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FEA Analysis and Design Optimization of Disk Brake

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Abstract: The disc brakes are vital components of vehicle for retarding its velocity. The proper design of disk brake is essential in dissipating heat from rubbing surface. The objective of current research is to investigate the thermal characteristics of cast iron disk brake under transient conditions. The designing and FE simulation of brake is conducted using ANSYS software. The existing design is then optimized to determine effect of each optimization variable and also to determine specific design points. The disc brake optimization results have provided significant information on design points at which heat dissipation and temperature is maximum or minimum and the effect of variable on heat flux is also established.
Keywords: Disk brake, Heat dissipation, optimization

I. INTRODUCTION

The moving vehicle has kinetic energy. When the brakes are applied on vehicle, the kinetic energy of vehicle is converted in to thermal energy. This is due to contact of brake pads with the rotating disc and the friction between these 2 parts generates heat. The heat generated is dissipated to the environment and the disc brake cools down to ambient temperature in some time.

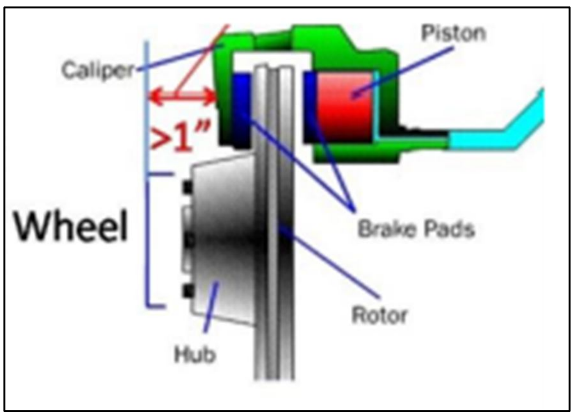

Figure 1: Disc brake system [9]

The disk brake parts comprise of piston, caliper, brake pads, hub and rotor as shown in figure 1 above. The stationary vehicle part(axle casing) is attached to caliper which has piston placed on inside of it. During braking process “the hydraulically actuated piston move the friction pads into contact with the disc, applying equal and opposite forces on the later and on releasing the brakes, rubber sealing rings act as return springs and retract the pistons and the friction pads away from the disc” [8].

II. LITERATURE REVIEW

Guan et al. [1] has investigated the methods for squeal suppression using optimization techniques. The results obtained from optimization are used to make modification in design of disk brake.

Spelsberg-Korspeter [2, 3] has conducted vibrational analysis on disk brake to determine resonant frequencies. The rotor geometry design is improved using structural optimization techniques to avoid excitations.

Lakkam and Koetniyom [4] has worked on reducing strain energy developed on vibrating pads. The method used to minimize strain energy is constraint layer damping. The results of this research could be a “guide to specify the position of the constrained layer damping patch under pressure conditions” [4].

Shintani and Azegami [5] has worked on suppressing of squeal noise using techniques of shape optimization. Using optimization technique, the brake pad design is optimized for which the squeal is lowest.

Lu and Yu [6, 7] has investigated the application of uncertainties (probabilistic) in design optimization of disc brake. The research findings have shown that more work needs to be done is reduction of brake squeal using interval uncertainness and more methods needs to be developed for this type of assessment.

III. OBJECTIVES

The objective of current research is to investigate the thermal characteristics of cast iron disk brake under transient conditions. The designing and FE simulation of brake is conducted using ANSYS software. The existing design is then optimized to determine effect of each optimization variable and also to determine specific design points.

IV. METHODOLOGY

The transient thermal analysis is conducted on disk brake under applied thermal loads. The disk brake design is developed in ANSYS design modeler using revolve tool. The initial sketch is developed with the dimensions shown in figure 2 below.

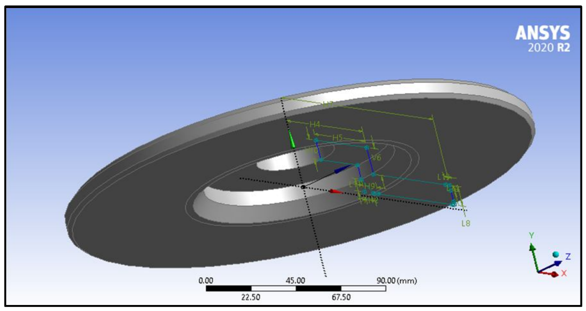

Figure 2: Sketched section of disc brake

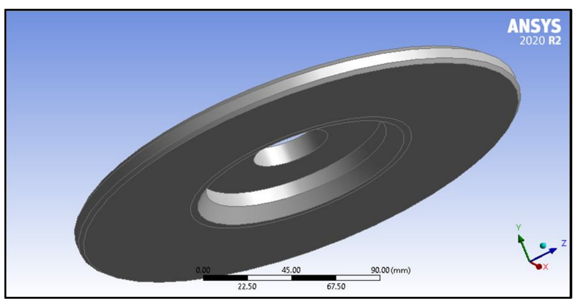

Figure 3: Developed model of disc brake

The disc brake model is developed as shown in figure 3 above. The model is checked for geometric errors like hard edges, surface patches and other defects etc. The disc brake model is discretized with tetrahedral elements using fine sizing, normal inflation, growth rate of 1.2 and defining layers to 5. The discretized model of disc brake is shown in figure 4 below.

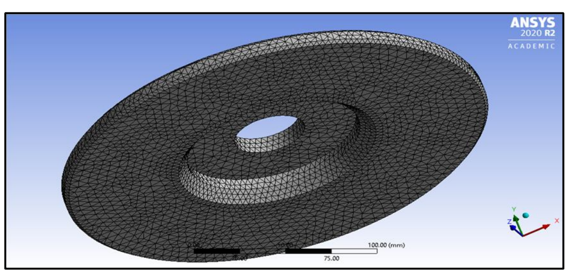

Figure 4: Discretized model of disc brake

The thermal loads are applied on disc brake design which is based on transient equation.

$$Q = t\omega$$

Where,
t is measured braking torque
ω is rig rotational speed

The edges are applied with heat flux to dissipate heat and brake pad surface is applied with heat flux. The thermal loads and boundary condition is shown in figure below.

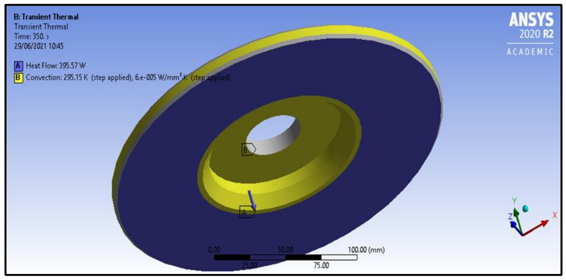

Figure 5: Thermal loads and boundary conditions on brake

After applying loads, the simulation is run for specified time interval. During the process of simulation, the matrices for each element are formulated and assembled.

V. RESULTS AND DISCUSSION

The thermal analysis is conducted on disk brake for stipulated period of time to determine heat flux plot and temperature plots. The plots are generated for different time intervals.

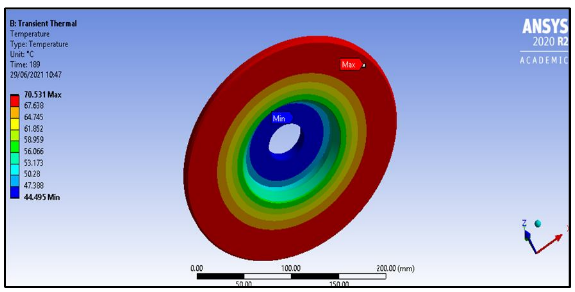

Figure 6: Temperature plot at 189 counter secs

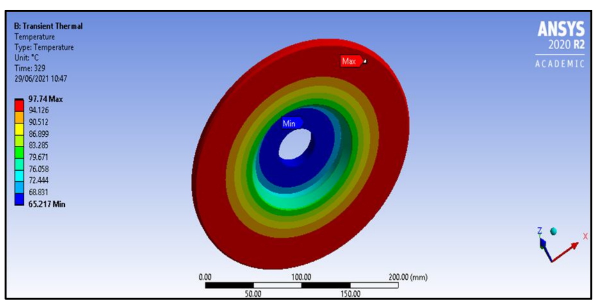

Figure 7: Temperature plot at 329 counter secs

The temperature plot of cast iron disc brake at 189 counter seconds shows maximum temperature on brake pad rubbing region. The temperature at this region is maximum with magnitude of 94^{0}C to 97^{0}C whereas the temperature on the hub region is below 72^{0}C.

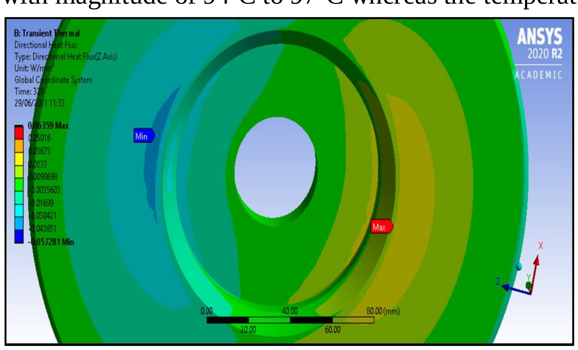

Figure 8: Heat flux plot at 329 counter secs

The heat flux plot shows maximum value at the hub corner regions. The heat flux at this region ranges from .05W/mm^2 to .06W/mm^2. The heat flux on other direction ranges from .04W/mm^2 to .05W/mm^2. The disc brake design is optimized to generate different design points and by using FE thermal analysis, the heat flux and temperature values are determined at these design points.

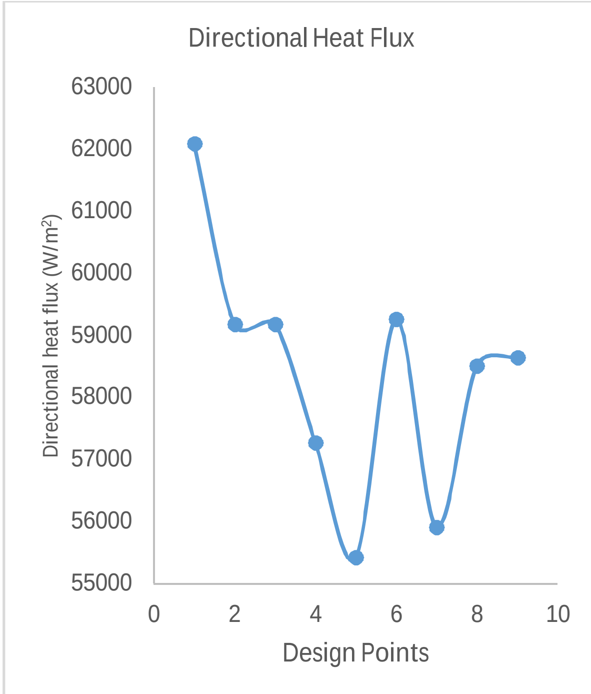

Figure 9: Variation of heat flux at different design points

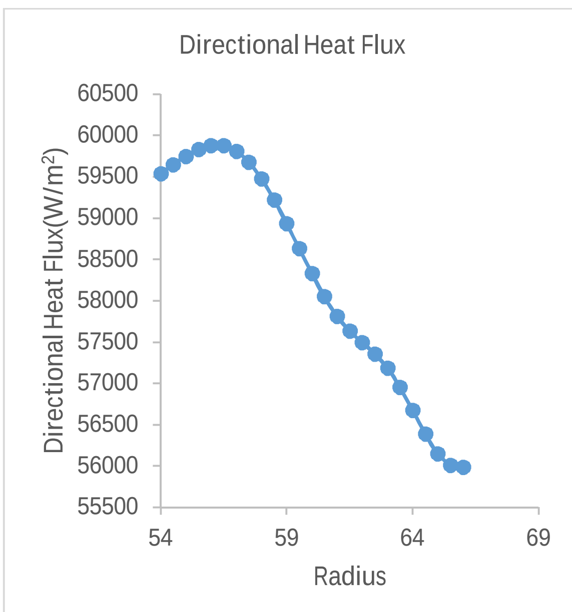

Figure 10: Variation of heat flux with respect to radius

The heat dissipation from disk brake is evaluated using parameter “heat flux” which signifies magnitude of heat flow along any direction. Using design optimization technique, different design points are generated and it is observed from figure 9 above that design point number 5 has minimum heat dissipation and design point number 1 has maximum heat dissipation. The design point 1 has height of hub as 11.48mm and radius of hub as 56mm. The variation of directional heat flux with respect to radius of hub is shown in figure 10 above which shows an increase in directional heat flux upto 56.5mm and then linear decrease which reaches to minimum value at 66mm.

VI. CONCLUSION

The FEA analysis is conducted on cast iron disk brake under transient thermal conditions to determine temperature distribution and heat dissipation capacity for varied time intervals. The disc brake optimization results have provided significant information on design points at which heat dissipation and temperature is maximum or minimum. Similarly, the effect of each variable on heat flux and temperature distribution is also established. The information gained from the research could aid in improving design of disk brake.

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