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Finite Element Analysis of Drum Brake by using ANSYS

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Abstract: The drum brake is a mechanical device which inhibits the rotational motion of the wheel by the action of friction generated between shoe brake and the brake drum. During braking, the brake drum experiences high temperature and thermal stresses. Due to this the drum brake material should possess a high thermal conductivity, thermal capacity and high strength in order to withstand these stresses. The aim of this research is to design the drum brake by using the finite element analysis. The most efficient material for the manufacturing of brake drum is found by analyzing different selected materials under given boundary conditions. This research emphasizing on the substitution of cast iron by any other lightweight material. A model is created with the help of software CATIA V5 and structural and thermal analysis are performed in ANSYS 16.0 work bench. A static structural and thermal analysis of different materials such as aluminium alloy, aluminium metal matrix composite (1), aluminium metal matrix composite (2) and titanium alloy for a brake drum is done. The results of all these four analysis are compared at the end to find out the most suitable material for brake drum.
Keyword: Drum brake, Static analysis, Thermal analysis, Ansys, Catia.

I. INTRODUCTION

Brake drum was invented by Louis Renault in 1902. He used woven asbestos lining for the brake drum lining as no alternative dissipated heat like the asbestos lining, though Maybach has used a less sophisticated brake drum. In the first brake drums, levers and rods or cables operated the shoes mechanically. From the mid-1930’s, oil pressure in a small wheel cylinder and pistons operated the brakes, though small vehicles continued with purely mechanical systems for decades. Some designs have two wheel cylinders. The shoes in brake drums wear thinner, and brakes required regular adjustment until the introduction of self-adjusting brake drums in 1950’s. The brake drum is used widely on road vehicles and consists of a drum attached to the rotating wheel. The drum has an internal machined cylindrical surface. Inside the drum and protected from the environment are two shoes lined with friction material which can be pivoted to make a forced contact with the internal cylindrical surface. A drum brake unit consists of two brake shoes mounted on a stationary backing plate. When the brake pedal is pressed, a hydraulically activated wheel cylinder pushes the shoes out to contact a rotating drum which creates friction and slows the vehicle.

A drum brake is a brake that uses friction caused by a set of shoes or pads that press against a rotating drum shaped part called a brake drum. The brake drum is generally made of cast iron that rotates with the wheel. When a driver applies the brakes, the lining pushes radially against the inner surface of the drum, and the ensuing friction slows or stops rotation of the wheel and axle, and thus the vehicle.

Drum brakes are mainly used for the rear wheels of passenger cars and trucks while disc brakes are used exclusively for front brakes because of their greater direction stability. The backing plate is a pressed steel plate, bolted to the rear axle housing. Since the brake shoes are fitted to the backing plate, all of the braking force acts on the backing plate.

II. LITERATURE REVIEW

A. L. Sravani

This paper describes that the brake drum is experiencing high temperature and thermal stresses during braking. In addition, during braking, brake shoe makes contact with the inner surface of rotation brake drum with high pressure which generates structural stresses in the brake drum as well as brake shoe assembly. Heat is also generated by the action of friction which contributes to increase in thermal stresses and hence the analysis takes into account both the thermal stresses and mechanical stresses together. Requirements not only in performance but also in comfort, serviceability and working lifetime are high and rising. The brake pad with the friction material, the counter body and caliper, can be modeled. This project was designed (drum, & pads) in solid works 2016 and structural and thermal analysis are performed in ansys work bench software.

B. K. Gowthami

This paper describes that the drum brake uses the concept of friction to decelerate. During the braking operation heat is generated this may cause damage to the brake assembly. In this condition the drum material should possess a high thermal conductivity, thermal capacity and high strength. A thermal analysis of different materials such as aluminium alloy, cast iron and stainless steel 304 for a brake drum is done. Steady state condition are studied. Transient state analysis, for regular 30 seconds, 90, 120 and 210, temperature distribution and thermal flux is studied. A comparison of all the three results is done and aluminium alloy material is proved better than the other materials.

C. Meenakshi Kushal

The aim of this paper is to optimize the design of Hero Honda Passion brake drum. Optimization is done by changing the material of the brake drum, under different braking time and operational conditions. Brake drum is optimized to obtained different stresses, deformation values, rise in temperature on different braking time and heat transfer rate. Optimized results obtained are compared for Aluminium and CE (Controlled Expansion) material alloys. It concludes that the CE (Controlled Expansion) alloys can be a better candidate material for the brake drum applications of light commercial vehicles and it also increases the braking performance.

D. A. Rehman

This paper describes the suitability of Aluminum alloy–Silicon Carbide MMC (Al–SiC MMC) in the automobile brake drum applications in comparison with cast iron (CI) brake drum. A brake drum dynamometer test rig was developed for this purpose. Al–SiC MMC was reinforced with 10% and 15% SiC particle by weight. The effect of heat treatment of the Al–SiC MMC brake drum was also studied. Performance was mainly evaluated on the basis of brake drum coefficient of friction (μ).

E. M. A. Maleque

The aim of this paper is to develop the material selection method and select the optimum material for the application of brake disc system emphasizing on the substitution of this cast iron by any other lightweight material. Two methods are introduced for the selection of materials, such as cost per unit property and digital logic methods. Material performance requirements were analyzed and alternative solutions were evaluated among cast iron, aluminium alloy, titanium alloy, ceramics and composites. Mechanical properties including compressive strength, friction coefficient, wear resistance, thermal conductivity and specific gravity as well as cost, were used as the key parameters in the material selection stages. The analysis led to aluminium metal matrix composite as the most appropriate material for brake disc system.

III. SCOPE OF PRESENT WORK

In the braking system, brake drum will be studied by doing structural and thermal analyses on different materials. Previous research was done on aluminium alloy and cast iron. In this research thermal analysis of aluminium metal matrix composite (1), (2), aluminium alloy and titanium alloy for a brake drum will be done because these materials are not analyzed in the past.

The objectives of this study are:

A. To develop 3D CAD model of Drum Brake in CATIA V5 workbench.
B. To study the behavior of different material of drum brake under static and thermal analysis in ANSYS 16.0 workbench.
C. To calculate the total deformation, equivalent stress, equivalent strain, total heat flux which is developed on a brake drum for aluminium alloy, aluminium metal matrix composite (1), (2) and titanium alloy.
D. To calculate the weight of cross section for the above stated materials for a particular geometry.
E. To compare all the four results and conclude a best material for the selection of a brake drum.

IV. METHOD AND MATERIALS

A model is created with the help of computer aided drafting software, CATIA V5. Using CATIA software we can create 3D model of brake drum as per measurement data and can Import the CATIA Model (IGES) in the Ansys 16.0 workbench for pre-processing and then the structural and thermal analysis is done on the brake drum. The Analysis involves the discretization called meshing, boundary conditions and loading. For analysis we take Aluminium metal matrix composite (1), (2), titanium alloy and aluminium alloy.

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A. Specifications of Brake Drum(from literature review (A))

A. Overall Diameter (mm) = 480
B. Dust Shield Recess Diameter/ Outer Diameter (mm) = 460
C. Brake Face Diameter/ Inside Diameter (mm) = 440
D. Brake Face Width (mm) = 190
E. Overall Height (mm) = 210
F. Squealer Band Thickness (mm) = 10
G. Depth of Dust Shield Recess (mm) = 10
H. Hub Pilot (mm) = 280
I. Bolt Hole Diameter/ Number (mm) = 20
J. Bolt Circle Diameter (mm) = 330

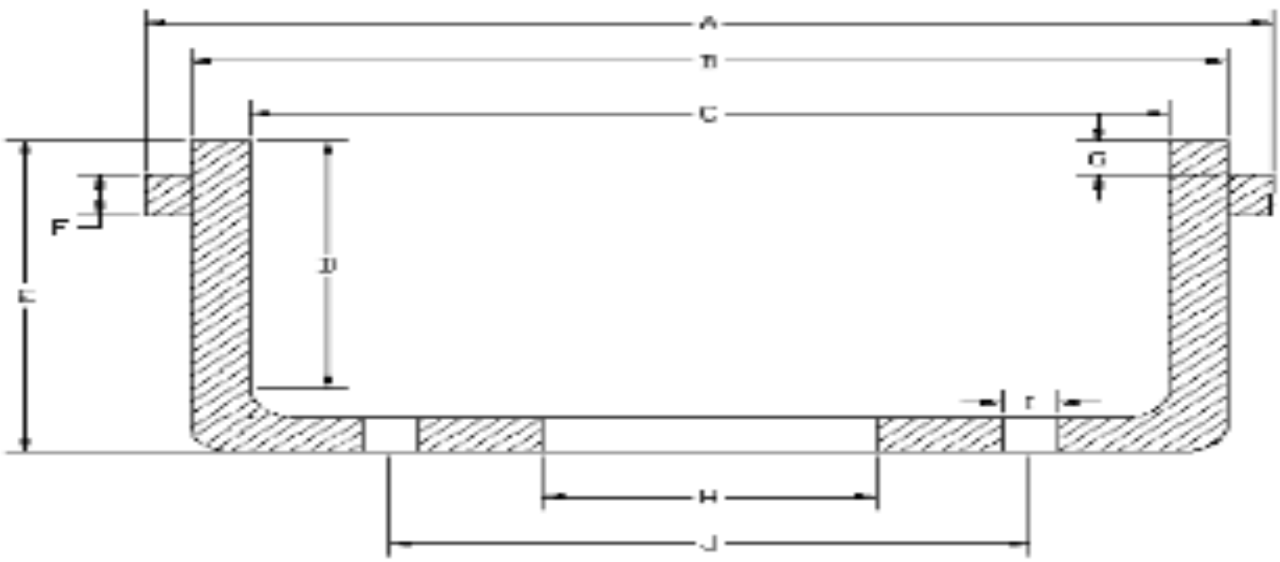

Fig: 1 – Sketch drum brake

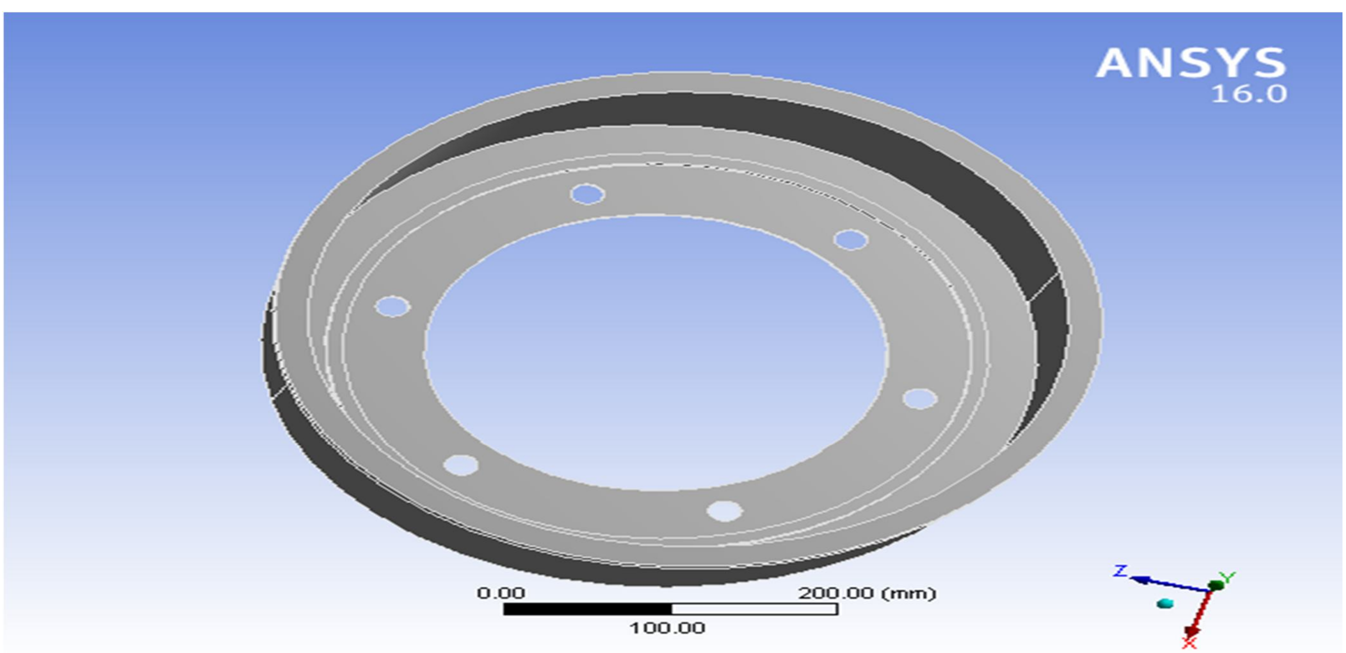

Fig: 2- 3D sketch of drum brake

B. Material Properties of Brake Drum

PROPERTIES / MATERIAL	Density (Kg/m^3)	Poisons Ratio (μ)	Thermal conductivity (W/m.K)	Compressive strength (MPa)	Specific heat Cp (KJ/Kg.K)
Aluminium alloy	2700	0.33	190	280	0.90
Titanium alloy	4420	0.34	21.6	1070	0.58
Aluminium metal matrix composite (1)	2700	0.35	185	406	0.98
Aluminium metal matrix composite (2)	2800	0.44	237	761	0.92

Table 1

V. BOUNDARY CONDITION

From above literature review (A), pressure is applied on the internal surface of the brake drum.
The boundary condition of drum brake are given as follows,
Pressure generated inside the drum brake: 1.2 MPa
Ambient temperature: 22^{0}C
Maximum temperature generated: 90^{0}C

VI. ANALYSIS OF DRUM BRAKE

Finite element analysis of brake drum is done with the help of Ansys 16.0 workbench software. Both stress analysis and thermal analysis is done for different materials and same operating conditions.

A. Static Structural Analysis

For Stress analysis, pressure is applied on the internal surface of the cylindrical face of the brake drum.

1) Aluminium Alloy

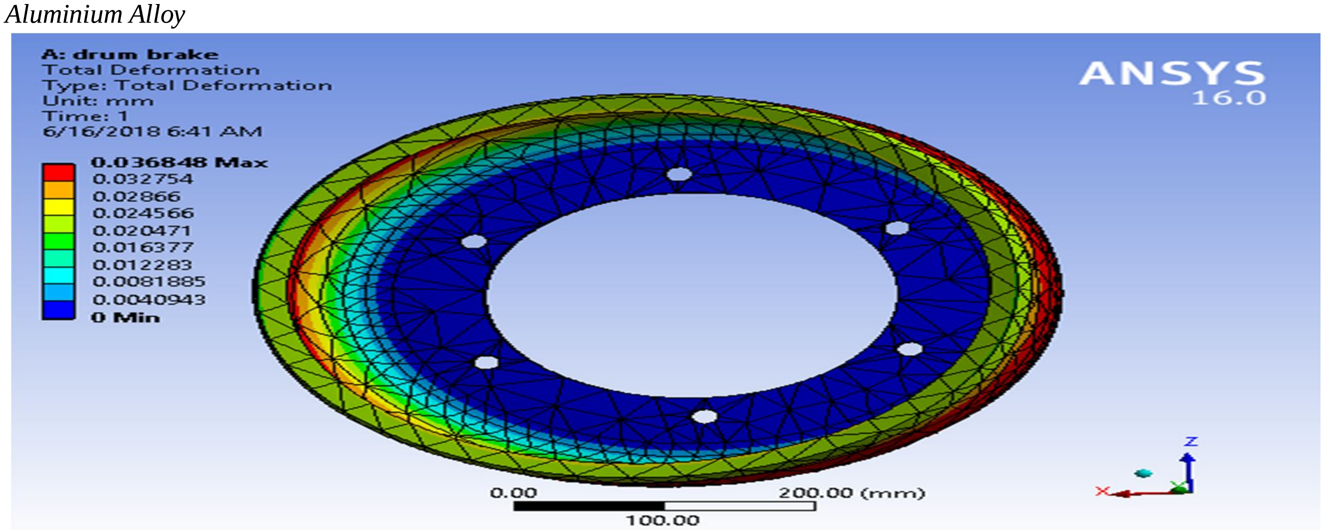

Fig: 3- Total deformation of aluminium alloy

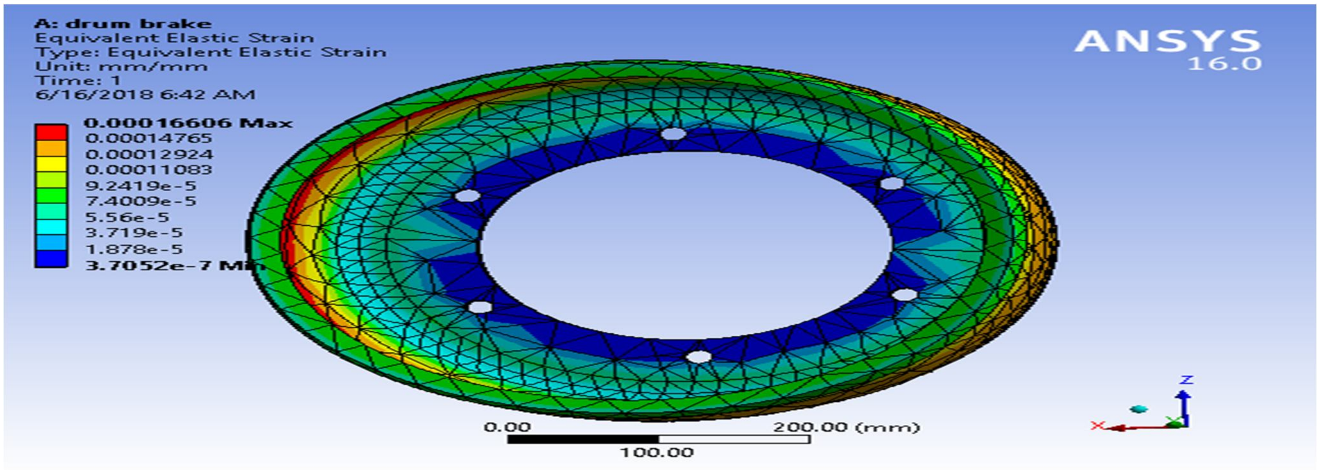

Fig: 4- Equivalent strain of aluminium alloy

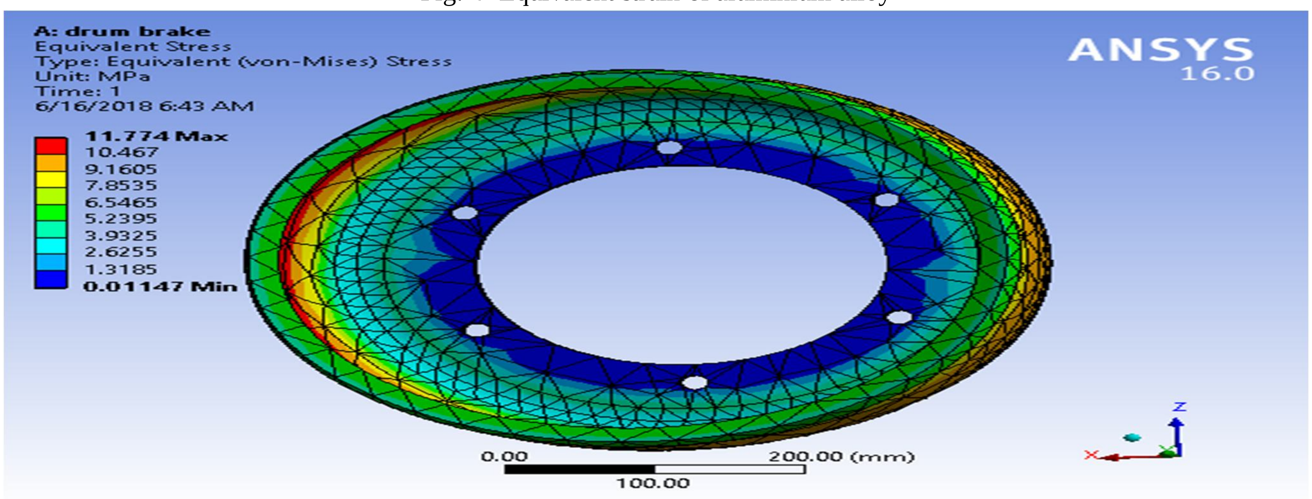

Fig: 5- Equivalent stress of aluminium alloy

2) Titanium Alloy

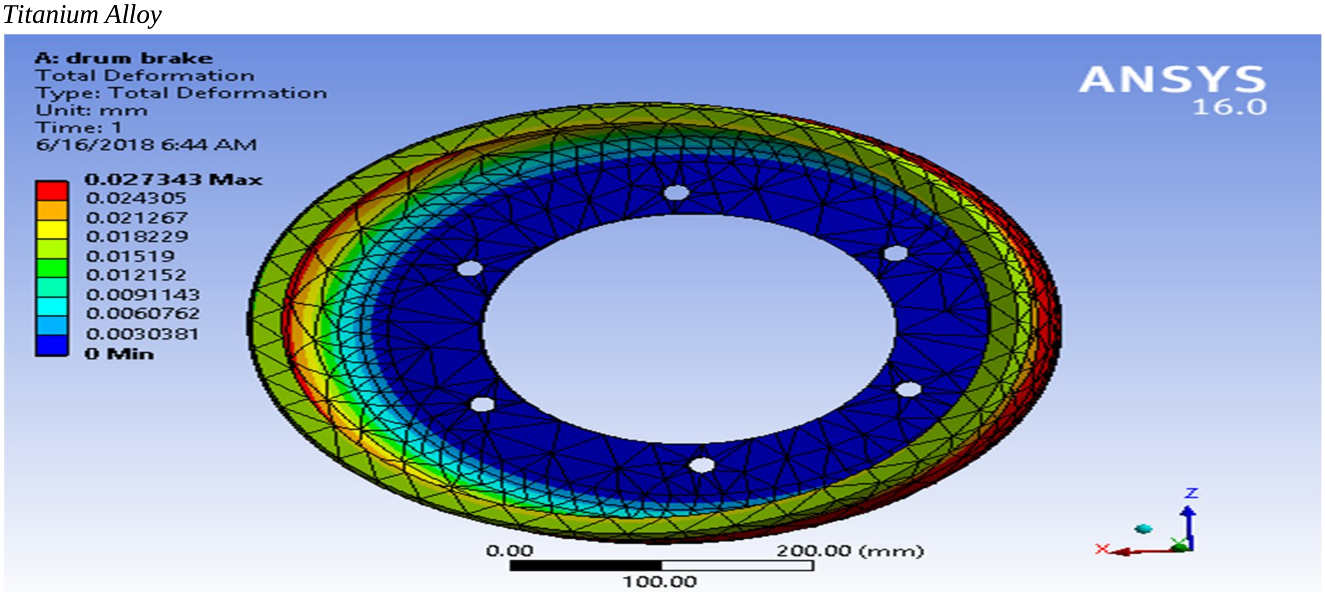

Fig: 6- Total deformation of titanium alloy

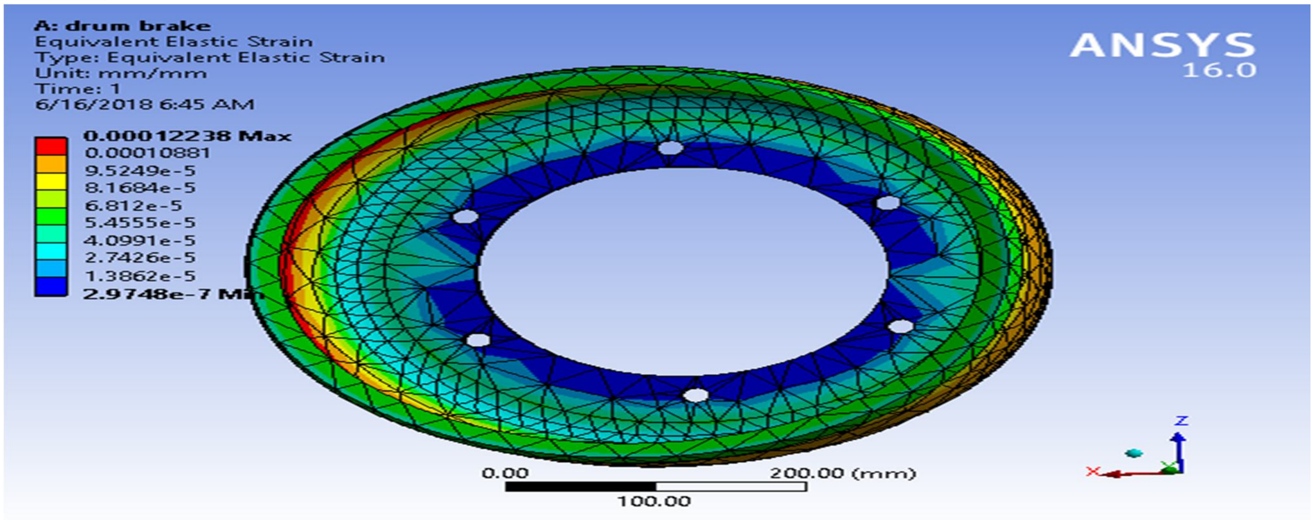

Fig: 7- Equivalent strain of titanium alloy

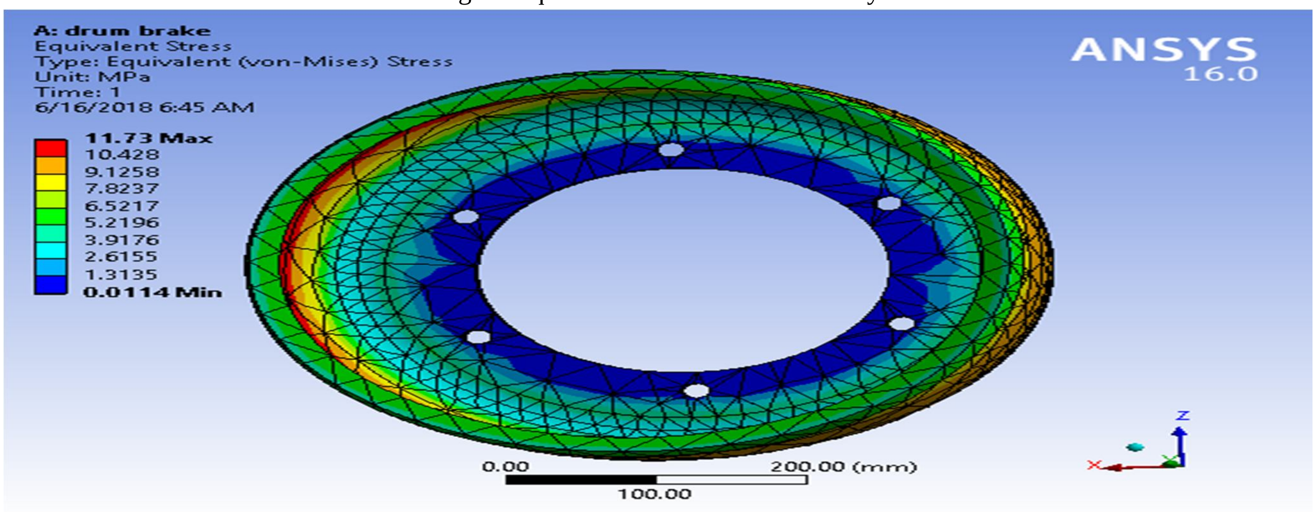

Fig: 8- Equivalent stress of titanium alloy

3) *Aluminium Metal Matrix 1.*

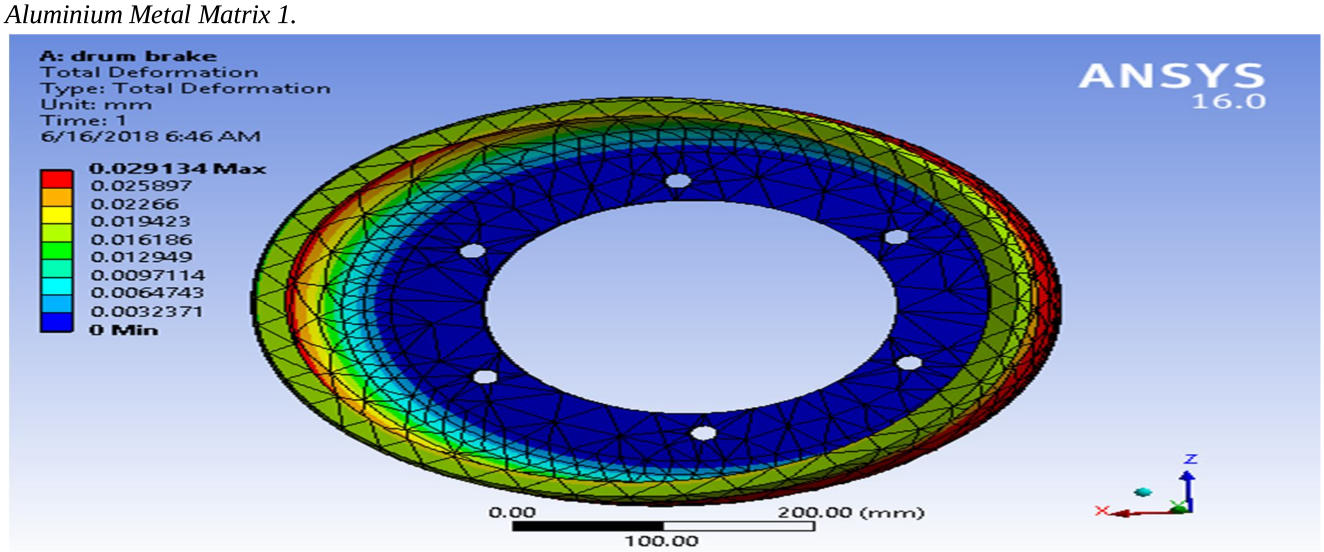

Fig: 9- Total deformation of aluminium metal matrix 1

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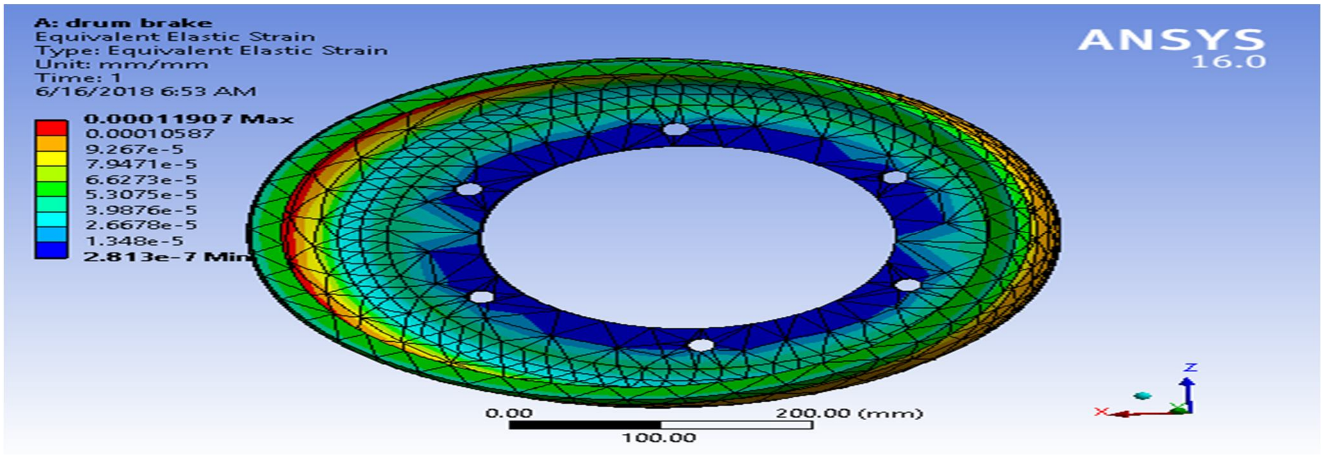

Fig: 10- Equivalent strain of aluminium metal matrix 1

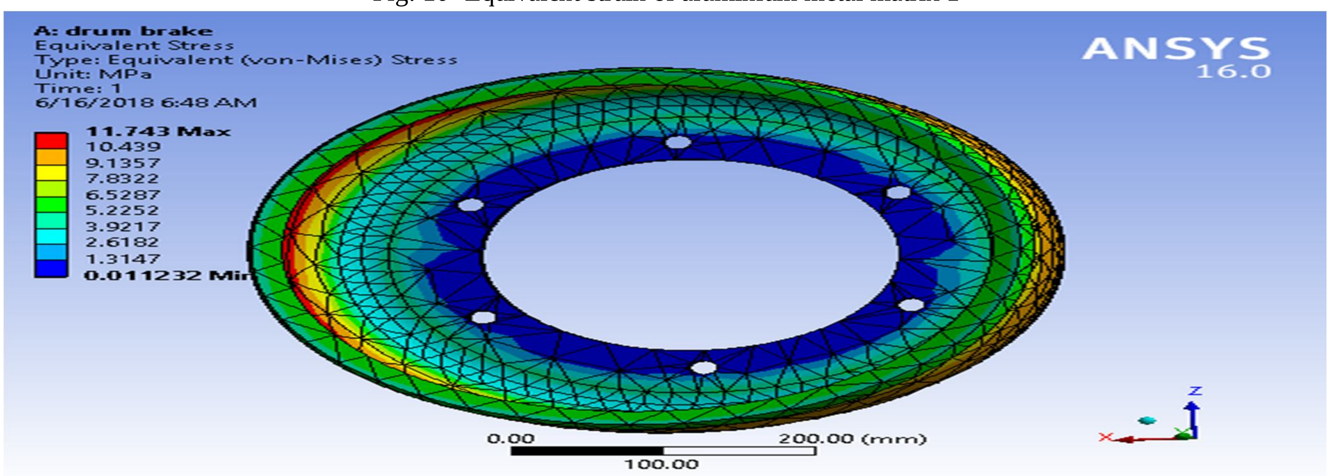

Fig: 11- Equivalent stress of aluminium metal matrix 1

4) Aluminium Metal Matrix 2

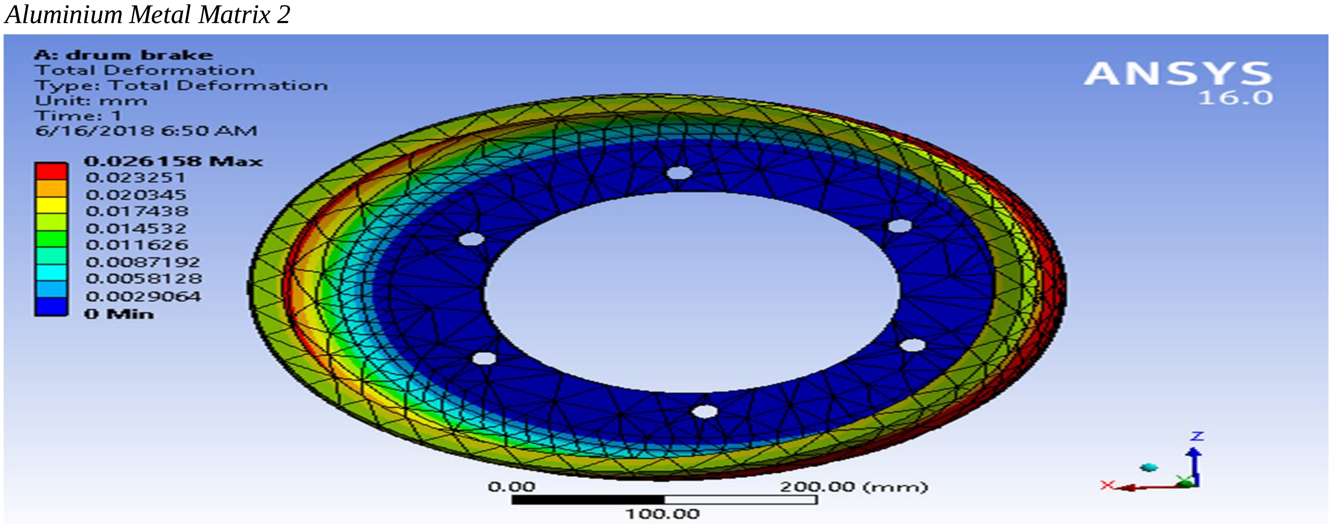

Fig: 12- Total deformation of aluminium metal matrix 2

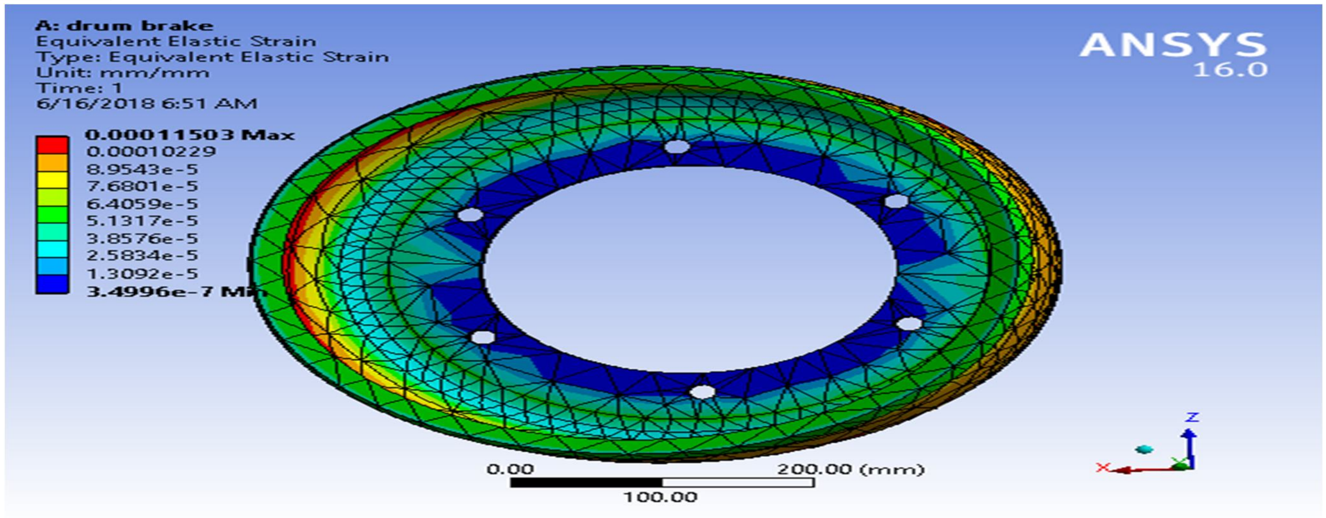

Fig: 13- Equivalent strain of aluminium metal matrix 2

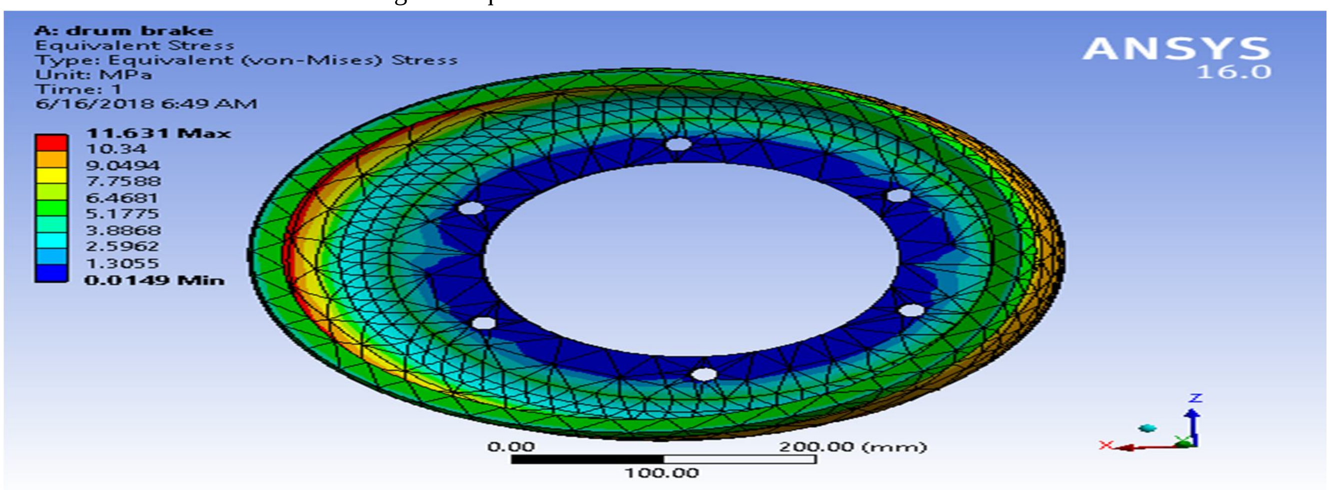

Fig: 14- Equivalent stress of aluminium metal matrix 2

B. Thermal Analysis

For thermal analysis we apply the maximum temperature on the inner face of brake drum.

1) Aluminium Alloy

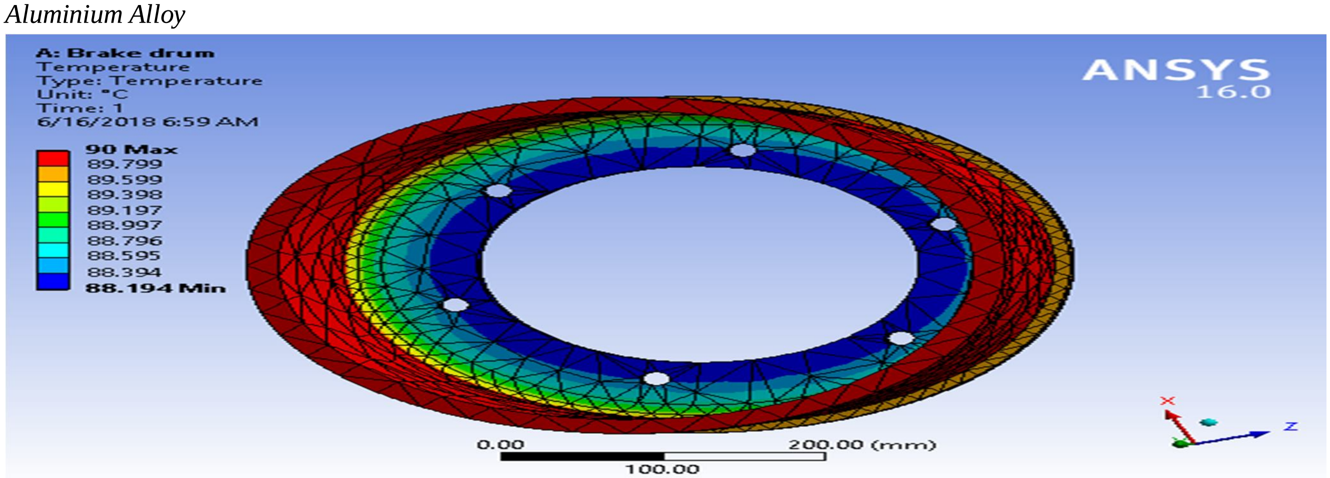

Fig: 15- Temperature distribution of aluminium alloy

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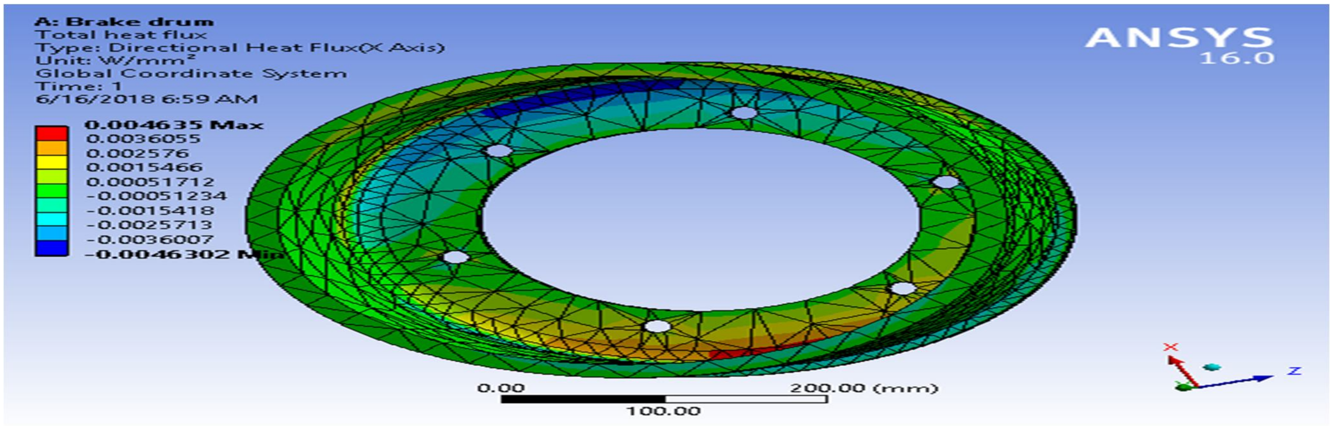

Fig: 16- Total heat flux of aluminium alloy

2) Titanium Alloy

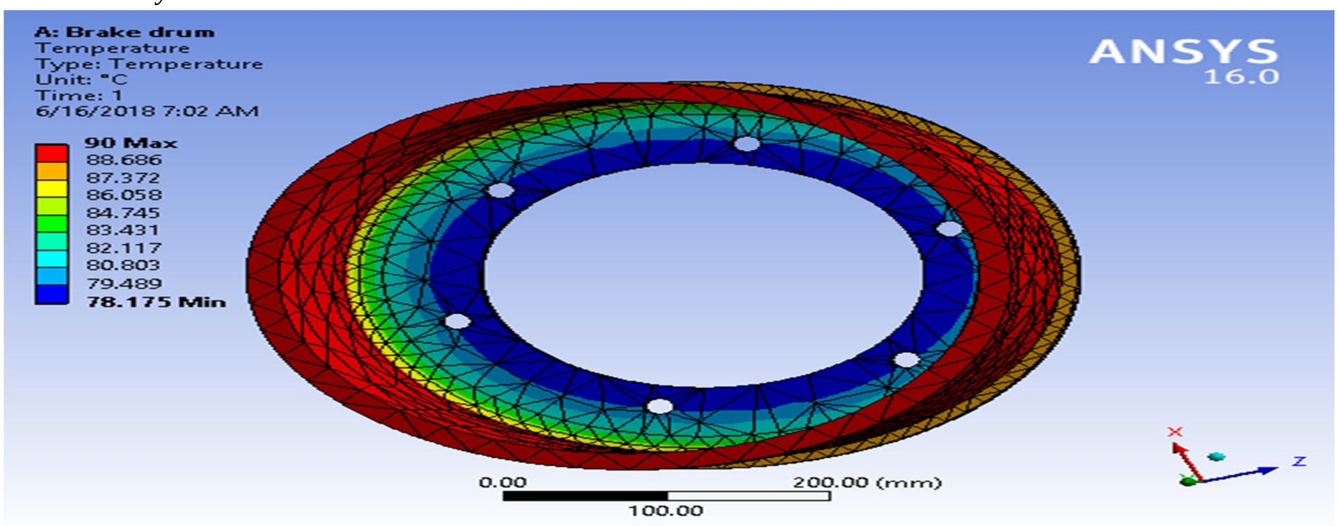

Fig: 17- Temperature distribution of titanium alloy

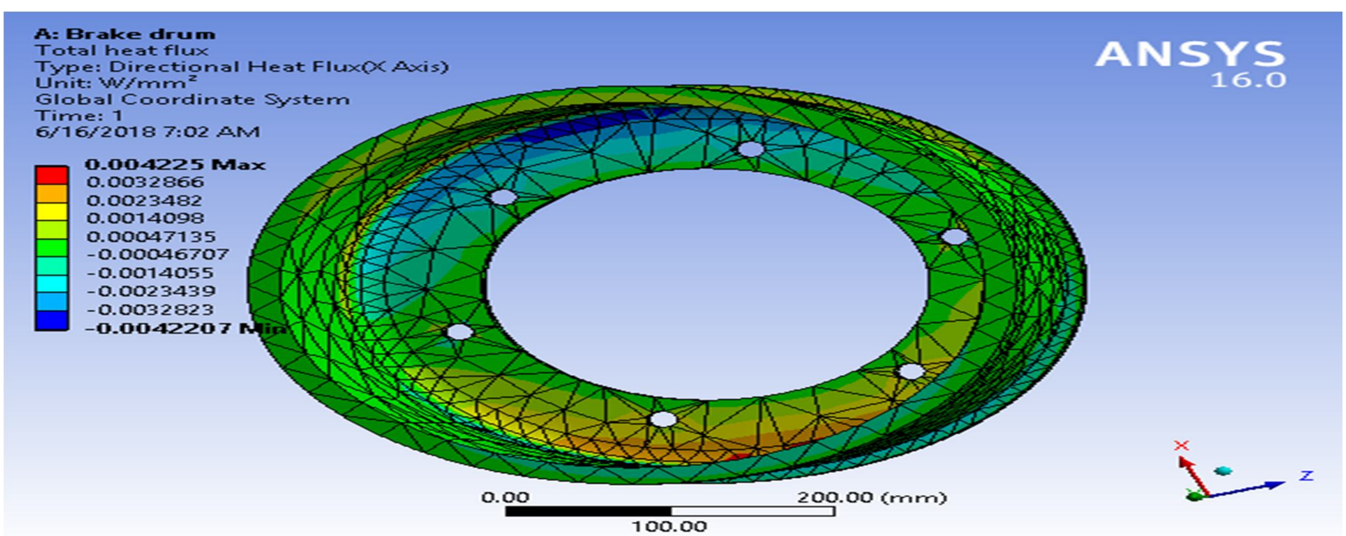

Fig: 18- Total heat flux of titanium alloy

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3) *Aluminium Metal Matrix 1*

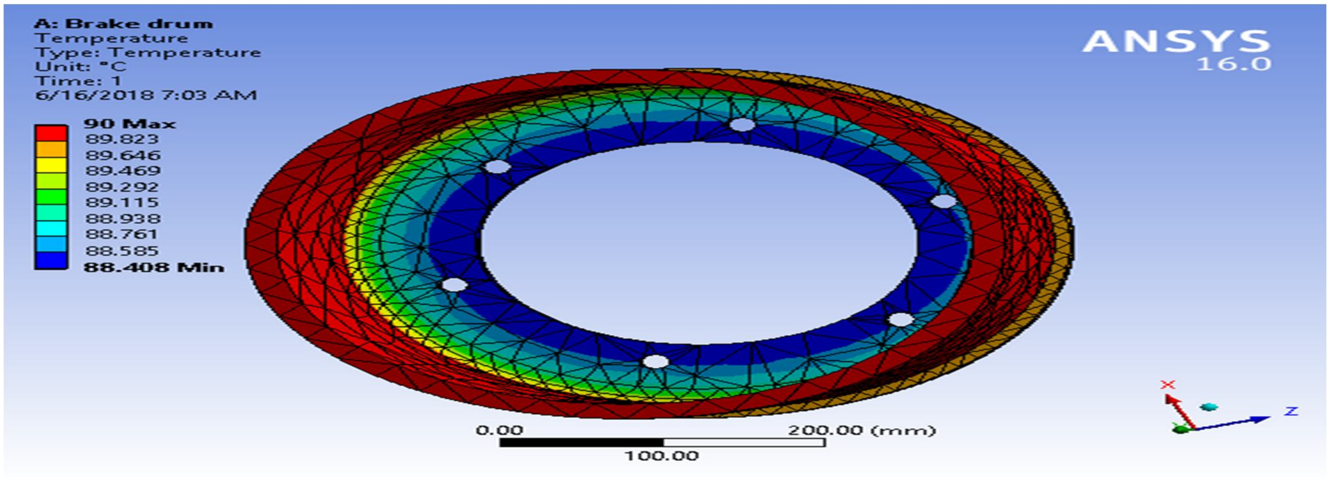

Fig: 19- Temperature distribution of aluminium metal matrix 1

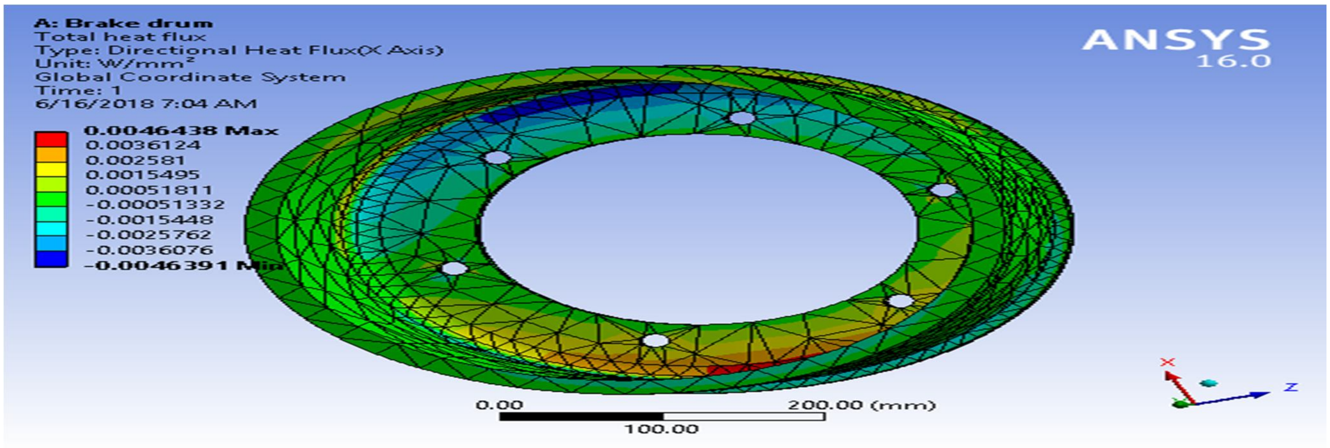

Fig: 20- Total heat flux of aluminium metal matrix 1

4) *Aluminium Metal Matrix 2*

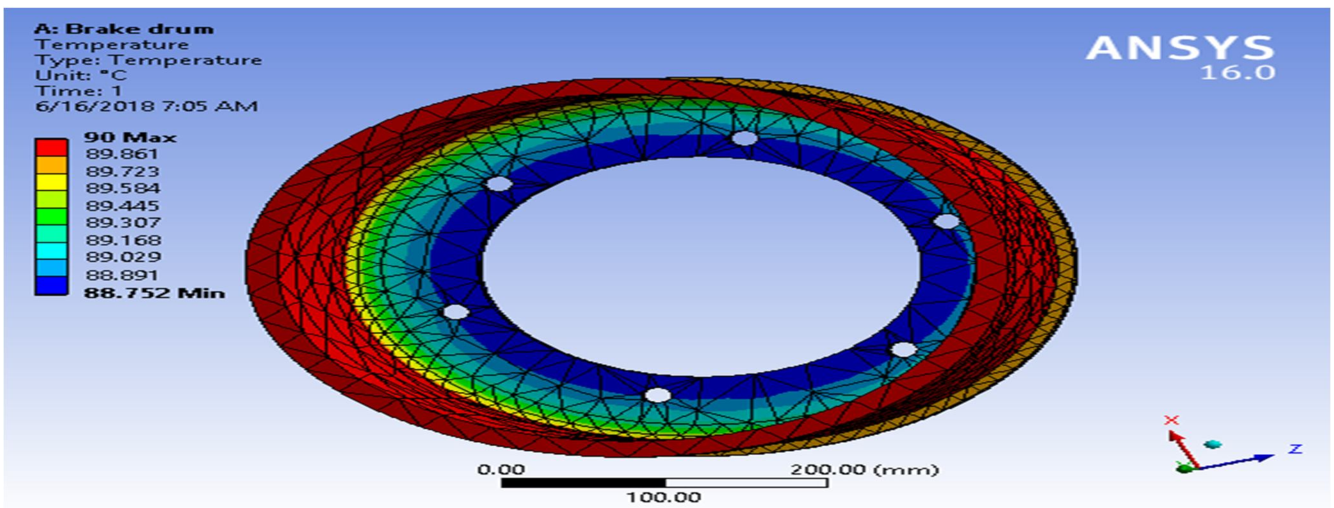

Fig: 21- Temperature distribution of aluminium metal 2

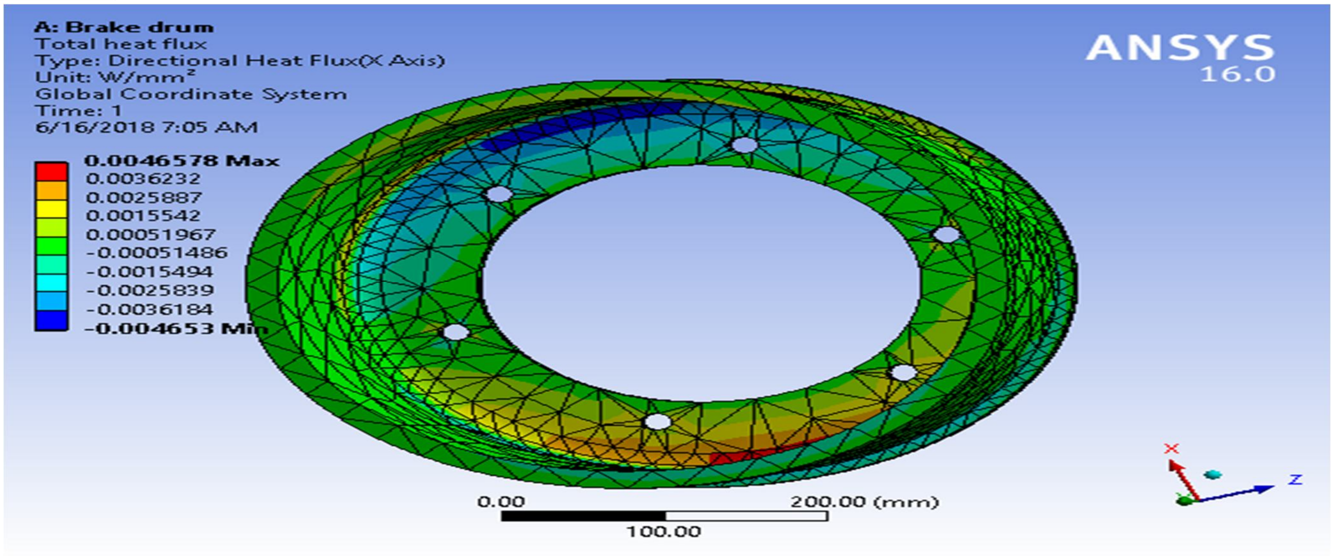

Fig: 22- Total heat flux of aluminium metal matrix 2

VII. RESULTS

A. Static Structural analysis

Parameters / Metal	Total deformation (mm)	Equivalent strain (mm/mm)	Equivalent stress (MPa)
Aluiminium alloy	0.036848	0.000166606	11.774
Titanium alloy	0.027343	0.00012238	11.730
Aluminium metal matrix 1	0.029134	0.00011907	11.743
Aluminium metal matrix 2	0.026158	0.00011503	11.631

Table 2

B. Thermal Analysis

Parameters / Metal	Temperature (^{0}C)	Total heat flux (W/mm^2)
Aluiminium alloy	90	0.004635
Titanium alloy	90	0.004225
Aluminium metal matrix 1	90	0.0046438
Aluminium metal matrix 2	90	0.0046578

Table 3

VIII. CONCLUSIONS

From above result we can conclude that beside general materials such as cast iron, aluminum metal matrix 2 shows less value of deformation as well as maximum von-mises stress under static structural analysis. Thermal analysis shows adequate values of heat flux which validates the heat dissipation ability of material. Over all it is seen that best material for designing drum brake in terms of total deformation, equivalent strain, equivalent stress and total heat flux is aluminium metal matrix 2. In addition to that it has very less weight compared to aluminium alloy and hence aluminium alloy can be replaced by aluminium metal matrix2.

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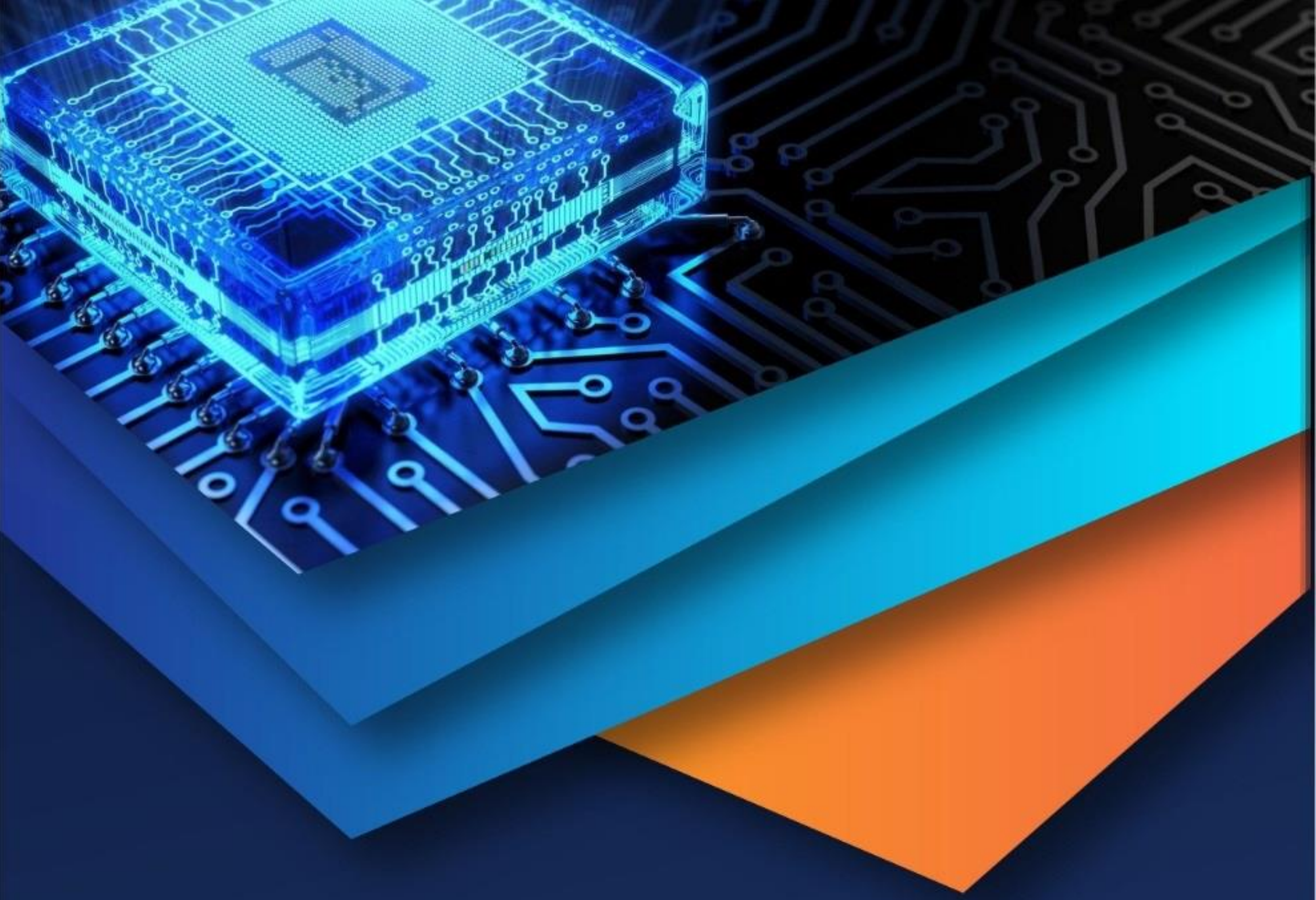

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