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Modeling and Exploration of a 2-Wheeler Automotive Brake Disc

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ABSTRACT:

Braking is a process which converts the kinetic energy of the automobile into mechanical energy which must be dissipated in the form of heat. The disc brake is equipment used for de-accelerating of the rationing wheel. A brake disc generally casted using cast iron metal or ceramic composites, connected to the wheel or axle. Number of occasionsutilizing the brake for vehicle generatesheat during braking, such that disc brake undergoes breakage due to high temperature.

The performances and parameters matches of the disc brakes directly effect on the automobile safety system. Initially, by using the traditional design theory designed a 2- wheeler brake disc. Then a model is created by using 3-Dimensional mechanical package UNI-GRAPHICS and analysis is done by using ANSYS work bench. The main purpose of this project is to study the thermal analysis of the materials for Titanium composite, Grey cast iron, Aluminum alloy, Stainless steel. A comparison between the four materials for the thermal values and material properties obtained. From the thermal analysis high temperature distribution, climatic supportive material is preferred. Hence high temperature distribution, anti-corrosive material Stainless steel is preferred for the disc brakes for better performance.

Key points: ***2- wheeler Brake disc, Analysis, Thermal analysis, Model preparation.***

LITERATURE REVIEW

Prof.smt.G.Prasanthi and Mr.N.Balasubramanyam [1]. A transient analysis for the thermo-elastic contact problem of the automotive brake discs with heat generation is accomplished using the finite element analysis. To analyze the thermo-elastic phenomenon occurring in the automotive brake discs, the employed heat-conducted and elastic equations are solved with contact problems.

The numerical simulation for the thermo-elastic behavior of brake disc is attained in the repeated brake condition. The computational results are available for the distribution of heat flux and temperature on each friction surface between the contacting bodies. Also thermo elastic instability phenomenon is examined in the study, and the effect of the material properties on the thermo-elastic behaviors are inspected to facilitate the conceptual design of the automotive brake disc system.

Based on the numerical results, the thermo-elastic behaviors of the carbon-carbon composites with excellent mechanical properties are also discussed.

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Mr.Manjunath.T.V [2].Analysis carried over the thermo mechanical behaviour of the dry contact of the brake disc through the braking phase.

The coupled thermal-structural analysis is used to define the distortion and the von misses stress established in the disc for the both solid and ventilated disc with two different materials to enhance performance of the rotor disc. A comparison between analytical and result obtained from FEM is done and all the values obtained from the analysis are less than their allowable values.

Hence best suitable design, material and rotor disc is suggested based on the performance, strength and rigidity criteria.

Eltoukhy and Asfour [3]. Here considered a case study regarding a transient analysis of the thermo elastic contact problem for automotive brake discs with frictional heat generation, performed using the finite element analysis (FEA) method is described in details.

The computational results are presented for the distribution of the temperature on the friction surface between the contacting bodies. Also the influence of the material properties on the thermo elastic behaviour, represented by the maximum temperature on the contact surface is compared among different types of brake disc materials found in the literature, such as grey cast iron, high-carbon grade iron, titanium alloyed grey iron, and compact graphite iron (CGI), aluminium metal matrix composites (AlMMC's), namely AL2O3 Al-MMC and SiC Al-MMC (ceramic brakes).

DIMENSIONAL PARAMETERS FOR MODEL BUILD UP

In the aspect of the bike accident prevention, the braking performance of vehicle has been a critical issue. The rotor model heat flux is calculated for the moving bike with a velocity 33.33 m/s (120km) and the following is the calculation.

Outer diameter of brake disc	(D)	240mm
Inside diameter of brake disc	(d)	102mm
Thickness of brake disc	(t)	6mm
Perforated hole diameter	(dp)	5mm
Disc brake lock hole diameter	(dl)	8mm
Mass of brake disc	(m)	1.5kg
Mass of the vehicle	(M)	300kg
Initial velocity	(u)	33.33m/s
Final velocity	(v)	0 m/s
Static front axle load/Total bike load	(γ)	0.30
Percentage of kinetic energy that disc absorbs	(k)	90%
Acceleration due to gravity	(g)	9.81m/s²
Coefficient of friction for dry pavement	(μ)	0.50

CALCULATION PROCEDURE

Energy generated during braking (K.E)

$$K.E=[\gamma km(u-v)^2]/2$$

Deceleration time (v)

$$v=u+at$$

Deceleration time=Braking time=5s

Braking power(Pb) Braking power during continued braking is obtained by differentiating energy with respect to time

Pb=K.E/t

Calculate the Heat flux(Q) Heat flux is defined as the amount of heat transferred per unit area per unittime

Q=Pb/A

Calculations for input parameters

S.NO	Parameters	Formulae	Result achieved for model
01	Kinetic energy	$K.E=[\gamma km(u-v)^2)/2]$	**44991.001J**
02	Deceleration time	V=u+at	**4s**
03	Braking power	Pb=K.E/t	**11247.75 J/s**
04	Area	$A=\pi(R^2-r^2)$	**0.03706 m²**
05	Heat flux	Q=Pb/A	**303501.07 W/m²**

Method of calculation

Energy generated during braking (K.E)

$K.E=[\gamma km(u-v)^2]/2$

$K.E=[0.3*0.9*300(33.33^2)]/2$

K.E=**44991.001J**

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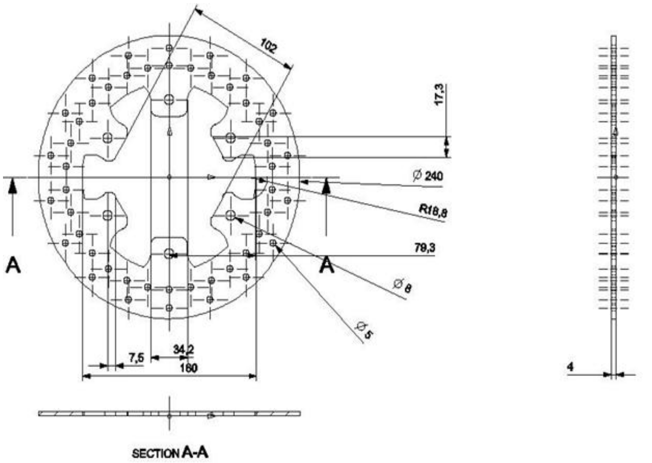
Deceleration time (v)
v=u+at
0=33.33+(9.81*t)
Deceleration time=Braking time=**t=4s**

Braking power(Pb) Braking power during continued braking is obtained by differentiating energy with respect to time
Pb=K.E/t
Pb=44991.001/4=**11247.75 J/s**

Calculate the Heat flux(Q) Heat flux is defined as the amount of heat transferred per unit area per unittime
Q=Pb/A
Q=11247.75/0.03706
Q=**303501.07 W/m²**

MODELLING OF DISC BRAKE



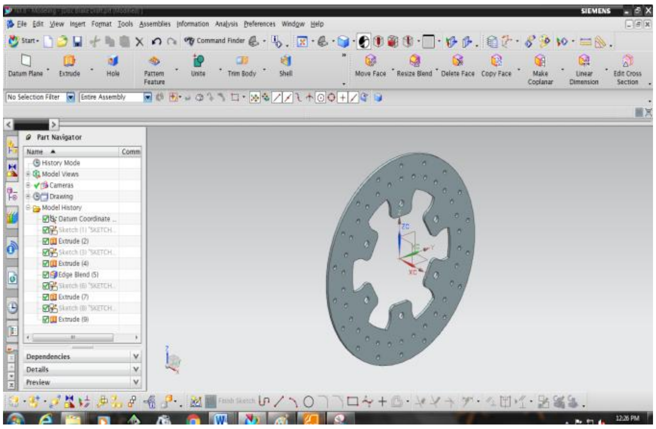


Figure: Completed model of disc brake

FEA MODEL FOR DEVOLOPED BRAKE DISC

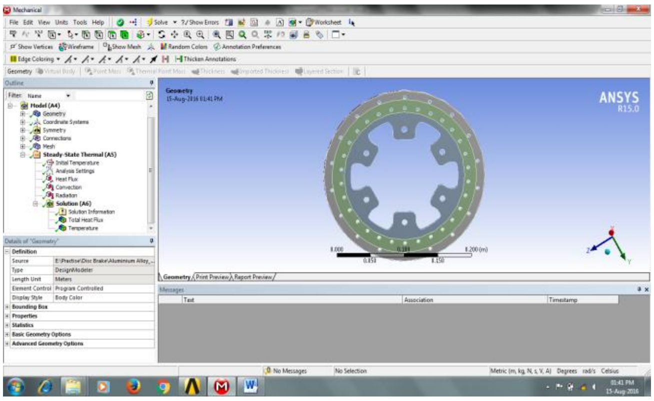


Figure: Preparation for FEA model of disc

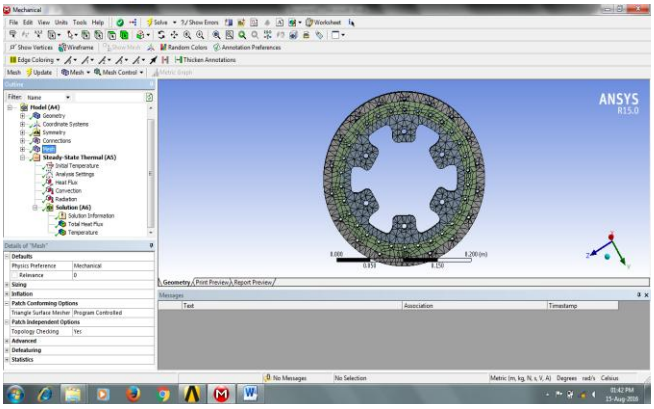


Figure: FEA Model for disc

RESULTS

MATERIAL SPECIFICATION

To complete Analysis here we have selected the disc brake materials as Aluminum alloy 6061, Grey cast iron, Titanium alloy, and Stainless steel. The properties of each material are explained below in a brief manner.

ALUMINIUM ALLOY 6061

- It is a lightweight aluminum ingredient
- Aluminum 6061 can be worked easily
- Aluminum is cheaper than several metal materials
- The thermal conductivity of aluminum alloy is good
- The strength of Aluminum alloy 6061 is poor when compared to other metals

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Aluminum alloy 6061 material properties

S.No	Property	Value
1	Thermal conductivity(w/mk)	173
2	Density(kg/m³)	2770
3	Specific Heat(J/kgk)	875
4	Thermal expansion(10^-6/k)	23*10^-6/k
5	E(GPa)	68.30
6	Coefficient of friction(u)	0.34
7	Convective coefficient(h)(w/m²k)	100

GREY CAST IRON

- It is an ordinary commercial iron having 3 to 3.5% having carbon.
- The grey colour is due to the fact that carbon is present in the form of free graphite
- Grey cast iron consists of low tensile strength and high compressive strength
- It doesn't consist any ductility
- Grey cast iron can be machined easily

Table 8.1.2 Grey cast iron material properties

S.No	Property	Value
1	Thermal conductivity(w/mk)	52
2	Density(kg/m³)	7200
3	Specific Heat(J/kgk)	447
4	Thermal expansion(10^-6/k)	5.8*10^-6/k
5	E(GPa)	130
6	Coefficient of friction(u)	0.28
7	Convective coefficient(h)(w/m²k)	100

TITANIUM ALLOY

- Titanium is transition metal with a white-silver metallic appearance
- It is a lustrous , strong metal that exhibits good resistance to atmospheric corrosion
- It is low in toxicity but powder form of titanium is an explosion hazard

Table 8.1.3 Titanium alloy material properties

S.No	Property	Value
1	Thermal conductivity(w/mk)	21.90
2	Density(kg/m³)	4620
3	Specific Heat(J/kgk)	522
4	Thermal expansion(10^-6/k)	8.9*10^-6/k
5	E(GPa)	116
6	Coefficient of friction(u)	0.34
7	Convective coefficient(h)(w/m²k)	100

STAINLESS STEEL

- Stainless steel a medium weight metal material
- Stainless steel is cannot be worked easily
- Strength of the stainless steel is a good factor
- The property of thermal conductivity of stainless steel is not good enough
- It is highly anti corrosive property because of Chromium element involvement in it

Table 8.1.4 Stainless steel material properties

S.No	Property	Value
1	Thermal conductivity(w/mk)	15.15
2	Density(kg/m³)	7750
3	Specific Heat(J/kgk)	480
4	Thermal expansion(10^-6/k)	17*10^-6/k
5	E(GPa)	203
6	Coefficient of friction(u)	0.28
7	Convective coefficient(h)(w/m²k)	100

THERMAL GRADIENTS CALCULATIONS

In this project for the developed model heat generated is same for all cases but the thermal conductivity changes according to the material applied. This shows the impact on thermal gradient of developed model.

Thermal gradient can be determine by using the formulae as stated below
Thermal Gradient= (Heat Flux/Thermal conductivity)
As we said before Heat flux is same for all materials because of common model and is calculated as Q=303501.07W/m²

By considering the thermal conductivity of each material from properties tables the thermal gradient follows as

THERMAL GRADIENTS OF SPECIFIED MATERIALS

Aluminum alloy 6061:	Q/T_c=303501.07/173=1754.34k/m
Grey cast iron:	Q/T_c=303501.07/52=5836.559k/m
Titanium alloy:	Q/T_c=303501.07/21.90=13858.49k/m
Stainless steel:	Q/T_c=303501.07/15.15=20033.07k/m

ANALYSIS ON DEVELOPED MODEL FOR SPECIFIED MATERIALS

The Analysis is carried out one the developed model for the materials Aluminum alloy 6061, Grey cast iron,

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Titanium alloy and Stainless steel by using ANSYS R15.0 version.

In each case Static thermal analysis and Transient thermal analysis are done for the developed model.

Here in our analysis we have consider each material properties which are needed to apply for material of the developed disc model.

The same are shown as followed.

Aluminum alloy 6061 Steady State Thermal Analysis

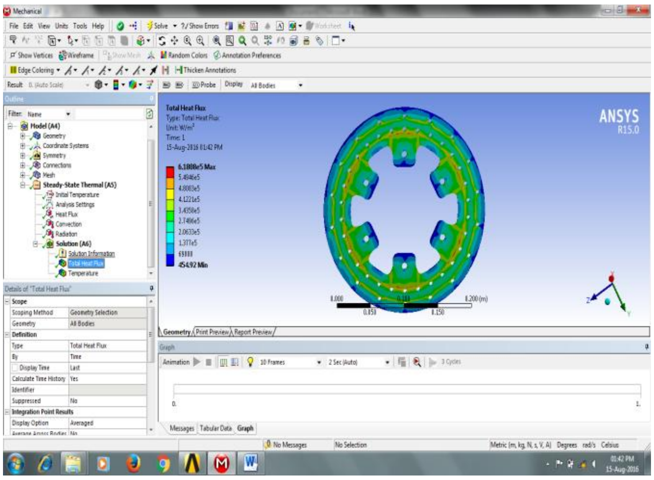

Figure: Aluminium alloy 6061 Steady state Total Heat Flux

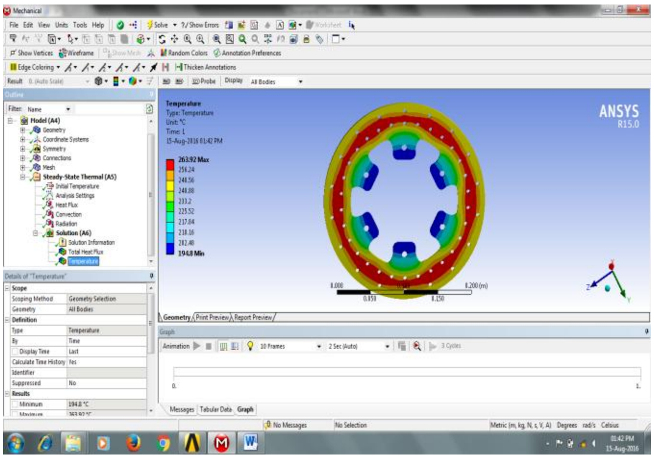

Figure :Aluminium alloy 6061 Steady state Temperature Distribution

Aluminium alloy 6061 Transient Thermal Analysis

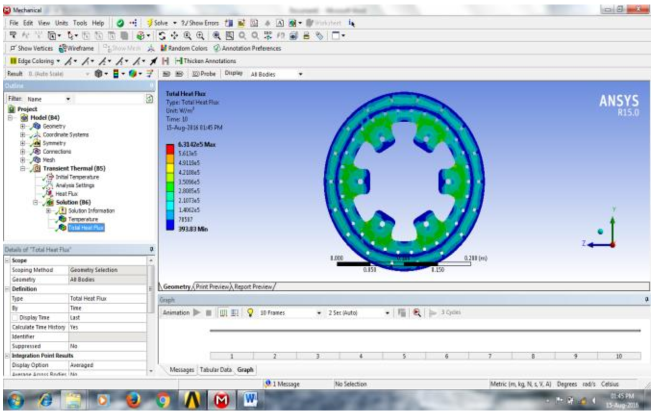

Figure :Aluminium alloy 6061 Transient Total Heat Flux

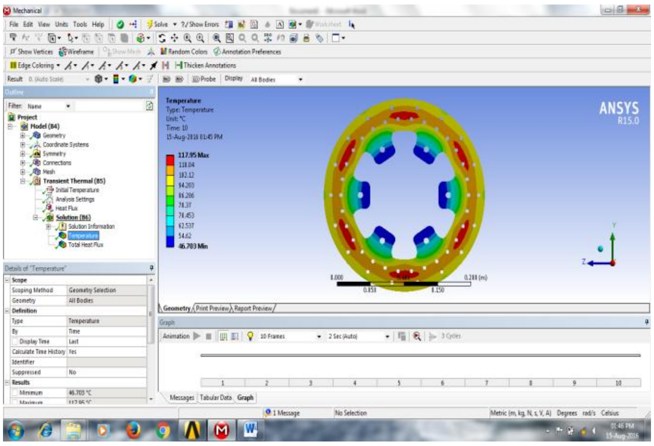

Figure :Aluminium alloy 6061 Transient Temperature Distribution

Grey cast iron Steady state Thermal Analysis

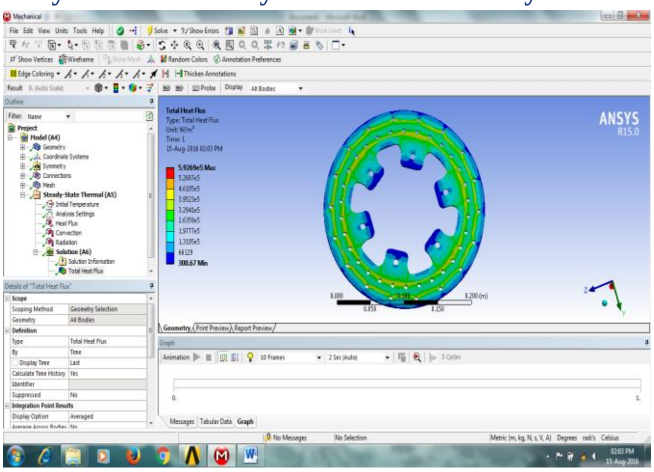

Figure: Grey cast iron Steady state Total Heat Flux

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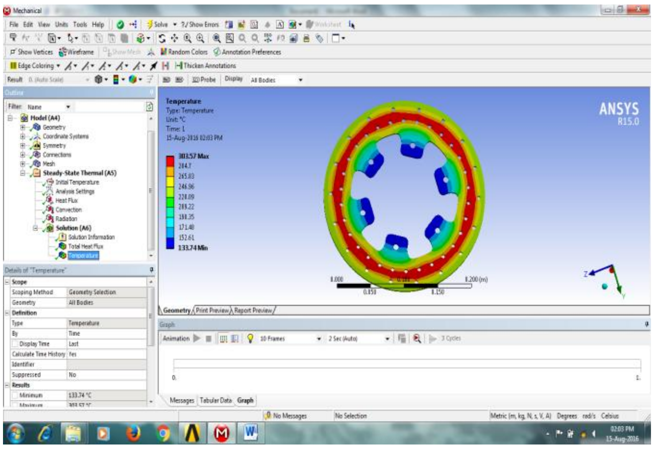

Figure : Grey cast iron Steady state Temperature Distribution

Grey cast iron Transient Thermal Analysis

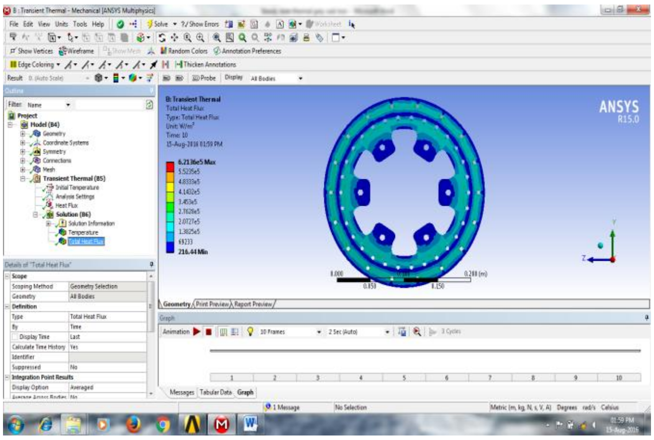

Figure : Grey cast iron Transient Total Heat Flux

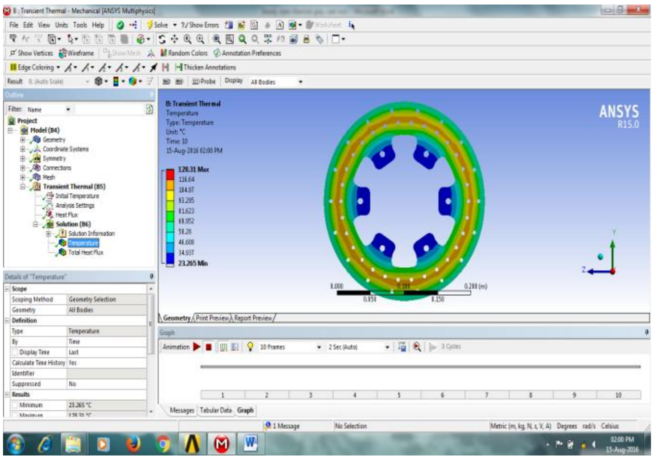

Figure : Grey cast iron Transient Temperature Distribution

Titanium alloy Steady State Thermal Analysis

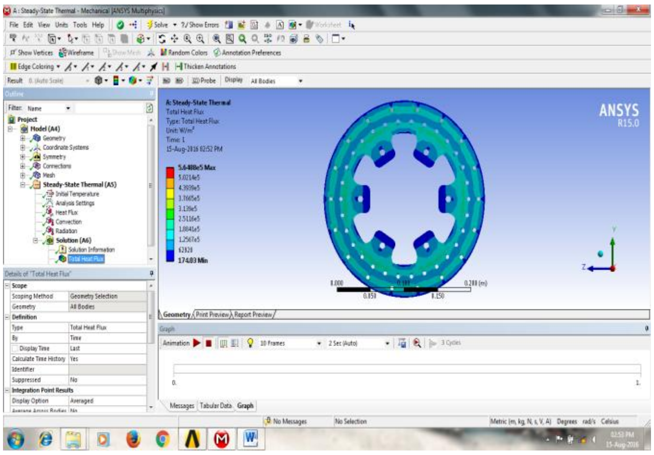

Figure : Titanium alloy Steady state Total Heat Flux

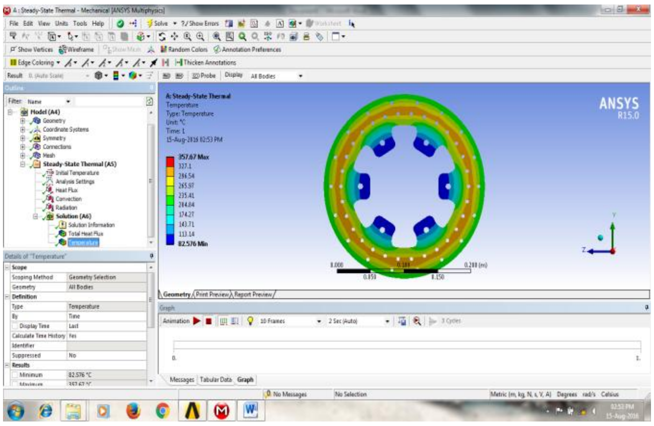

Figure : Titanium alloy Steady state Temperature Distribution

Titanium alloy Transient Thermal Analysis

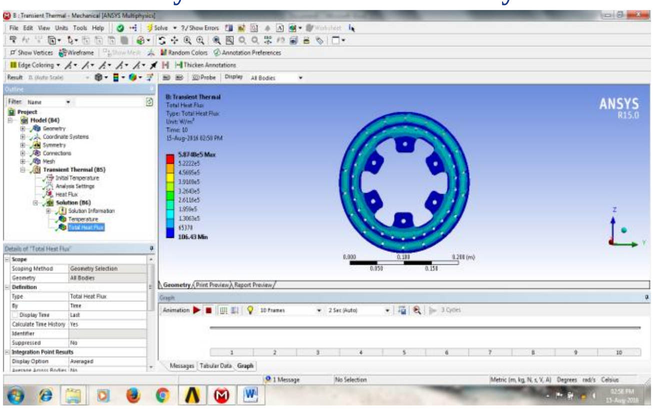

Figure : Titanium alloy Transient Total Heat Flux

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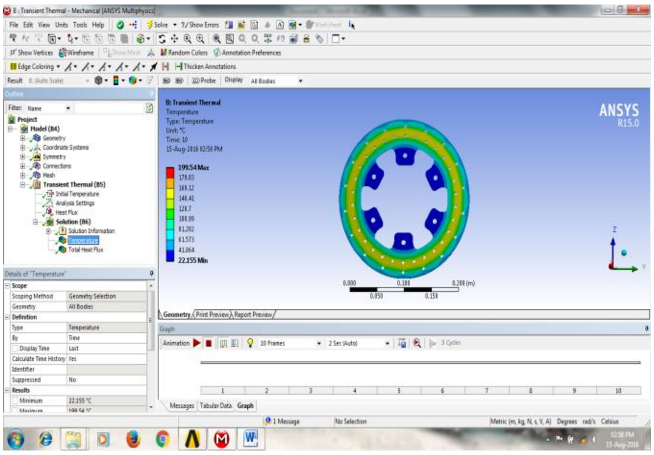

Figure : Titanium alloy Transient Temperature Distribution

Stainless Steel Steady State Thermal Analysis

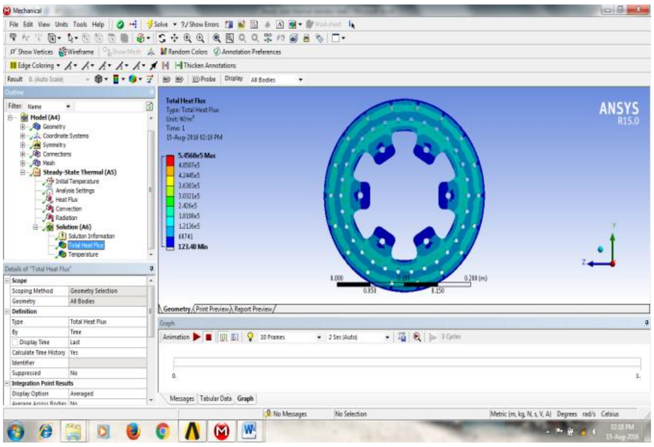

Figure : Stainless steel Steady state Total Heat Flux

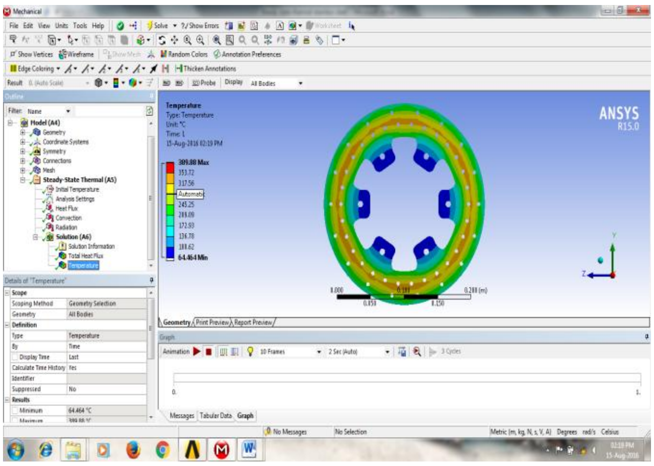

Figure : Stainless steel Steady state Temperature Distribution

Stainless Steel Transient Thermal Analysis

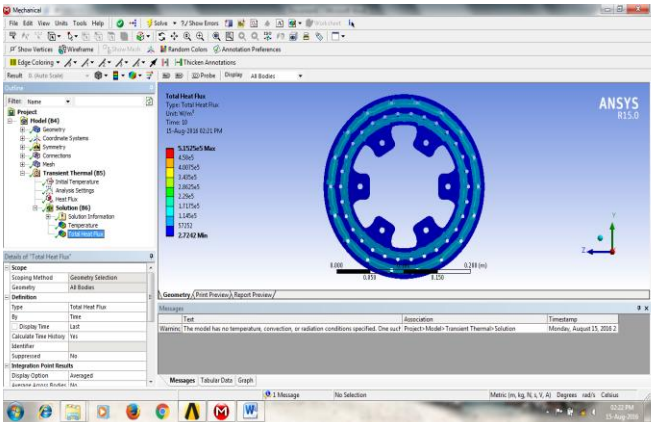

Figure: Stainless steel Transient Total Heat Flux

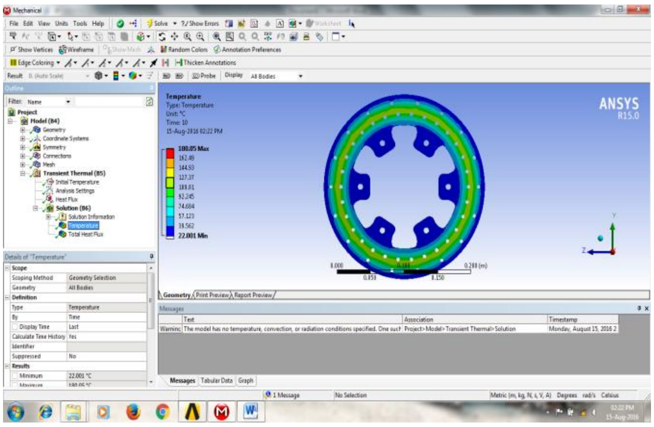

Figure : Stainless steel Transient Temperature Distribution

DISCUSSIONS

From the all achieved results we may move to comparative analysis to know the better material of brake disc. The following graphs can give the details of all materials performance in graphical representation.

Table: Total Heat Flux Steady state thermal

Total Heat Flux Steady State Thermal		
S.No	Material	Steady state thermal (w/m²)
1	Aluminium alloy 6061	6.1808*10^5
2	Grey cast iron	5.9269*10^5
3	Titanium alloy	5.6488*10^5
4	Stainless steel	5.4568*10^5

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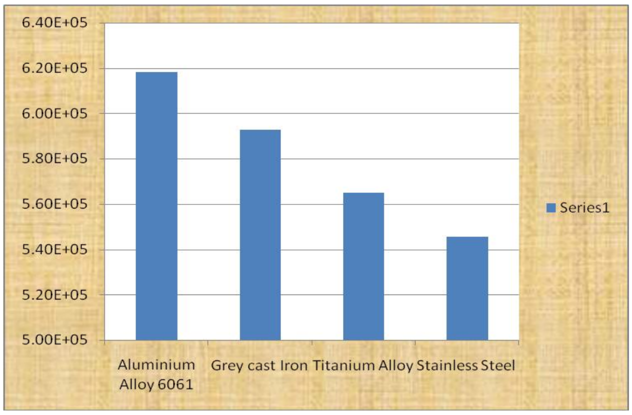

Figure: Steady state thermal total Heat Flux-Graph

Table 9.2 Total Heat Flux Transient thermal

Total Heat Flux Transient Thermal		
S.No	Material	Transient thermal (w/m²)
1	Aluminium alloy 6061	6.3142*10^5
2	Grey cast iron	6.2136*10^5
3	Titanium alloy	5.8748*10^5
4	Stainless steel	5.1525*10^5

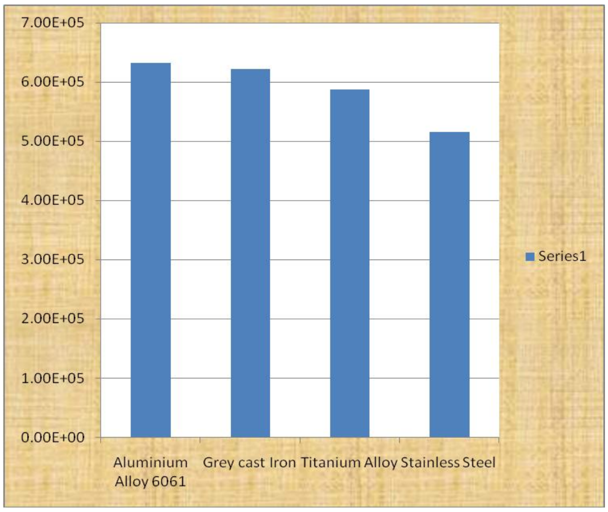

Figure (9.2): Transient thermal total Heat Flux-Graph

Table 9.3 Temperature Distribution Steady state Thermal

Temperature Distribution-Steady state thermal		
S.No	Material	Steady state Thermal(Celsius)
1	Aluminium alloy 6061	263.92
2	Grey cast iron	303.57
3	Titanium alloy	357.67
4	Stainless steel	398.98

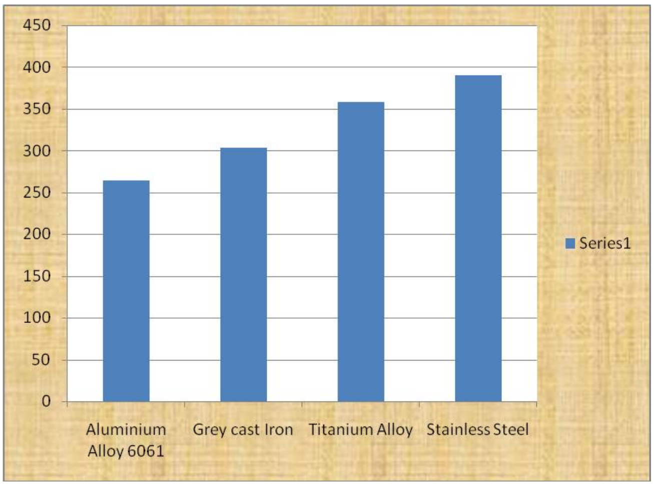

Figure (9.3): Steady state thermal Temperature distribution-Graph

Table 9.4 Temperature Distribution Transient Thermal

Temperature Distribution-Transient thermal		
S.No	Material	Transient Thermal(Celsius)
1	Aluminium alloy 6061	117.95
2	Grey cast iron	128.31
3	Titanium alloy	199.54
4	Stainless steel	180.05

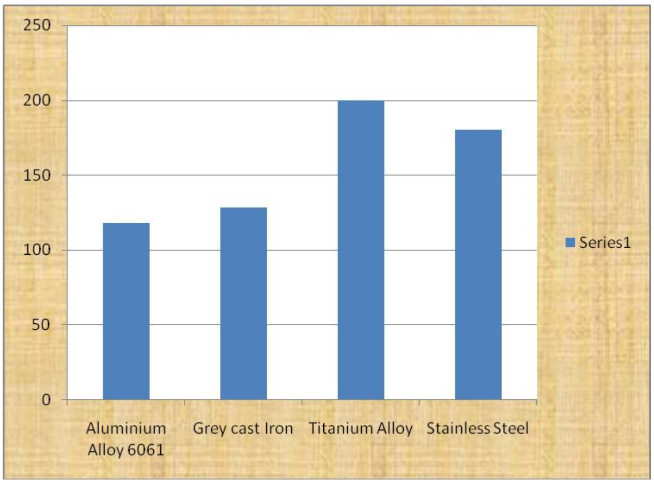

Figure (9.4): Transient thermal Temperature distribution-Graph

CONCLUSION

- A typical model of two wheeler brake disc is developed by using Uni-graphics

- Brake disc model is carried over to Thermal Analysis for Aluminum alloy 6061,Grey cast iron, Titanium alloy, Stainless steel
- Total heat flux is more for Aluminum alloy 6061 in steady state thermal analysis
- Total heat flux is low for Stainless steel in steady state thermal analysis
- Total heat flux is more for Aluminum alloy 6061 in transient thermal analysis
- Total heat flux is low for stainless steel in transient thermal analysis
- The temperature distribution is more for stainless steel in steady state and transient thermal analysis
- By considering all the factors we can easily understand that thermal gradient is effective as Stainless steel>Aluminum alloy 6061>Titanium alloy>Grey cast iron. The heat fluxes are compared as Aluminum alloy 6061>Grey cast iron>Titanium alloy>Stainless steel. The temperature distribution is followed as Titanium alloy>Stainless steel>Grey cast iron>Aluminum alloy 6061in transient conditions. We can recommend Stainless steel and aluminum alloy 6061 for disc brake preparation. But the climatic conditions effect the working as oxidation reaction produces pit on aluminum alloy 6061 component which it is not a healthy issue for component. Hence stainless steel is recommended as best material for disc brake preparation among all of the suggested materials.

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