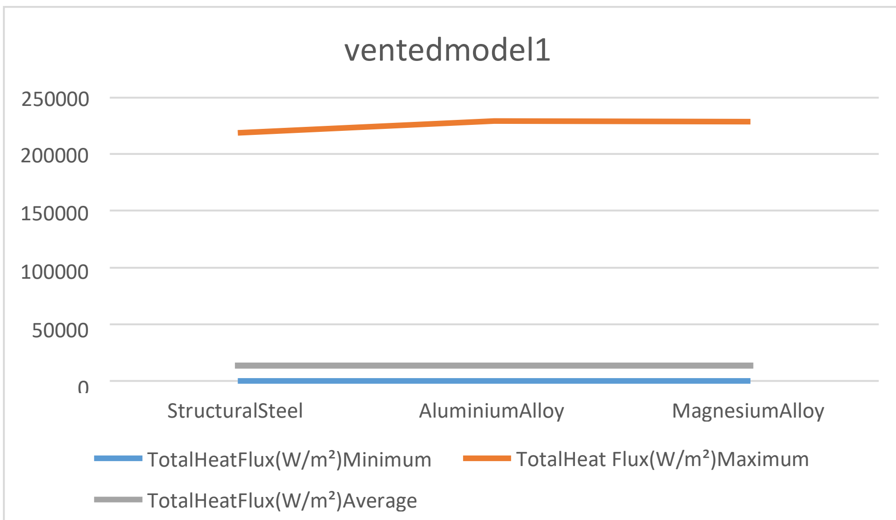
vented model1	Temperature(°C)			TotalHeatFlux(W/m²)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
StructuralSteel	348.93	400	397.63	121.17	2.19E+05	13458
Aluminium Alloy	381.05	400	399.13	121.37	2.29E+05	13826
Magnesium Alloy	378.85	400	399.03	121.35	2.29E+05	13801

Structural analysis

vented model1	Total Deformation(m)			Equivalent ElasticStrain (m/m)			Equivalent(von-Mises) Stress(Pa)		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Structural Steel	0	3.98E-04	3.03E-04	1.48E-06	1.35E-02	2.18E-04	82671	2.71E+09	3.98E+07
Aluminium Alloy	0	7.66E-04	5.83E-04	7.50E-07	2.84E-02	4.29E-04	19968	2.01E+09	2.79E+07
MagnesiumAlloy	0	8.66E-04	6.59E-04	5.46E-07	3.22E-02	4.86E-04	16717	1.45E+09	2.00E+07

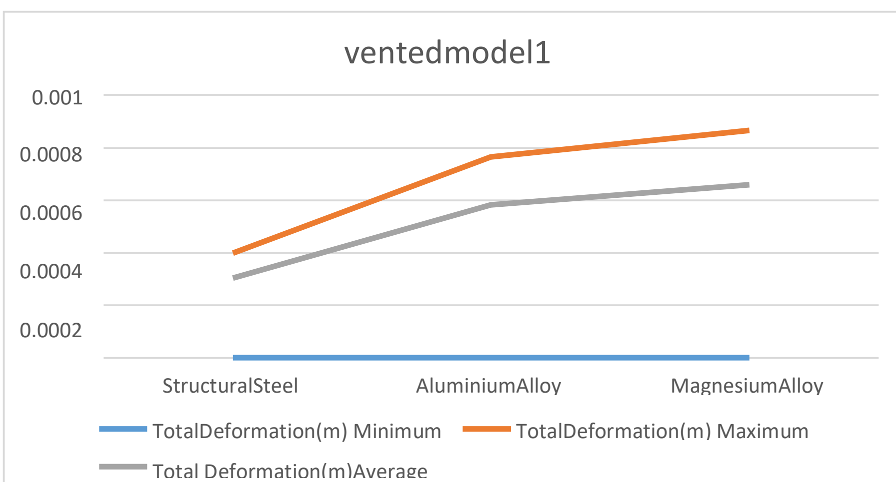


Graphs

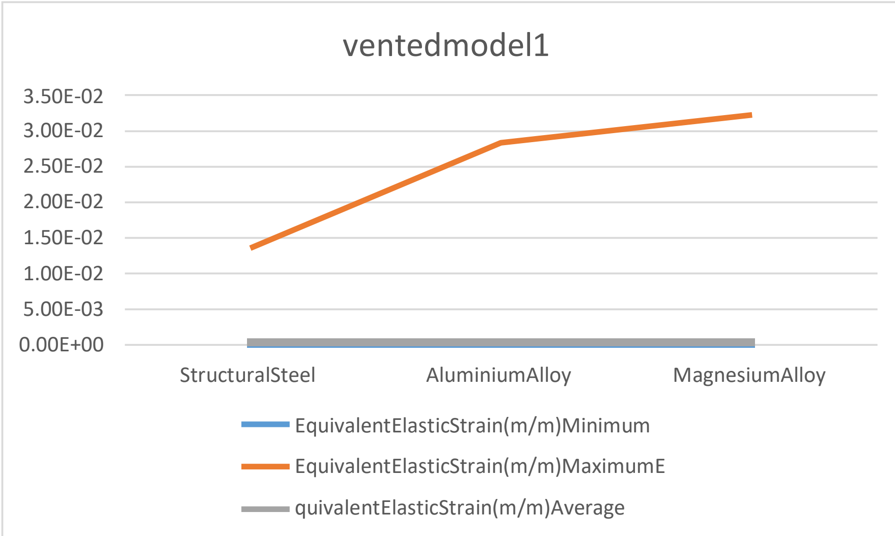


Temperature comparison graph for model 2

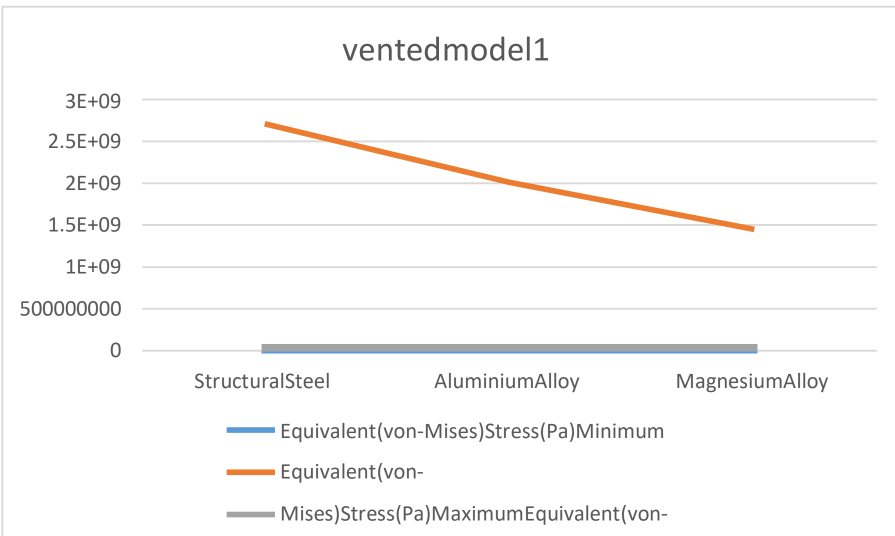
Total heat flux comparison graph for model 2



Total deformation graph for model 2



Equivalent elastic strain comparison graph for model 2



Equivalent (von-Mises) stress comparison for model 2

4.3 Vented model2

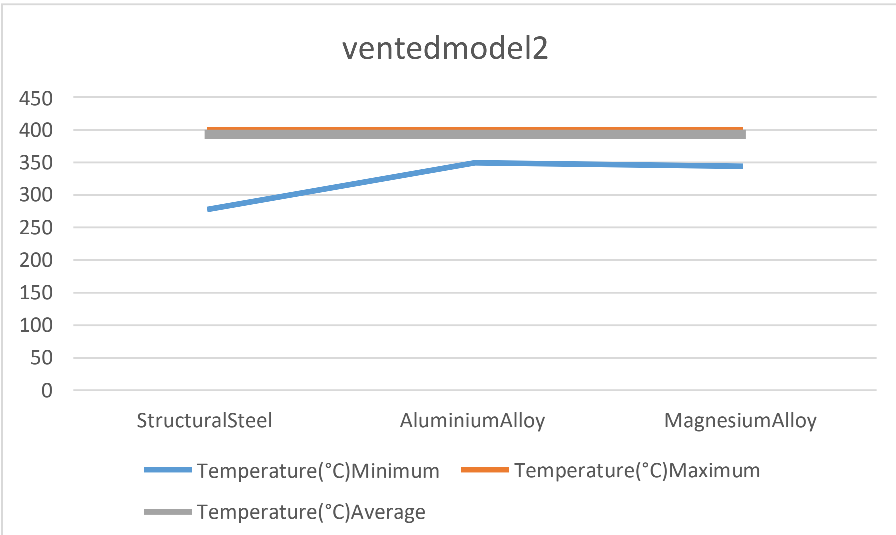
Thermal analysis

vented model2	Temperature(°C)			Total Heat Flux (W/m²)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Structura lSteel	277.86	400	390.75	4.2544	47504	6913.7
Aluminium Alloy	349.32	400	396.34	176.24	53608	7456.4
Magnesium Alloy	343.87	400	395.94	176.19	53152	7416

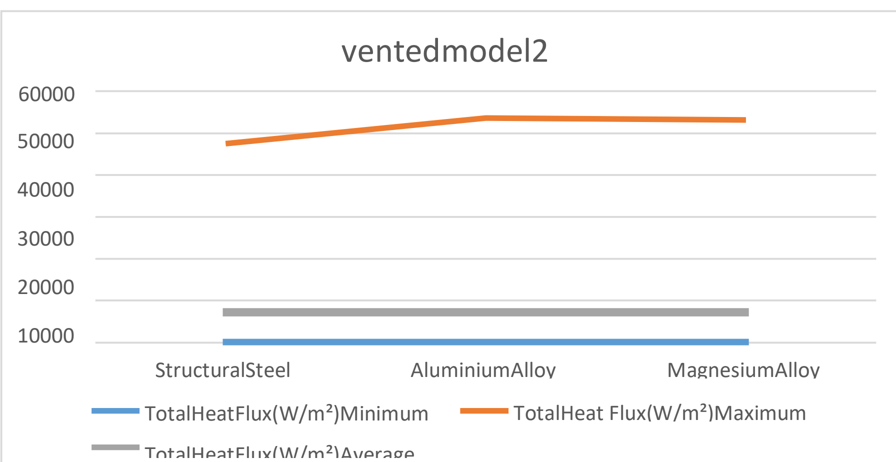
Structural analysis

vented model2	TotalDeformation(m)			EquivalentElasticStrain (m/m)			Equivalent(von-Mises) Stress(Pa)		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
StructuralSteel	0	5.12E-03	2.84E-03	2.32E-06	1.54E-02	1.08E-03	1.41E+05	3.09E+09	2.03E+08
Aluminium Alloy	0	9.39E-03	5.35E-03	2.14E-06	3.67E-02	2.11E-03	97025	2.60E+09	1.41E+08
MagnesiumAlloy	0	1.06E-02	6.02E-03	2.74E-06	4.23E-02	2.37E-03	87078	1.90E+09	1.01E+08

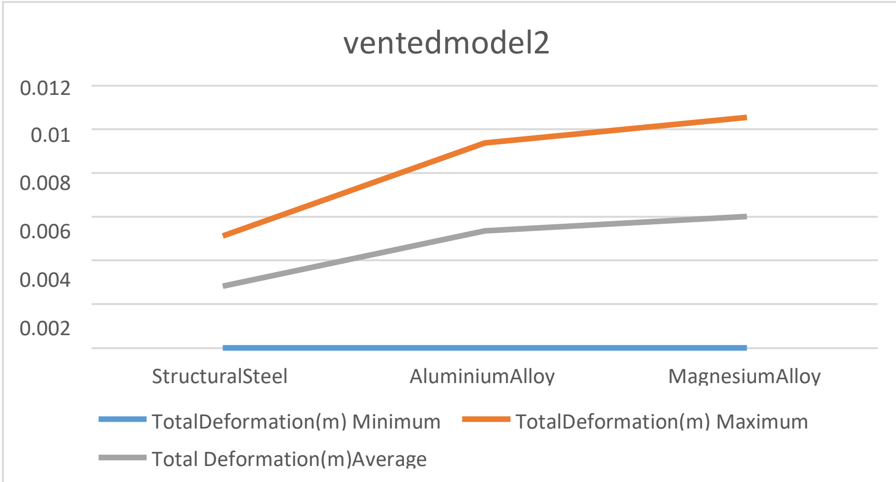
Graphs



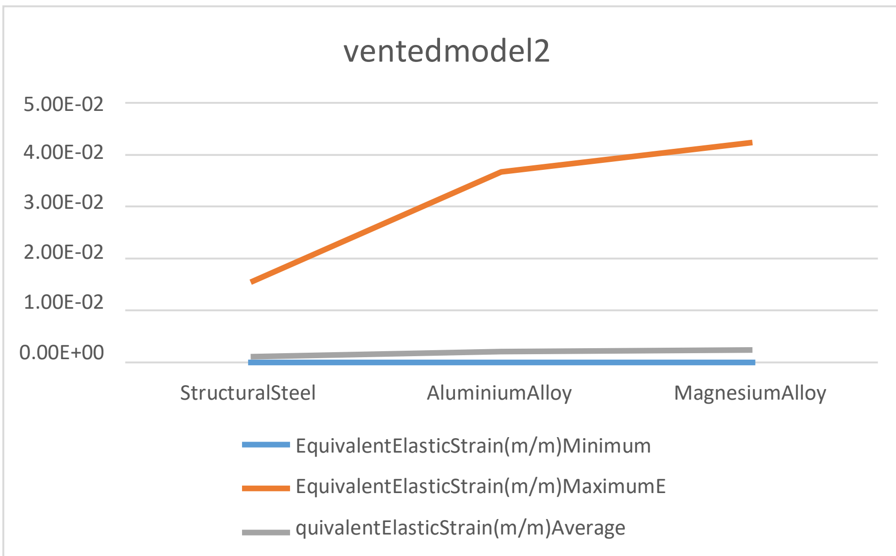
Temperature comparison graph for model 3



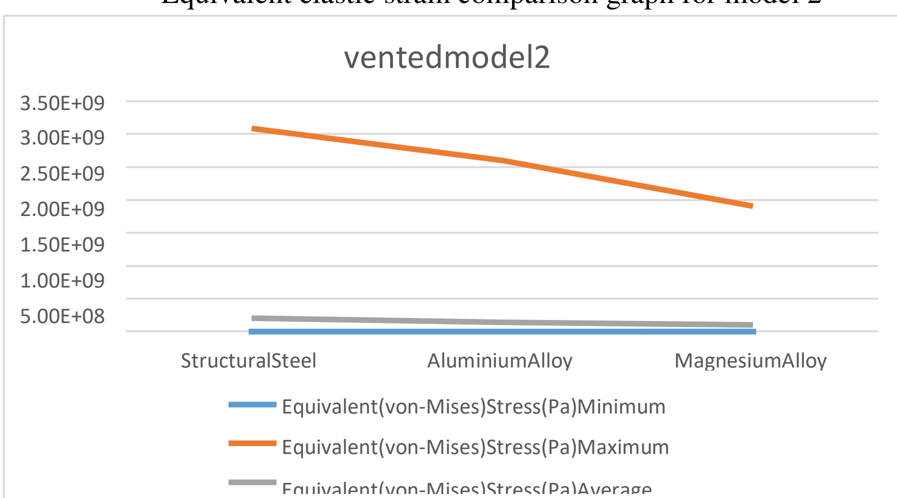
Total heat flux graph for model 3



Total deformation graph for model 3



Equivalent elastic strain comparison graph for model 2



Equivalent (von-Mises) stress comparison for model 3

5. CONCLUSIONS

From the above simulation results the thermal behavior of disk brakes is characterized and discussed. In this present study three different models of disk brakes are studied, first model is a solid disk break and the remaining are with vents of different geometry, hear heat transfer rate and mean temperatures are calculated using ANSYS. The following observation are made from the results

1. The temperatures are significantly low invented models
2. Total heat flux is high in solid model; hence the temperature raises evenly through the body raising the average temperatures.
3. The deformations (change in dimensions due to thermal expansions)are very low invented model 1
4. Stress are also very low in vented model as they are directly proportional to change in dimensions

5.2 FUTURE SCOPE

This work can be further extended by conducting experimentations and numerical calculations, disk brakes are complex geometries and it is hard to make formulation of them, any work showcasing numerical and experimental study is highly recommended.

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