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"A Review on Disc Brake Design Analysis Using Various Optimization Techniques"

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Abstract— This paper reviews numerical methods and analysis procedures used in the study of automotive disc brake. It covers Finite element Method approaches in the automotive industry, and in complex contact analysis. The advantages and limitations of each approach will be examined. Disc brakes have evolved over time to be a reliable method of decelerating and stopping a vehicle. There have been different designs of disc brake systems for different applications. This review can help analysts to choose right methods and make decisions on new areas of method development in the field of improving disc brakes. It points out some outstanding issues in modeling and analysis of disc brake squeal.

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Keywords- Disk brake; Finite element Method, analysis, disc brake.

I. INTRODUCTION

A vehicle requires a brake system to stop or adjust its speed with changing road and traffic conditions. The basic principle used in braking systems is to convert the kinetic energy of a vehicle into some other form of energy. For example, in friction breaking; it is converted into heat, and in regenerative breaking; it is converted into electricity or compressed air etc. During a braking operation not all the kinetic energy is converted into the desired form, e.g. in friction breaking some energy might be dissipated in the form of vibrations. Brake types such as friction brakes, drum brakes and disc brakes, are widely used. Disc brakes as compared to drum brakes cool down faster, due to larger swept area and relatively higher exposure to air flow, and show self-cleaning ability due to centrifugal forces. Due to these reasons and some other advantages disc brakes have become the universal choice for front brakes on cars and are also expected to dominate the truck market in the near future.

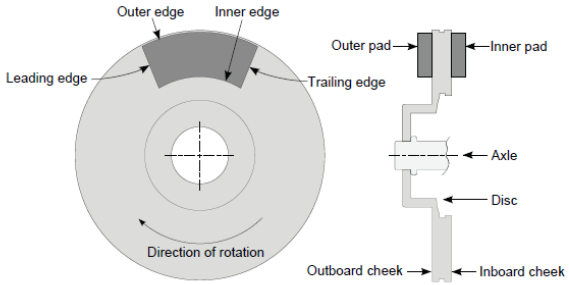

Fig 1-simplified disc brake with the terminology in common use

A. Disc brakes

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 disc which increases the cooling rate. Brake discs could be divided in two categories:

1) Solid brake discs

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 the disc which improves cooling [3] and

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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.

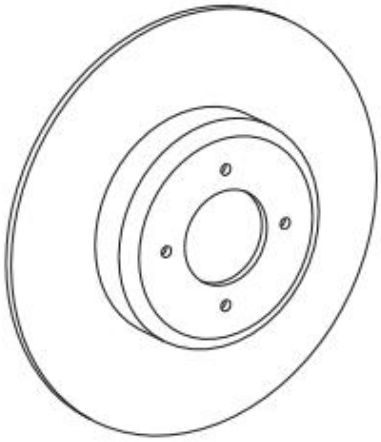

Fig 2-simplified disc brake

2) Ventilated brake discs

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 3 shows three different configurations used 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. This could be a problem when a disc is used in a demanding situation.

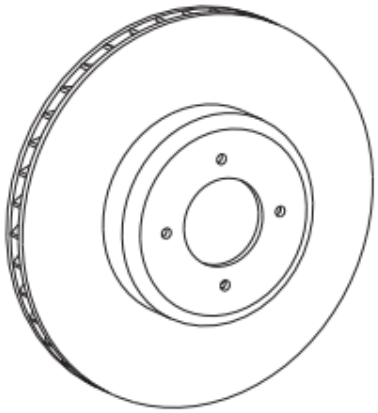

Fig 3-ventilated disk brake

B. Main components of a Disc brake

- Brake pads
- Calipers, containing piston(s)
- Disc brake rotor

The brake pads squeeze the rotor mounted in the brake hub along with the wheel. The rotor rotates or spins along with the wheel at the same rotational velocity (rpm) as that of the wheel. Force, in this case, from the pads to the rotor is transmitted through the hydraulic action of a fluid called the brake fluid as described earlier in the project report. Friction is created between the rotors and the pad resulting into retardation action and stopping of the vehicle (Figure 5).

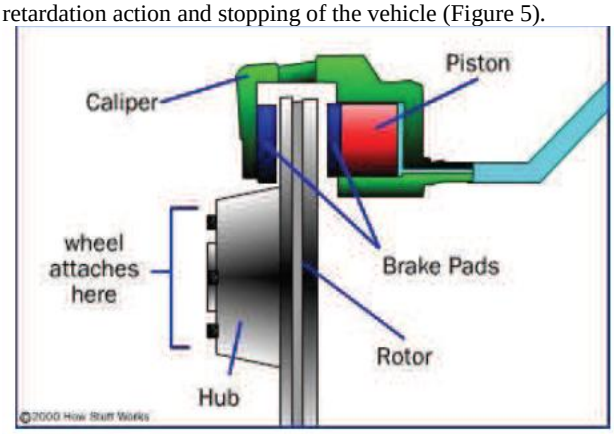

Fig 3 - Working of disc brakes

II. LITERATURE REVIEW

(Manthan Vidiya 2017) studied the theory on brakes through thermal analysis, and calculated the energy conversion of kinectic energy of the car to heat energy from brakes. It was done calculate the convection currents due to air flow on the car to find out the rise in temperature of the disc brakes. The analysis was performed in software and the results were obtained in form of graphs and table data. These reults were then compared with the actual result data obtained from the car using sensors, hence its reliability and accuracy was checked.

(Qifei Jian 2017) studied the transient field of temperature in automobile under hard braking conditions. In this experiment a test was carried out professionally to study the conditions in hard braking of automobile and results were obtained for circumferential and radial directions. These results when compared to the simulated results using FEA, it was found to be equal.

(Prof. Swapneel D. Rawool 2017) performed thermal analysis using steady state analysis on a disc rotor of a two wheeler and evaluated the performance of braking under conditions of hard braking. The loading conditions, mathematical inputs, and calculations of various parameters were based on assumptions. For the design solid works 15 was used and for analysis ansys 14.5 was used.

(A. Vennila 2016) performed analysis on disc brake using Ansys 16. The modelling was too done in ansys software. The main aim was to change the design structure

by giving a hole on the disc at top position. This resulted in the inflow of air from atmosphere and reduced the thermal conductivity avoiding high temperature rise.

This experiment concluded that, the disc can withstand working conditions with higher temperatures. The overall lifetime of the disc was increased. The new design of proving hole on the top of the disc prevented the possible hotspots and wear out of the disc brake. This can be implemented on sports bike where there is constant hard braking and heat dissipation is maximum.

(Duvvuru Nirmala 2016) The investigation was carried out using the cut pattern in the ventilated model of the disc brake. The model was optimized and analyzed using thermal and structural analysis the analytical study showed that the wt. of the disc get decreased from 4.2 kg to 3.8 kg while result was unfavorable in terms of equivalent stress as it was increased form 3.5 x 10^{-3} to 3.9x 10^{-3}.The deformation the disc brake also increased from 4.3x10^{-7} to 2.21x10^{-6}.

(Vijay dadi 2015) In the present paper material and design optimization was performed on the rotor disc of rhe disc brake. Three different materials were used for disc which includes CI, SS and aluminium alloy. The analysis was performed on two proposed model one is solid model and other is ventilated model. In structural analysis it was found that aluminium ventilated disc performed better with minimum displacement of 0.260121mm and for equivalent stress SS ventilated Disc performed better with stress value 134.06Mpa, during thermal analysis temperature produced during the braking for ventilated CI disc was less with value 187.5K the thermal gradient was observed less for ventilated aluminium disc with value 185.02 K/mm. The result shows that heat dissipation was more in ventilated aluminium rotor disc.

(C.Radhakrishnan 2015) In the present research material optimization was carried out to analyse the distribution of temperature and total deformation on the ventilated disc brake. For the optimization the conventional material ie grey cast iron was replaced with the titanium alloy 550.The model of the disc brake was prepared using the SOLIDWORKS software. In the analysis result it was revealed that the titanium alloy performed batter as compared to the grey cast iron in thermal analysis. In results it was found that the total deformation was GCI was 0.012 meter while the for TI alloy 0.0000067, equivalent stress for GCI 18.27 MPa and for TI alloy 3.996 MPa.

III. OBJECTIVE

1. To study the effect of different type of force acting on disk brake rotor
2. To study the weight reduction method of disc brake by analyzing the different type of designs.

IV. EXXPECTED METHODOLOGY

A. *Modeling*

Modeling generally refers to a process in design which employs mathematical representation of model for 3D Surface of a model. There are various tools used for the modeling purpose in design industry, CATIA V5 R20 which is one of them is used for the modeling of this research work.

B. *Finite Element Analysis*

The finite element analysis is a numerical method for solving problems of engineering. It is traditionally a branch of Solid Mechanics. Most common areas of interest are Heat Transfer, Structural Analysis, and Mass Transport. ANSYS is software used for solving a number of mathematical problems.

The results which are obtained by post analysis procedure depend on the mesh size. ANSYS Workbench provides potent, practical applications which simplifies the process of mesh generation, decreases the design cycle time, reduces the number of prototype production and testing, thus helps providing an optimum design.

The Process of Analysis is divided in following steps;

1. Pre-Processing
2. Solver
3. Post-Processing

V. CONCLUSION

From the above study of various literatures reviews it is clearly seen that a new way of optimizing the disc brake can be introduced to optimize the disc brake system which can reduce the weight of existing bulky disc brake at a same time decreasing the cost factor also.

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