Design Optimization of Disk Brake by Using Finite Element Analysis

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***Abstract* - A brake is a mechanical device which simulated frictional safety is connected to moving machine part, to stop the movement of a machine. At present performing this function, the brakes take in either kinetic energy of the moving part or the potential energy surrendered by items being brought down by lifts and so forth. The energy absorbed by the brakes is scattered as heat. Disc brake is a recognizable car application where they are utilized broadly for car and bike wheels. The disc is sandwiched between two pads activated by cylinders backed in a caliper mounted on the stud shaft. At the point when the brake lever is pressed using pressurized hydraulic pressurized fluid is constrained into the chambers pushing the contradicting cylinders and brake pads into frictional contact with the disc. The frictional heat produced amid braking application can result in various negative impacts on the brake assembly, for example, brake blur, untimely wear, thermal splits and disc thickness variation (DTV). Previously, surface roughness and wear at the pad interface have infrequently been considered in investigations of thermal analysis of a disc brake finite element method. The main purpose of this project is to Optimization of Automotive Brake Disc and analysis the steady state thermal behavior of the dry contact between the brake disc and pads during the braking phase. The thermal-structural analysis to determine the deformation and the Von Misses stresses established in the disc. The objective of the project is the design, analysis and optimization of solid and ventilated disc brake using Solid works, Hyper mesh and Ansys. The ventilated brake disc assembly is built by a 3D model in Solid Works and imported to ANSYS to evaluate the stress fields and of deformations which are established in the disc with the pressure on the pads and in the conditions of tightening of the disc.**

***Index Terms* - Brake, Mechanical Device, Kinetic Energy, Disc Thickness Variation.**

1.INTRODUCTION

A brake is a contact mechanical device for changing over the momentum or kinetic energy of the moving vehicle into heat by method for rubbing. It is obliged to stop or ease off the vehicle in the most brief conceivable separation when needed to do so. Braking of a vehicle relies on the static function that demonstration in the middle of tires and street surface. Brakes take a shot at the following standard to stop the vehicle: "The kinetic energy because of movement of the vehicle is scattered as heat energy because of contact between moving parts (wheel or wheel drum) and stationary parts of the vehicle (brake shoes)". The heat energy so produced because of use of the brakes is dispersed into the air. Brakes work most successfully when they are connected in a way so the wheels don't bolt totally, yet keep on moving without slipping on the surface of the street. The whole time, the brakes take in either kinetic energy of the moving part or the potential energy surrendered by articles being brought down by lifts, and so on. The energy absorbed by the brakes is scattered as heat. The brakes are solid enough to stop the vehicle inside a base Distance.2. The driver ought to have fitting control over the vehicle amid braking, not to slip.3. The brakes must have great against blur aspects. 4. The brakes ought to have great against wear properties. In light of mode of operation brakes are named after: Hydraulic brakes, Electric brakes Mechanical brakes. The mechanical brakes are subdivided as per the bearing of acting energy may be the following two assemblies: Radial brakes: The force on the brake drum is in the outspread heading. The outspread brake may be subdivided into outer brakes and inside brakes. Axial brakes: The force on the brake drum is in the hub heading.

2. LITERATURER SURVEY

A disc brake is a type of brake that uses the calipers to squeeze pairs of pads against a disc or a "rotor"1 to create friction.2 This action slows the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. Hydraulically actuated disc brakes are the most commonly used form of brake for motor vehicles, but the principles of a disc brake are applicable to almost any rotating shaft. The components includes the disc, master cylinder, caliper (which contains cylinder and two brake pads) on both side of the disc. Development of disc-type brakes began in England in the 1890s. In 1902, the Lanchester Motor Company designed brakes that looked and operated in a similar way to a modern disc-brake system even though the disc was thin and a cable activated the brake pad. Other designs were not practical or widely available in cars for another 60 years. Successful application began in airplanes before World War II, and even the German Tiger tank was fitted with discs in 1942. After the war, technological progress began to arrive in 1949, with caliper-type four-wheel disc brakes on the Crosley line, and a Chrysler non-caliper type. In the 1950s, there was a critical demonstration of superiority at the 1953 24 Hours of Le Mans race, which required braking from high speeds several times per lap. The Jaguar racing team won, using disc brake equipped cars, with much of the cr being given to the brakes' superior performance over rivals equipped with drum brakes. Mass production began with the 1949 Crosley, with sustained mass production beginning in 1955 Citroën DS. Compared to drum brakes, disc brakes offer better stopping performance because the disc is more readily cooled. As a consequence discs are less prone to the brake fade caused when brake components overheat. Disc brakes also recover more quickly from immersion (wet brakes are less effective than dry ones). Most drum brake designs have at least one leading shoe, which gives a servo effect.

By contrast, a disc brake has no self-servo effect and its braking force is always proportional to the pressure placed on the brake pad by the braking system via any brake servo, braking pedal, or lever. This tends to give the driver better "feel" and helps to avoid impending lockup. Drums are also prone to "bell mouthing" and trap worn lining material within the assembly, both causes of various braking problems. The disc is usually made of cast iron, but may in some cases be made of composites such as reinforced carbon–carbon or ceramic matrix composites. This is connected to the wheel and/or the axle. To slow down the wheel, friction material in the form of brake pads, mounted on the brake caliper, is forced mechanically, hydraulically, pneumatically, or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. The first caliper-type automobile disc brake was patented by Frederick William Lanchester in his Birmingham factory in 1902 and used successfully on Lanchester cars. However, the limited choice of metals in this period meant that he had to use copper as the braking medium acting on the disc. The poor state of the roads at this time, no more than dusty, rough tracks, meant that the copper wore quickly making the system impractical. In 1921, the Douglas motorcycle company introduced a form of disc brake on the front wheel of their overhead-valve sports models. Patented by the British Motorcycle & Cycle-Car Research Association, Douglas described the device as a "novel wedge brake" working on a "bevelled hub flange", the brake was operated by a Bowden cable. Front and rear brakes of this type were fitted to the machine on which Tom Sheard rode to victory in the 1923 Senior TT. . Successful application began on railroad streamliner passenger trains and in airplanes and tanks before and during World War II. In the US, the Budd Company introduced disc brakes on the General Pershing Zephyr for the Burlington Railroad in 1938. By the early 1950s, disc brakes were being regularly applied to new passenger rolling stock. In Britain, the Daimler Company used disc brakes on its Daimler Armoured Car of 1939, the disc brakes, made by the Girling company, were necessary because in that four-wheel drive (4x4) vehicle the epicyclic final drive was in the wheel hubs and therefore left no room for conventional hub-mounted drum brakes. At Germany's Argus Motoren, Hermann Klaue (1912-2001) had patented7 disc brakes in 1940. Argus supplied wheels fitted with disc brakes e.g. for the Arado Ar 96 The German Tiger I heavy tank, was introduced in 1942 with a 55 cm Argus- Werke disc on each drive shaft. The American Crosley Hot Shot is often given cr for the first automotive production disc brakes. In 1949 and 1950, Crosley built several models (Hot Shot, Super Sport, Sedan, Station

Wagon, Pickup) with four-wheel disc brakes, then returned to drum brakes. Lack of sufficient research caused reliability problems, such as sticking and corrosion, especially in regions using salt on winter roads.10 Crosley four-wheel Disc Brakes made Crosleys and Crosley based specials popular in SCCA H-Production and H-modified racing in the 1950s. Their superior braking, made them difficult to beat. Drum brake conversions for Hot Shots were quite popular. The Crosley disc was a Goodyear-Hawley design, a modern caliper "spot" type with modern disc, derived from a design from aircraft applications. Chrysler developed a unique braking system, offered from 1949 to 1953. Instead of the disc with caliper squeezing on it, this system used twin expanding discs that rubbed against the inner surface of a cast-iron brake drum, which doubled as the brake housing. The discs spread apart to create friction against the inner drum surface through the action of standard wheel cylinders. Because of the expense, the brakes were only standard on the Chrysler Crown and the Town and Country Newport in 1950. They were optional, however, on other Chryslers, priced around $400, at a time when an entire Crosley Hot Shot retailed for $935. This four-wheel disc brake system was built by Auto Specialties Manufacturing Company (Ausco) of St. Joseph, Michigan, under patents of inventor H.L. Lambert, and was first tested on a 1939 Plymouth. Chrysler discs were "self energizing," in that some of the braking energy itself contributed to the braking effort. This was accomplished by small balls set into oval holes leading to the brake surface. When the disc made initial contact with the friction surface, the balls would be forced up the holes forcing the discs further apart and augmenting the braking energy. This made for lighter braking pressure than with calipers, avoided brake fade, promoted cooler running, and provided one-third more friction surface than standard Chrysler twelve-inch drums. Today's owners consider the Ausco-Lambert very reliable and powerful, but admit its grabbiness and sensitivity.

3. WORKING CONSTRUCTION

Disc brakes are increasingly used on very large and heavy road vehicles, where previously large drum brakes were nearly universal. One reason is that the disc's lack of self-assist makes brake force much more predictable, so peak brake force can be raised without more risk of braking-induced steering or jackknife on articulated vehicles. Another is disc brakes fade less when hot, and in a heavy vehicle air and rolling drag and engine braking are small parts of total braking force, so brakes are used harder than on lighter vehicles, and drum brake fade can occur in a single stop. For these reasons, a heavy truck with disc brakes can stop in about 120% the distance of a passenger car, but with drums stopping takes about 150% the distance.35 In Europe, stopping distance regulations essentially require disc brakes for heavy vehicles. In the U.S., drums are allowed and are typically preferred for their lower purchase price, despite higher total lifetime cost and more frequent service intervals. A railroad bogie and disc brakes Still-larger discs are used for railroad cars, trams and some airplanes. Passenger rail cars and light rail vehicles often use disc brakes outboard of the wheels, which helps ensure a free flow of cooling air. Some modern passenger rail cars, such as the Amfleet II cars, use inboard disc brakes. This reduces wear from debris, and provides protection from rain and snow, which would make the discs slippery and unreliable. However, there is still plenty of cooling for reliable operation. Some airplanes have the brake mounted with very little cooling, and the brake gets quite hot in a stop. This is acceptable as there is sufficient time for cooling, where the maximum braking energy is very predictable. Should the braking energy exceed the maximum, for example during an emergency occurring during take-off, aircraft wheels can be fitted with a fusible plug to prevent the tyre bursting. This is a milestone test in aircraft development.

4. DESIGN PROBLEMS

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. Manufacturers that use drilled discs as OEM typically do so for two reasons: appearance, if they determine that the average owner of the vehicle model will prefer the look while not overly stressing the hardware; or as a function of reducing the unsprung weight of the brake assembly, with the engineering assumption that enough brake disc mass remains to absorb racing temperatures and stresses. A brake disc is a heat sink, but the loss of heat sink mass may be balanced by increased surface area to radiate away heat. Small hairline cracks may appear in any cross drilled metal disc as a normal wear mechanism, but in the severe case the disc will fail catastrophically. No repair is possible for the cracks, and if cracking becomes severe, the disc must be replaced. These cracks occur due to the phenomenon of low cycle fatigue as a result of repeated hard braking. GM disc brake caliper (twin-piston, floating) removed from its mounting for changing pads The brake caliper is the assembly which 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 and is thus less tolerant of disc imperfections. It uses one or more 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. Floating caliper (single piston) designs are subject to sticking failure, caused by dirt or corrosion entering at least one mounting mechanism and stopping its normal movement. This can lead to the caliper's pads rubbing on the disc when the brake is not engaged or engaging it at an angle. Sticking can result from infrequent vehicle use, failure of a seal or rubber protection boot allowing debris entry, dry-out of the grease in the mounting mechanism and subsequent moisture incursion leading to corrosion, or some combination of these factors. Consequences may include reduced fuel efficiency, extreme heating of the disc or excessive wear on the affected pad. A sticking front caliper may also cause steering vibration. Another type of floating caliper is a swinging caliper. Instead of a pair of horizontal bolts that allow the caliper to move straight in and out respective to the car body, a swinging caliper utilizes a single, vertical pivot bolt located somewhere behind the axle centerline. When the driver presses the brakes, the brake piston pushes on the inside piston and rotates the whole caliper inward, when viewed from the top. Because the swinging caliper's piston angle changes relative to the disc, this design uses wedge-shaped pads that are narrower in the rear on the outside and narrower on the front on the inside. Various types of brake calipers are also used on bicycle rim brakes.

5. DESIGN AND MODELLING

RESULT TABULATION

S.NO	PARTICLES	AL	TI	ZI	STEEL
1	TOTAL DEFORMATION	9.1669*E-10	9.43*E-10	9.7281*E-10	10.1*E-10
2	NORMAL ELASTIC STRAIN	1.8118*E-12	1.86*E-12	0.19228*E-12	-
3	NORMAL STRESS	6.52*E-6	6.52*E-6	6.528*E-6	-
4	TEMPERATURE	129.85	129.85	129.87	129.81
5	TOTAL HEAT FLUX	0.004006	0.0040063	0.0040103	0.003998
6	DIRECTIONAL HEAT FLUX	0.0020742	0.0020742	0.0020743	0.0020741
7	THERMAL ERROR	84.855	84.855	75.008	105.66

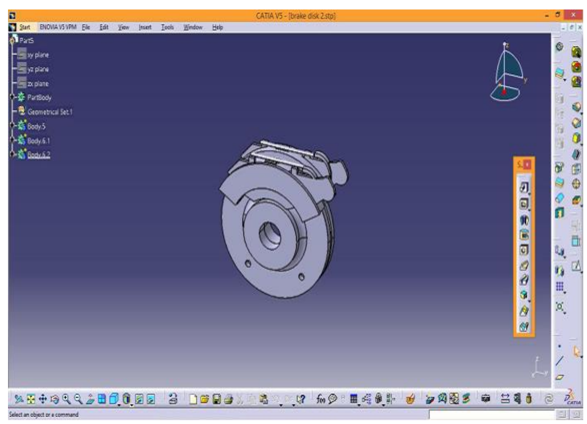

Chart -1: BOUNDRY CONDITION

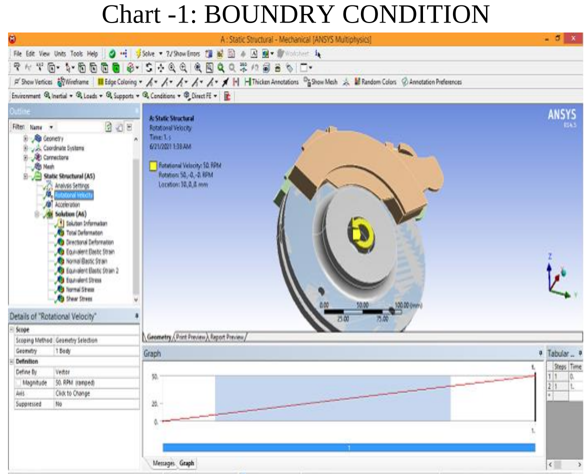

Fig -2: BOUNDRY CONDITION

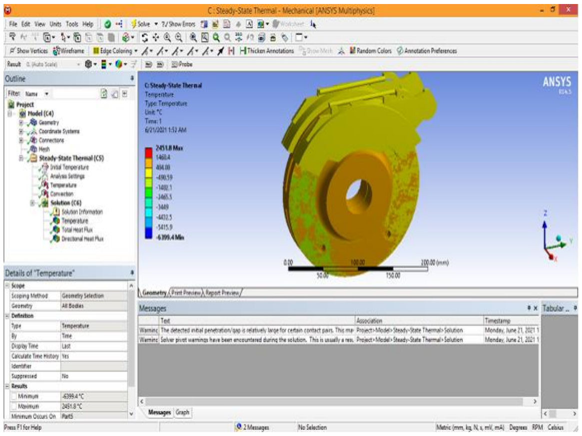

Fig -3: STATE STATE THERMAL

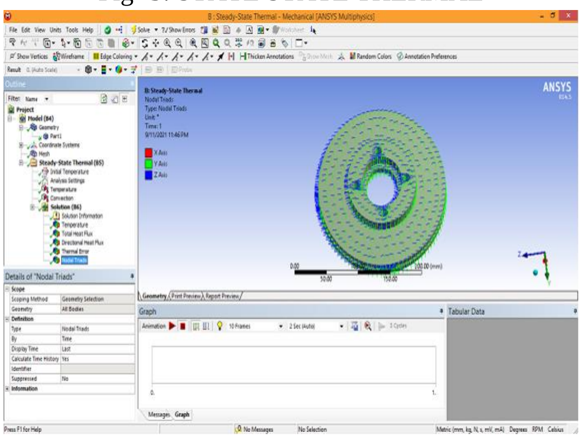

Fig -4: NODEL TRIADS

6. CONCLUSIONS

This paper explains about the design of a straight & vented brake discs in Solid Works. It also includes the deck preparation in hyper mesh, i.e., meshed part with applying the temperatures. Finally both the brake discs are been analyzed in Ansys for the Steady Static Thermal analysis. In these results, we get that, by changing the straight vents to curved vents in the brake disc the vonmises stresses & displacement vector sum & mass of the brakes disc has been reduced. And also curved vented brake disc is generated a high thermal flux than a straight vented brake disc.

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