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Thermal Analysis of Disc brake Using ANSYS

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Abstract— The disc brake is a mechanism that used for reducing speed or discontinuing the cycle of the vehicle. many times using the brake for vehicle starts to heat producing during braking process, such that disc brake undergoes breakage due to high Temperature. Disc brake design is done through Solidwork and analysis is completed by using ANSYS workbench. The main purpose of this project is to study the Thermal analysis of the Materials for the Cast Iron, and Stainless steel. A comparison between the two materials for the Thermal values and material properties obtained from the Thermal analysis low thermal gradient material is preferred. Hence best appropriate design, low thermal gradient material cast iron is chosen for the Disc Brakes for better result.

Keywords— ANSYS, Disc brake, Braking System, FEM, Thermal analysis.

I. INTRODUCTION

A brake is a device by way of which frictional resistance is found to shifting system member, in order to discontinue the motion of a system. Modern vehicles have disc brakes on the front wheels, and there is a developing fashion to have them at the rear wheels as nicely. The braking system is in truth the matter of power stability and purpose of braking system is to transform mechanical strength of shifting vehicle into some other shape, which leads to lessening the rate of the vehicle. The kinetic energy is converted into the thermal energy via dry friction results, which then is, heat dissipated into the environment [1]. A brake disc plate is definitely fitted to and spins with the wheel. Two brake pads are positioned inner a caliper set up on the knuckle, that is hooked up at the chassis. When the driving force hits the brakes, the brake cylinder strain will increase and the piston pushes the pads into contact with the disc. The friction pressure between the brake pads and disc exerts braking torque on the disc, that's related to the wheel, and the following friction among the tire and the road makes the auto sluggish down. An instance of a disc brake meeting that includes a ventilated disc, a cross-section of a sliding caliper with a single piston, and two brake pads is presented in Figure 1.

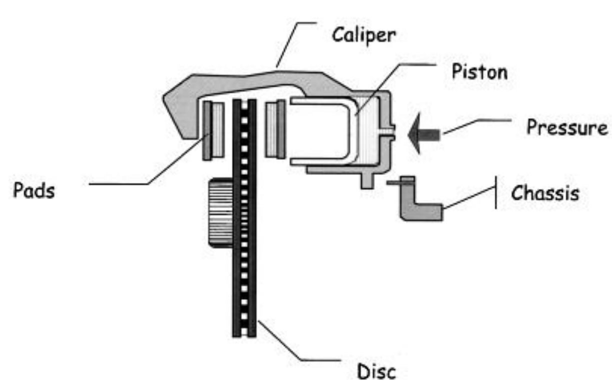

Figure 1: Disc brake assembly

A. Disc Brake

A disc brake device normally includes brake disc rotor, brake pads and a caliper. The arrangement of these elements permits the moving wheel to revel in intense braking in a short stopping distance. The middle a part of the brake disc has a round aperture, which is located at the wheel hub. It is surrounded by means of some of the holes for the wheel bolts. The brake disc rotates at the side of the wheel. The normal load, produced when the brake is actuated result in the era of an in-plane friction pressure at the disc-pad interface. This in turn, produces a brake torque about the middle of rotation of the wheel. The response to the brake torque is visible in the brake force, between the tire and ground, which slow the automobile.

Disc brakes work through making use of pressure to two brake pads on different sides of a spinning rotor connected the hub of a wheel. Disc brake pad are set up in a caliper that sits above the spinning disc. All friction additives of disc brake are exposed to the air, which facilitates to cool the brake components and braking effectiveness at some stage in repeated hard stops from higher speeds. A disc brake calls for better hydraulic strain and greater pressure to attain the equal preventing energy as a similar drum brake. Disc brakes are extensively used for lowering speed through the friction because of pushing brake pad against a brake disc with a set of calipers. The brake disc normally made by cast iron, but may additionally in a few cases made by using composites. The contacts conditions between the disk and pads correspond to warmth flux which is characteristic of the time and space variables. The thermal boundary situations outside the touch area correspond to convection, radiation and the recognized temperature. The sliding pace and the frictional warmness flux are time based and there is intensity related with stress increasing model. Solid disc brake is frequently used on smaller in width, lighter, and much less high-priced compare with vented disc brake extra using in heavier brake. Solid disc also has various establishing profile likes drilled, grooves and aggregate each of them. For this challenge, stable disc with opening diverse profile changed into selected that's everyday disc brake, drilled disc brake, grooves disc brake and combination drilled and grooves disc brake.

B. Braking system

A brake is a tool with the aid of which simulated frictional resistance is carried out to rotating machine part, in order to stop the movement of a machine. In the process of acting this characteristic, the brakes soak up both kinetic energy of the shifting member or the ability of electricity given up via objects being reduced by hoists, elevators and many others. The energy absorbed through brakes is dissipated inside the form of heat. This heat is dissipated into the encompassing ecosystem to prevent the car, so the brake system need to have the following necessities:

i. The brakes ought to be sturdy sufficient to stop the automobile with in a minimum Distance in an emergency.
ii. The motive force must have proper manipulate over the vehicle at some stage in braking and the automobile must no longer skid.
iii. The brakes need to have exact ant fade features i.e. Their usefulness should no longer lower with steady prolonged utility.
iv. The brakes should have desirable anti-wear residences.

Based on mode of operation brakes are categorized as follows:

- Hydraulic brakes.
- Electric brakes.
- Mechanical brakes.

The mechanical brakes in step with the course of acting pressure can be sub divided into the following businesses:

i. Radial brakes:

   In those brakes the pressure performing on the brake drum is in radial course. The radial brake can be subdivided into outside brakes and internal brakes.

ii. Axial brakes:

   In those brakes the force appearing on the brake drum is best within the axial course. e.g. Disc brakes, Cone brakes.

C. *Heat transfer in Disc brake*:

When a system is at a dissimilar temperature than its atmospheres, the Nature attempts to maintain thermal equilibrium. To do so, as the second law of thermodynamics explains, the thermal energy always moves from the system of higher temperature to the system of lower temperature.

This transfer of thermal energy occurs due to one or a combination of the three basic heat transport mechanisms: Conduction, Convection and Radiation.

D. Conduction:

Is the transmission of heat by direct molecular transmission, i.e. by physical connection of the particles within a medium or between mediums it happens in gases, liquids and solids, in conduction, there is no movement of any of the material mediums.

The governing equation for conduction is called the Fourier's law of heat conduction and it express that the heat flow per unit area is proportional to the normal temperature gradient, where the proportionality constant is the thermal conductivity:

$$q = -kA\frac{\partial T}{\partial x}$$

Where q is the heat flux perpendicular to a floor of place A, [W]; A is the surface vicinity via which the heat drift takes place, [m2]; k is the thermal conductivity, [W/(mK)]; T is the temperature, [K] or [°C]; and x is the perpendicular distance to the surface traveled by means of the heat flux.

E. Convection:

Convection is the heat transfer by means of mass motion of a fluid, when the heated fluid moves away from the heat supply. It combines conduction with the impact of a contemporary of fluid that movements its heated particles to cooler areas and update them by way of cooler ones. The float can be both because of buoyancy forces (natural convection) or due to artificially brought about currents (compelled convection).

The equation that represents convection comes from the Newton's regulation of cooling and is of the form:

$$q = -hA(T_\infty - T_s)$$

Where h is the convective heat transfer coefficient [W/ (m2K)]; T_∞ is the temperature of the cold fluid; and Ts is the temperature of the surface of the body.

II. FINITE ELEMENT ANALYSIS

To execute the finite element investigation of the piston when the pressure of the gasses acts upon it, a structural examination using ANSYS Workbench V.14.0 takes place. At this step the investigation of the piston is a linear static one, when minor modification in rigidity take place, there are no modifications in the direction of the loading, the materials stay within linear flexible region and miner deformations and stresses are produced. The model of the piston is designed in Solidwork 2016 and saved in this file as *.igs, and then imported in ANSYS Workbench.

Experimental Piston Model was optimized by with ANSYS that is relate with engineering simulation commercially used software set allowing a complete group that extents the complete variety of physics, offering right to use to almost several field of thermal engineering application that a design method needs. The software package uses its tools to place a virtual product through a rigorous testing procedure like testing a Piston model below totally different loading circumstances before it turns into a considerable object.

III. DESIGN AND ANALYSIS OF DISC BRAKE

1. Modeling of Disc brake

Two different metals used to design disc brake in this study first one are cast iron and other stainless steel. Solidwork used to design disc brake and ANSYS used to thermal analysis. The practical use of finite element modeling is known as FEA which is best understood during the real problem solving. FEA has been widely used by the automotive industry. It is a very popular tool for design engineers in the product enlargement method. FEA allows design engineers to analyze their designs while the designs are still in the procedure of an adjustable computer aided design (Solidwork) model. This helps and gives flexibility to the design engineers to go back and forth to implement of the FEA analysis results in the whole design process and improve the model. It is important to understand the FEA basics, modeling techniques, the inherent errors and their effects on the quality of the results so as to render FEA as a successful design tool. FEA is also used as a computational tool for carrying out engineering problem analyses.

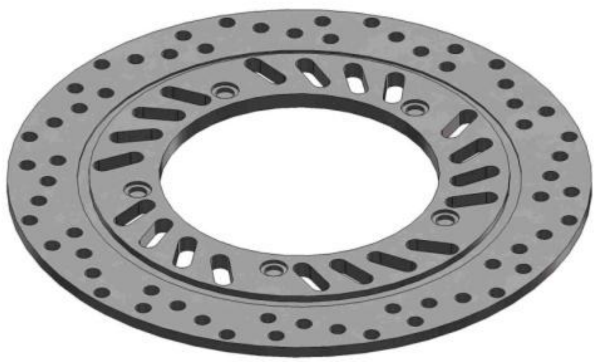

Figure 2: Geometry of disc brake

2. Dimensions of Disc brake

Dimensions of disc brake are explained in figure 3.

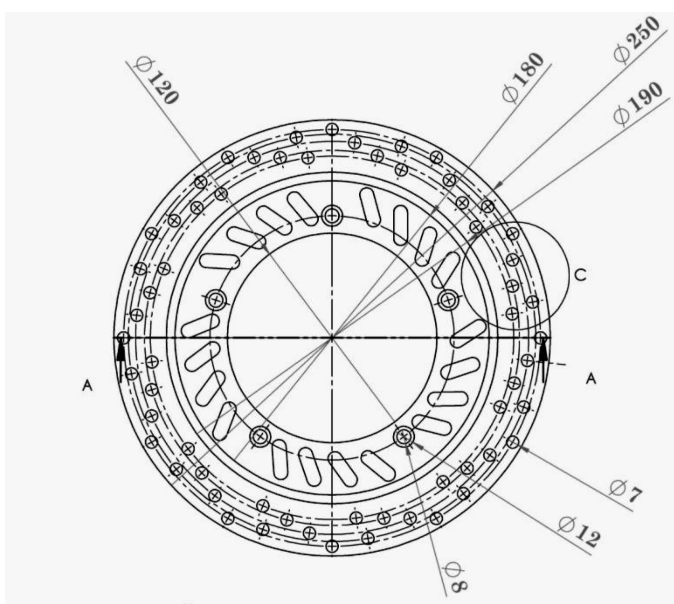

Figure 3: Geometry dimensions of disc brake

3. Applying boundary conditions

Figure represents the applied boundary conditions on disc brake has been kept fixed while convection on the top surface of the disc brake has been applied, to optimize failure of disc brake. Figure shows the applied boundary conditions of disc brake.

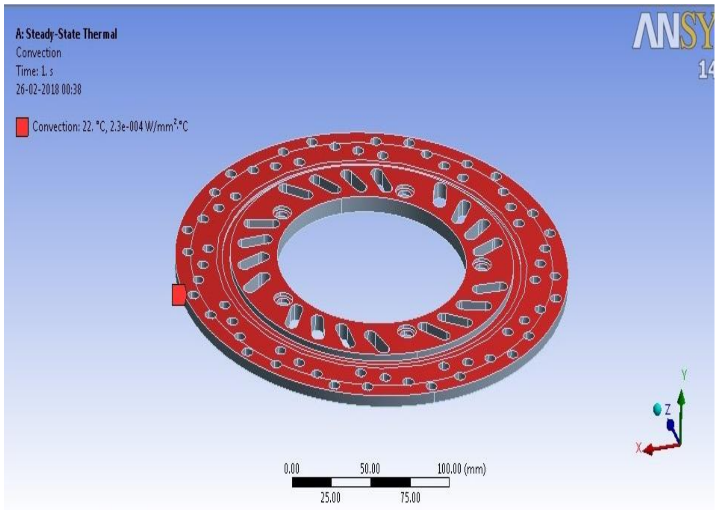

Figure 4: Boundary conditions

IV. MATERIAL PROPERTIES

Stainless steel and Cast iron considered as material in present study. Two types of material design of disc brake used in this study Properties of material are described below.

Table.5.1: Material Properties for Stainless Steel and Cast Iron

Material Properties	**Stainless Steel (Model I)**	**Cast Iron (Model II)**
Thermal conductivity(w/m k)	36	50
Density , ρ (kg/m3)	7100	6600
Specific heat , c (J/Kg c)	320	380
Thermal expansion , α (10-6 / k)	0.12	0.16
Elastic modulus, E (GPa)	210	110
Coefficient of friction, μ	0.5	0.5
Film co-efficient h(w/km2)	240	280
Operation conditions		
Angular velocity,(rad /s)	50	50
Braking Time Sec	5	6
Hydraulic pressure, P (M pa)	1	1

Thermal analysis is used to determine temperature and different thermal quantities that exchange over time. The change in temperature distribution through the years is critical in many applications which includes in quenching analysis for warmth treatment. Also of hobby are the temperature distribution effects in thermal stresses which could reason the failure. In such cases temperature from the brief thermal evaluation for thermal stress assessment. Heat flux is applied for distinct design shape discs is three.9417e-002 W/mm^2.The following figure 5 suggests the result of thermal analysis in disc brake.

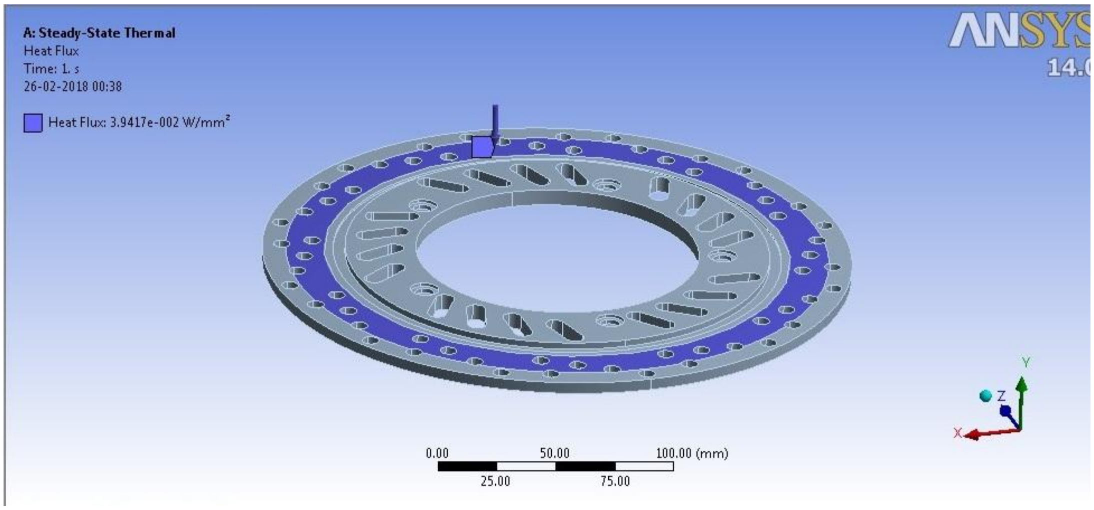

Figure 5: Heat flux conditions on disc brake

V. RESULTS AND DISCUSSION

As shown in figure 6 thermal analysis was conducted on the cast iron brake disc and maximum temperature observed is 56.932 ^{o}C and minimum temperature observed is 33.674 ^{o}C.

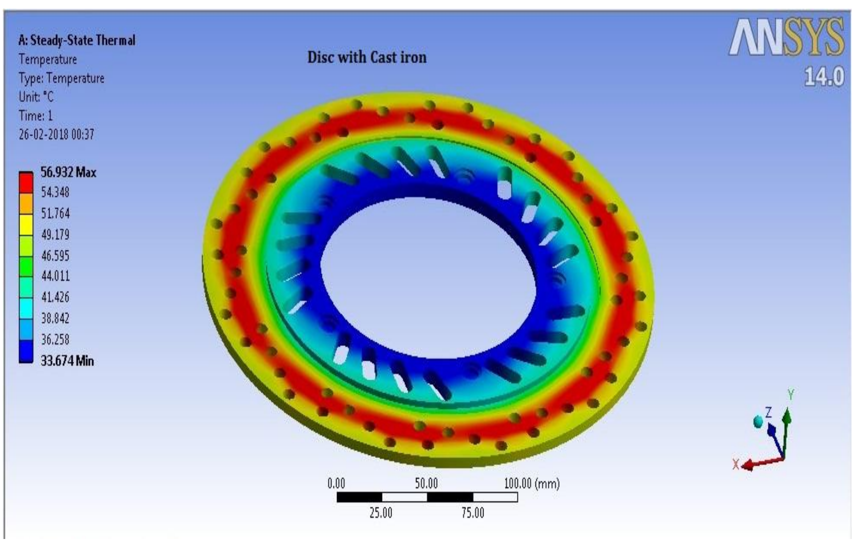

Figure 6: Temperature distribution of cast iron disc brake (Model-I)

As shown in figure 7 thermal analysis was conducted on the stainless steel brake disc and maximum temperature observed is 69.819 ^{o}C and minimum temperature observed is 25.642 ^{o}C.

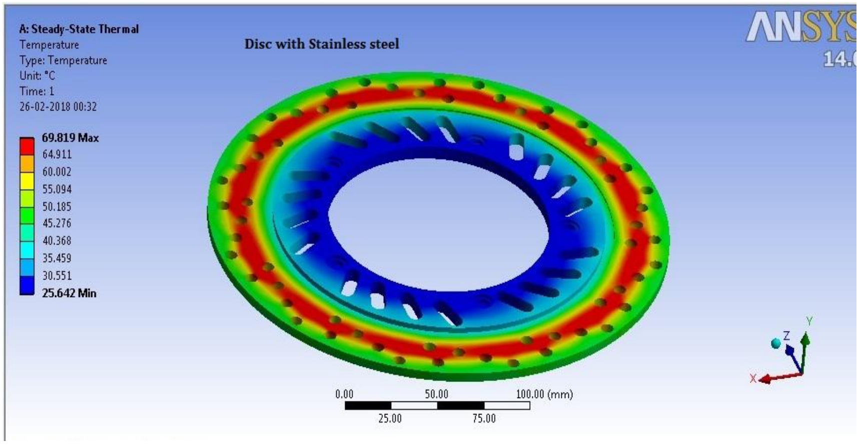

Figure 7: Temperature distribution of Stainless steel disc brake (Model-II)

From the figures 8, given above, we can summarize the results in the following manner: -

Table no. 9.1 Maximum and minimum Temperature Distribution

Materials	**Temperature Distribution (^oC)**	
	Min	**Max**
Stainless Steel	33.67	56.93
Cast Iron	25.64	69.81

As shown in figure 5.4 thermal analysis was conducted on the cast iron brake disc and maximum Heat flux observed is 8.2427 W/mm^2 and minimum Heat flux observed is 1.6624e-5 W/mm^2.

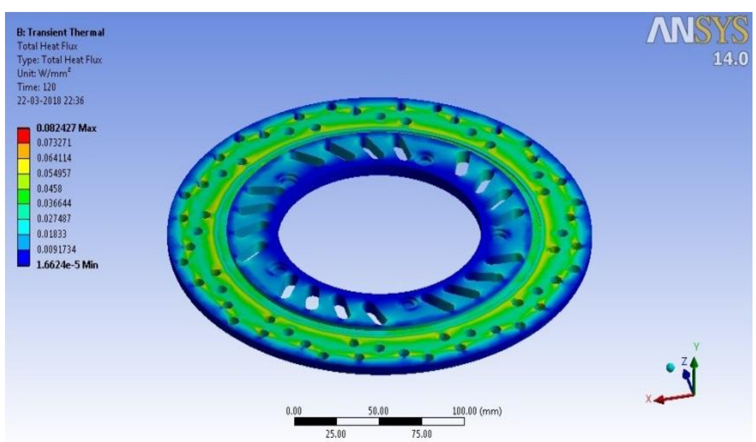

Figure 8: Heat flux of cast iron disc brake (Model-I)

As shown in figure 9 thermal analysis was conducted on the stainless steel brake disc and maximum Heat flux observed is 7.6624 W/mm^2 and minimum Heat flux observed is 1.2645e-6 W/mm^2.

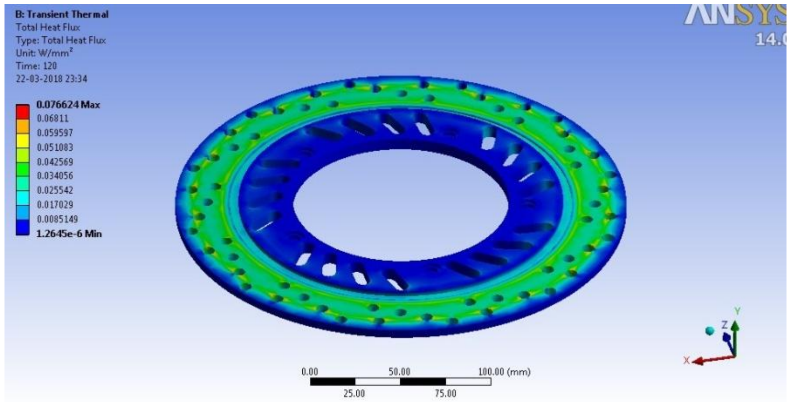

Figure 9: Heat flux of Stainless steel disc brake (Model-II)

Table shows the heat flux variations of cast iron and stainless steel disc brake.

Table no. 5.2 Maximum and minimum Total Heat Flux

Materials	Total Heat Flux (W/mm^2)	
	Min	Max
Stainless Steel	1.2645e-6	7.6624
Cast Iron	1.6624e-5	8.2427

Graph 10 shows the Maximum heat loss of cast iron disc brake with respect to time.

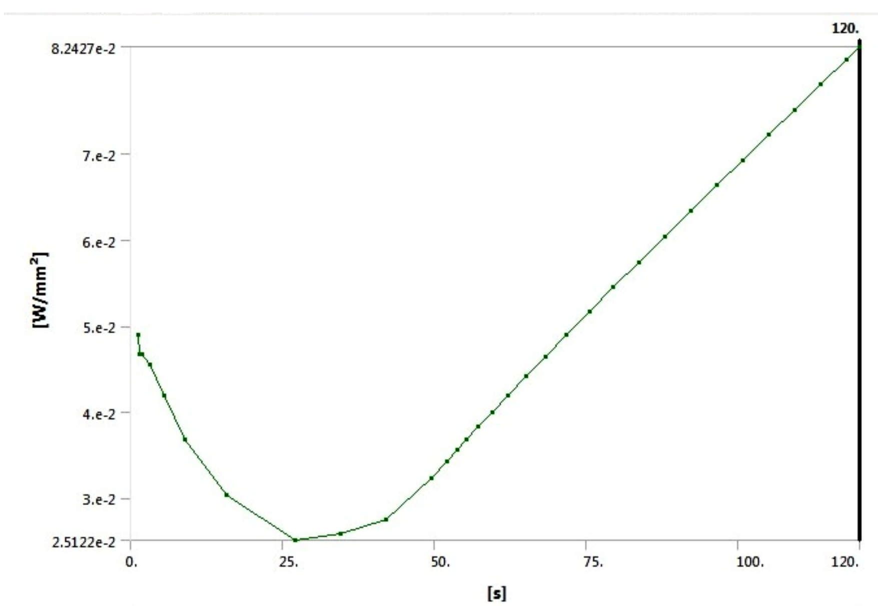

Figure 10: Maximum heat loss Vs Time of Cast iron disc brake

Graph 11 shows the Maximum heat loss of Stainless steel disc brake with respect to time.

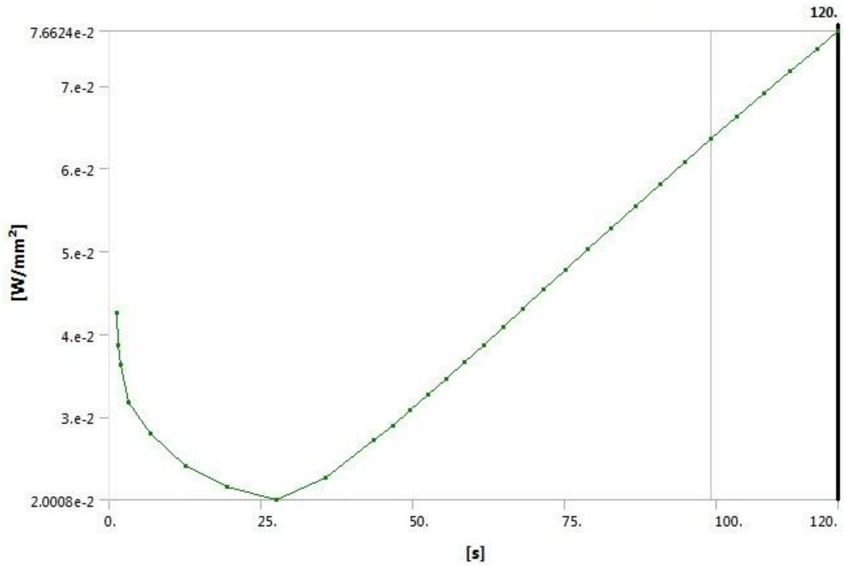

Figure 11: Maximum heat loss Vs Time of Stainless steel disc brake

VI. CONCLUSION

The above study can provide a useful design and help to improve the brake performance of disc brake system. From the above result, from our study of various design patterns for different materials we have observed that the maximum temperature rise of cast iron disc is much small with compared to stainless steel and therefore on the basic of thermal investigation, cast iron is the best desirable substantial for manufacturing disc brake. Though, cast iron disc brake some drawback of getting corroded when it comes in contact with wetness and hence it cannot be used in two wheelers and thus we prefer stainless steel.

The present study can provide a useful de-sign tool and improve the brake performance of Disc brake system. The values achieved from the investigation are less than their permissible values. Hence the brake Disc analysis is safe depend on the strength and rigidity criteria. From the above study work the following conclusions are made:

- Profiles made up of Cast iron also have better heat dissipation rate but the tendency of the cast iron is that it gets corroded when comes in contact with water or moisture. Hence it is not suitable for production purpose.
- Maximum temperature found on cast iron disc brake is 56.93 ^{0}C and temperature drop 33.67 ^{0}C.
- Maximum temperature found on stainless steel disc brake is 69.81 ^{0}C and temperature drop 25.64 ^{0}C.
- Maximum temperature drop found on stainless steel disc so this material is suitable for design.

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