Design Modification of Disc Brake and Performance Analysis of it by varying the Patterns of Hole

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Abstract— Automobile braking system is one of the most important mechanical devices among the others. The disc brake is a device that slows or stops the rotation of a wheel by converting the friction to heat. But if the brakes get too hot, they will cease to work as they cannot dissipate enough heat. This condition of failure is known as brake fade. Disc brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. Ventilation applications on disc brake can significantly improve the brake system performance by reducing the heating of the discs. In this study, the thermal behavior as well as the performance of ventilated brake discs using different pattern of holes will be investigated at continuous brake conditions with finite element analysis and the results will be compared with a solid disc.

Key words: Disc Rotor, Performance Analysis, Thermal Analysis, Pattern, Finite Element Analysis

I. INTRODUCTION

A disc brake is a device for slowing or stopping the rotation of a wheel, attached to the wheel or axle. The friction caused by pushing brake pads against a brake disc with a set of calipers causes the wheel to slow or stop. Brake caliper may be forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Compared to drum brakes, disc brakes offer better stopping performance, because the disc is more readily cooled and disc brakes recover more quickly from immersion, so they are used in the cars widely.

In today's growing automotive market the competition for better performance vehicle is growing enormously. The racing fans involved will surely know the importance of a good brake system not only for safety but also for staying competitive. As we are aware of the fact that races are won over split of a second therefore the capacity of the brake system to slow down quickly at turns or corners is very important. The brakes designed for the purpose of racing need to have very high braking efficiency. The wear and tear of the pads or the cost is not of great concern to the manufacturer of the racing car brakes.

II. COMPONENT OF DISC BRAKE

A. Calipers

The brake caliper is the assembly that houses the brake pads and pistons. The pistons are usually made of Plastic, Aluminium or Chrome plated steel. Calipers are of two types, floating or fixed. A fixed caliper does not move relative to the disc. It uses one or more, single or pairs of opposing pistons to clamp from each side of the disc, and is more complex and expensive than a floating caliper. A floating caliper (also called a "sliding caliper") moves with respect to the disc, along a line parallel to the axis of rotation of the disc; a piston on one side of the disc pushes the inner brake pad until it makes contact with the braking surface, then pulls the caliper body with the outer brake pad so pressure is applied to both sides of the disc.

B. Brake Pad

Friction material in the form of brake pads, mounted on a device called a brake caliper, is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc thus causing the disc and attached wheel to slow and stop. Different brake design application requires different kind of friction material. The coefficient of friction must remain constant over a wide range of temperature. The brake pad must not wear out rapidly nor should they wear the disc rotors, withstanding highest temperature without fading it and should be able to do all this without any noise. Materials which make up the brake pad include Friction modifiers such as graphite and cashew nut shells which alter the friction coefficient. Powdered metal such as lead, zinc, brass, aluminum and other metals increase a material's resistance to heat fade. Binders are the glues that hold the friction material together. Phenolic resin is the most common binder in current use. Fillers are added to friction material in small quantities to reduce brake noise.

1) Brake Pad Materials

- Asbestos
- Non-Asbestos Organics
- Semi-Metallic
- Low Steel
- Carbon

C. Pistons and cylinders.

The most common caliper design uses a single hydraulically actuated piston within a cylinder. As far as the high performance brakes are concerned they use as many as twelve. Modern cars use different hydraulic circuits to actuate the brakes on each set of wheel as a safety measure. The hydraulic design also helps in multiplying the braking force. The number of pistons in a caliper is often referred to as the number of 'pots', so if a vehicle has 'four pot' calipers it means that each caliper houses four pistons.

D. Disc brake rotor

The disc brake rotor is the disc component against which the brake pads are applied. Generally the disc brake rotors are made of gray cast iron and are either solid or ventilated. The ventilated type rotor consists of holes, slots and cooling fins to ensure good cooling.

1) Material of disc rotor.

- Nickel Chrome Steel.
- Aluminum Alloy.
- Cast Iron.
- Carbon Reinforced polymer.
- Titanium Alloy.

Many high performance brakes have holes drilled through them for a heat dissipation purpose which is known as cross-drilling. Slotted Discs are mostly preferred in racing cars, within which shallow channels are machined thus, helping in removing dust, gas and water. Some disc are both drilled and slotted. In the wet condition the slotted and drilled rotor have a positive effect.

2) *Patterns for the Cross drilled rotor.*
- The opulent mongoose.
- Slick swiss cheeser.
- Swirl mcholy.
- The universal Augmentator.

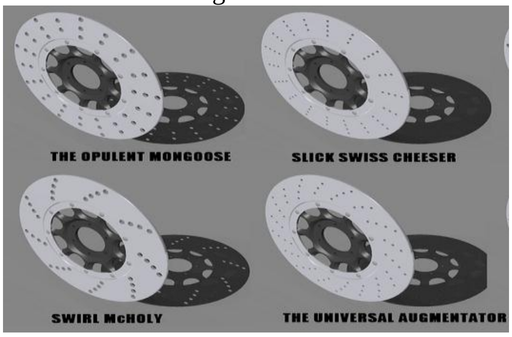

Fig - 1 show above mentioned Patterns for the Cross drilled rotor

- The violet moonbeam
- Shrapnel supreme.
- Rabid spectrum dialysis.
- Turbo syndicator.

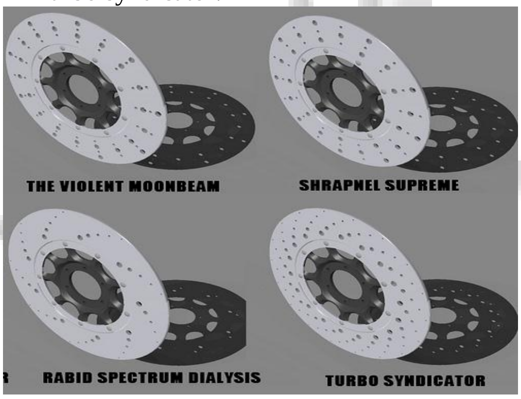

Fig - 2 show above mentioned Patterns for the Cross drilled rotor

- The centrifugal genome.
- Purple squish mitten.
- Bio – Screemsicle.
- The apocalyptic gyration.

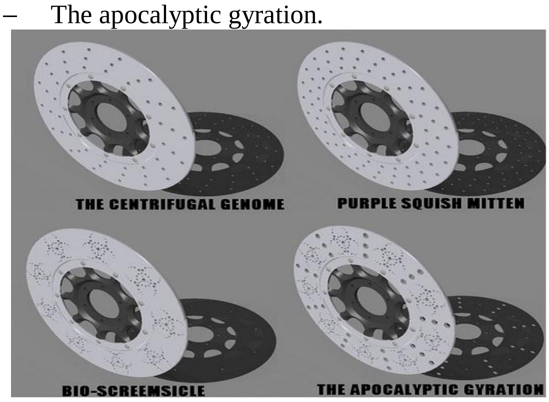

Fig - 3 show above mentioned Patterns for the Cross drilled rotor

III. LITERATURE REVIEW

Ventilated brake discs were originally tested on racing cars in the 1960s, and they have been employed widely in the automotive and railway industry using different designs [1]. Ventilated discs brake rotors are produced by making holes or slots (or both) of different shapes on disc surfaces. During braking, kinetic energy is converted into heat among which 90% of this energy is absorbed by the brake disc and then transferred to air. Solid brake discs dissipate heat slowly compared to ventilated brake discs [2]. Ventilated disc brake generally exhibit convective heat transfer coefficient that is approximately twice as large as those associated with solid discs [3].

There are numerous studies related to ventilation applications on brake discs.

Mesut Duzgun [2] used three different configurations and proved that the heat generation was reduced to a maximum of 24% with ventilation applications when compared with a solid disc whereas in the cross drilled design rotors having a universal augmentator pattern the heat generation was reduced by 4% then the solid disc. M. K. Khalid et al. [3] utilized a single cross-drilled rotor having Swirl mcholy pattern with fixed caliper design which Resulted into the maximum temperature of 119.20C at the brake disc surface during the thermal analysis, which was within the allowable service temperature of the disc material. Yathish K.O et al. [4] performed a structural and thermal analysis and reduce the stress, displacement, sliding contact and contact pressure on the disc brake by replacing the solid disc brake with the 36-holes cross drilled pattern. Antanaitis and Rifici [5] proved that the 90-hole cross-drilled pattern improved heat rejection capability of the disc between 8.8% and 20.1% depending on the vehicle speed. Gnanesh P et al. [6] carried out Transient thermal, static structural and modal analysis on the disc brake rotor using three different materials and three different 36-hole ventilated profiles like (circular - opulent mongoose, triangular, hexagon profiles) in comparison with solid disc, as a result 9%, 15%, 20%, heat reduction was noted. Mohd firdaus abu Bakar et al. [7] adopted a new design of 60-holes cross drilled rotor pattern and conducted a thermal analysis on it as a result improvement till the 10th cycle were at 288.4oC while the allowable service temperature was 550oC. Ameer Fareed Basha Shaik et al. [8] made design changes by drilling holes in opulent mongoose pattern on a solid disc rotor used in Honda Civic. Coupled field analysis (Structural + Thermal) was done on the disc brake. However, ventilated brake rotors also have some disadvantages. Cracking is one of them and this is a phenomenon that has been correlated to stresses during braking [9]. Since the early 20th century, disc brake squeal remained an elusive problem in the automotive industry many investigators examined the problem with experimental, analytical, and computational techniques, but yet there is no method to completely suppress disc brake squeal [10]. Dattatray S. Galhe et al. [11] reduced the braking pressure to achieve the same braking performance as existing, since braking pressure is directly proportional to the vibrations generated during braking which is the main cause of brake squeal. Hwang and Wu [12] investigated temperature and thermal stress in a ventilated brake disc based on a thermo-mechanical coupling model. Decreasing the brake temperatures and/or re-designing the hub-rotor unit were some considerable conclusions of Mackin et al. [13] to eliminate cracking in brake rotors. Heat generation also affects thermo-mechanical instability of brake discs [14].

IV. CONCLUSION

From review of above literature we can conclude the following points

- Ventilated brake discs rotors are better than solid disc brake rotor.
- Ventilated disc brake exhibits convective heat transfer coefficient that is approximately twice as large as those associated with solid.
- By using the cross drilled rotor one can increase performance, thermal properties, heat rejection, as well as can improve the life time of the rotor by changing the design of the disc rotor from solid disc rotor to cross drilled rotor.

REFERENCES

[1] T. C. Chatterley and M. P. Macnaughtan, "Cast iron brake discs-current position, performance and future trends in Europe" (1999) SAE 1999-108-1, 505-514
[2] Mesut Duzgun "Investigation of thermo-structural behaviors of different ventilation applications on brake discs" Journal of Mechanical Science and Technology 26 (1) (2012) 235~240.
[3] M. K. Khalid, M. R. Mansor, S. I. Abdul Kudus, M. M. Tahir, and M. Z. Hassan "Performance Investigation of the UTeM EcoCar Disc Brake System" International Journal of Engineering & Technology IJET-IJENS Vol: 11 No: 06. December 2011.
[4] Yathish K.O, Arun L.R, Kuldeep B, Muthanna K.P "PERFORMANCE ANALYSIS AND MATERIAL OPTIMIZATION OF DISC BRAKE USING MMC" International Journal of Innovative Research in Science, Engineering and Technology ISSN: 2319-8753 Vol. 2, Issue 8, August 2013.
[5] D. B. Antanaitis and A. Rifici, "The effect of rotor cross drilling on brake performance (2006) SAE, 2006-01-0691, 571-596.
[6] Gnanesh P, Naresh C and Syed Altaf Hussain "FINITE ELEMENT ANALYSIS OF NORMAL AND VENTED DISC BRAKE ROTOR" International Journal of Mechanical Engineering & Robotics Research 2014 ISSN 2278 – 0149 www.ijmerr.com Vol. 3, No. 1, January 2014.
[7] Mohd Firdaus Abu Bakar, Muhd Ridzuan Mansor, Mohd Zaid Akop, Mohd Afzanizam Mohd Rosli, Mohd Azli Salim "Thermal analysis of Ventilated disc Brake rotor for UTem formula Varsity race car" Journal of Engineering and Technology ISSN: 2180-3811 Vol. 2 June 2011.
[8] Ameer Fareed Basha Shaik, Ch.Lakshmi Srinivas "STRUCTURAL AND THERMAL ANALYSIS OF DISC BRAKE WITH AND WITHOUT CROSSDRILLED ROTAR OF RACE CAR" International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974 IJAERS/Vol. I/ Issue IV/July-Sept., 2012/39-43.
[9] Y. Yildiz and M. Duzgun, "Stress analysis of ventilated brake discs with finite element method", International Journal of Automotive Technology, 11 (1) (2010) 133-138. 1229− 9138/2010/050− 18.
[10] N.M. Kinkaid, O.M. O'Reilly, P. Papadopoulos "Automotive disc brake squeal" Journal of Sound and Vibration 267 (2003) 105 – 166.
[11] Dattatray S. Galhe. Vishnu D. Wakchaure. "REDUCTION OF BRAKE SQUEAL BY OPTIMIZING BRAKE DISC MATERIAL CONSIDERING BRAKING PRESSURE AS PARAMETER" International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 3, March 2013. International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 3, March 2013.
[12] P. Hwang and X. Wu, "Investigation of temperature and thermal stress in ventilated disc brake based on 3D thermomechanical coupling model" Journal of Mechanical Science and Technology, 24 (2010) 81-84.
[13] T. J. Mackin et al., "Thermal cracking in disc brakes" Engineering Failure Analysis, 9 (2002) 63-76.
[14] T. K. Kao, J. W. Richmond and A. Douarre, "Brake disc hot spotting and thermal judder: an experimental and finite element study", International Journal of Vehicle Design, 23 (3/4) (2000) 276-296.

