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Finite Element Analysis of Brake Shoe Lining by using Ansys

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Abstract: Braking is the process which converts kinetic energy of vehicle into mechanical energy which must be dissipated in the form of heat. The 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 shoe experiences high temperature and thermal stresses. Due to this the brake shoe 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 brake shoe 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 materials. A model is created with the help of software CATIA V5 and structural and thermal analysis is 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 shoe lining is done. The results of all these four analysis are compared at the end to find out the most suitable material for brake shoe lining.
Keyword: Brake shoe lining, Static analysis, Thermal analysis, Ansys, Catia.

I. INTRODUCTION

The modern automobile drum brake was first used in a car made by May bach in 1900, although the principle was only later patented in 1902 by Louis Renault. He used woven asbestos lining for the drum brake lining, as no alternative dissipated heat like the asbestos lining, though Maybach had used a less sophisticated drum brake. In the first drum brakes, levers and rods or cables operated the shoes mechanically. From the mid-1930s, oil pressure in a small wheel cylinder and pistons operated the brakes, though some vehicles continued with purely mechanical systems for decades. Early brake shoes contained asbestos. When working on brake systems of older cars, care must be taken not to inhale any dust present in the brake assembly. The United States Federal Government began to regulate asbestos production, and brake manufacturers had to switch to non-asbestos linings. Owners initially complained of poor braking with the replacements; however, technology eventually advanced to compensate. A majority of daily-driven older vehicles have been fitted with asbestos-free linings. Many other countries also limit the use of asbestos in brakes.

The brake shoe is a critical component that experiences high temperatures and develop thermal stresses during application of brakes. In addition, the application of shoe pressure gives rise to mechanical loads. So the analysis takes into account both the thermal stresses and mechanical stresses together. Since the analytical solution is not possible due to combination of loads and varying of contour of the brake shoe, it is necessary to carry out finite element approach in order to evaluate the exact stress distribution and make sure that the stress values are well below the allowable limits. Brake shoe modeled here is, of the internal expanding type brake. The shoes of this kind of brake are contained within the drum and expand outwards when the brake is applied. Such kind of brakes is used in medium heavy-duty vehicles. Brake shoes are typically made of two pieces of steel welded together. The friction material is either riveted to the lining table or attached with adhesive. The crescent-shaped piece is called the Web and contains holes and slots in different shapes for return springs, hold-down hardware, parking brake linkage and self-adjusting components. All the application force of the wheel cylinder is applied through the web to the lining table and brake lining. The edge of the lining table generally has three ―V"-shaped notches or tabs on each side called nibs. The nibs rest against the support pads of the backing plate to which the shoes are installed. Each brake assembly has two shoes, a primary and secondary. The primary shoe is located toward the front of the vehicle and has the lining positioned differently from the secondary shoe. Quite often, the two shoes are interchangeable, so close inspection for any variation is important. Linings must be resistant to heat and wear and have a high friction coefficient unaffected by fluctuations in temperature and humidity. Materials that make up the brake shoe include, friction modifiers (which can include graphite and cashew nut shells), powdered metal such as lead, zinc, brass, aluminum and other metals that resist heat fade, binders, curing agents and fillers such as rubber chips to reduce brake noise.

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II. LITERATURE REVIEW

A. Dvsrbm Subramanyam L.Sravan

In this project design of the model of drum brake (drum, & pads) in solid works 2016 and structural and thermal analysis are performed in ANSYS work bench software. First structural analysis of pressure of 1.5 MPa is applied with three different materials such as aluminum alloy, Carbon Steel, aluminum Metal matrix. From result we can conclude that beside general material, aluminum metal matrix (ks1275) which is economically less cost and less weight ratio gives nearly same stress and deformation value in static analysis and giving good thermal distribution value so it can also use as the material for drum brake beside general materials.

B. Nagesh S.N

The brake pads were manufactured by using powder metallurgy techniques. The manufactured brake pads were tested for coefficient of friction, wear, shear strength, hardness and micro structural analysis. The various tests were compared with existing brake pads composition. Hard friction materials were found on brake pads wear at lower rates but results in high brake noise. Brake pads S2 and S4 showed results which were equivalent to existing brake pad.

C. 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.

D. J.Kukutschova

A model semi-metallic brake lining was subjected to full-scale automotive brake dynamometer tests. The structural properties and surface topography of brake linings were analyzed at different stages of wear testing and correlated to frictional performance. Characteristics of released wear particles were also addressed. A combination of abrasive and adhesive wear with oxidative processes dominated the friction process. Formation of a friction layer adhering to the friction surfaces of pads and discs is the major feature responsible for friction performance. Wear debris generated during the dynamometer tests was collected from containers placed under the brake inside dynamometer chamber. The collected debris was compared with ball-milled particles from identical brake lining. Wear debris released during automotive brake dynamometer test has similar chemistry as friction layer detected on surface of brake lining. While wear debris generated in dynamometer was toxic (killing bacterial cells) after metabolic activation, the ball-milled samples "only" demonstrated potential mutagenicity, changing DNA of bacterial cells. Acute inflammatory response of bronchi and translocation of ball-milled particles to lymphatic tissue of rats was detected for particle fraction smaller than 5_m and for doses 3mg/1 ml instilled to rats.

E. Zmago Stadler

This paper reports on the friction and wear properties of sintered metallic (MMC) brake linings, which appear to combine well with a C/C-SiC brake disc. The friction characteristics were examined with a dynamometer on two different commercial motorcycle brake systems, differing in terms of the brake caliper and the dimensions of the disc. The influence of the components, such as graphite, and the abrasives in the metallic matrix on the formation of the friction layer was investigated. Due to plastic deformation, resulting in mixing of the metallic phases and the consequent enhanced oxidation, a friction layer is formed, the addition of SiC increases the hardness of the base metallic lining by more than 50%, whereas its influence on the mean COF is less significant. Although graphite is a lubricant, it raises the COF of the lining by 10%, presumably due to the lower hardness, reflected in a larger actual contact area between the lining and the disk, increasing the COF.

F. Seong Jin Kim

An experimental investigation was carried out to examine the tribological behavior of NAO (non-asbestos organic) type brake linings containing different volume ratios of graphite and antimony trisulfide ($Sb2S3$). A scale dynamometer was used for friction tests and particular emphases were given to the effect of applied pressure, sliding speed, and temperature on the coefficient of friction according to the relative amounts of the two solid lubricants. Results showed that the brake linings with both solid lubricants exhibited better friction stability and less speed sensitivity than the friction materials containing a single solid lubricant. In particular, the brake lining containing higher concentrations of graphite showed better fade resistance than others during high-temperature friction test. The brake linings with both solid lubricants were better in friction stability due to the complementary role of the two lubricants.

III. SCOPE OF PRESENT WORK

In the braking system, brake shoe lining will be studied by doing structural and thermal analyses on different materials. Previous research was done on aluminium alloys and cast iron. In this research thermal analysis of aluminium metal matrix composite (1), (2), aluminium alloy and titanium alloy for a brake shoe lining 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 brake shoe lining.
B. To study the behavior of different material of brake shoe lining under static and thermal analysis.
C. To calculate the total deformation, stress, heat flux which is developed on a brake shoe lining 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 shoe lining.

IV. METHOD AND MATERIAL

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

A. Specifications of brake shoe lining

Outer Diameter (mm) = 150
Inner Diameter (mm) = 140
Offset from centre (mm) = 10
Width of slot (mm) = 3.5
Height of slot (mm) = 2.5
Thickness of rib (mm) = 8
Bolt hole diameter (mm) = 10

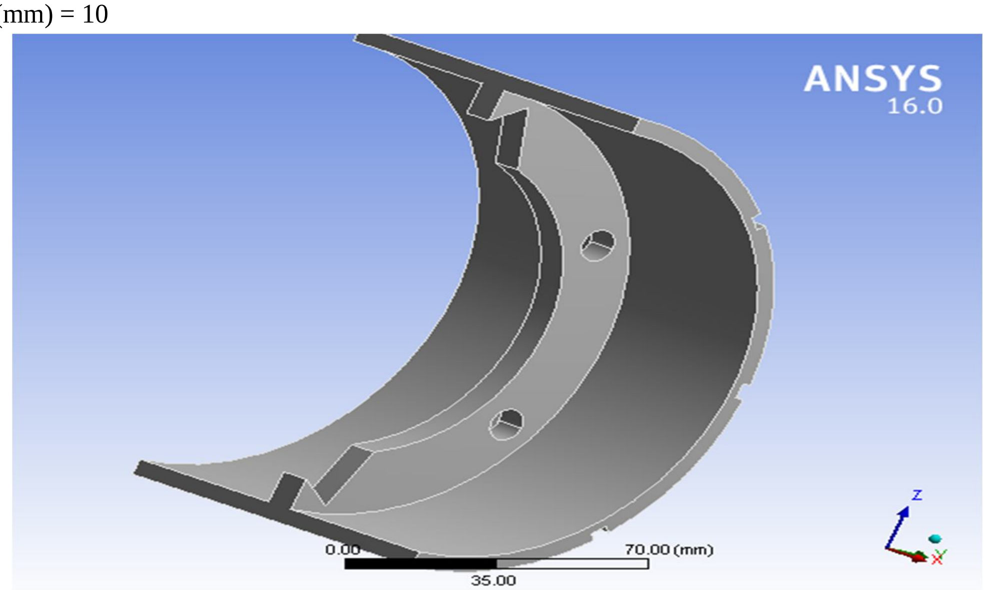

Fig: 1.1 – 3D Diagram of Brake Shoe

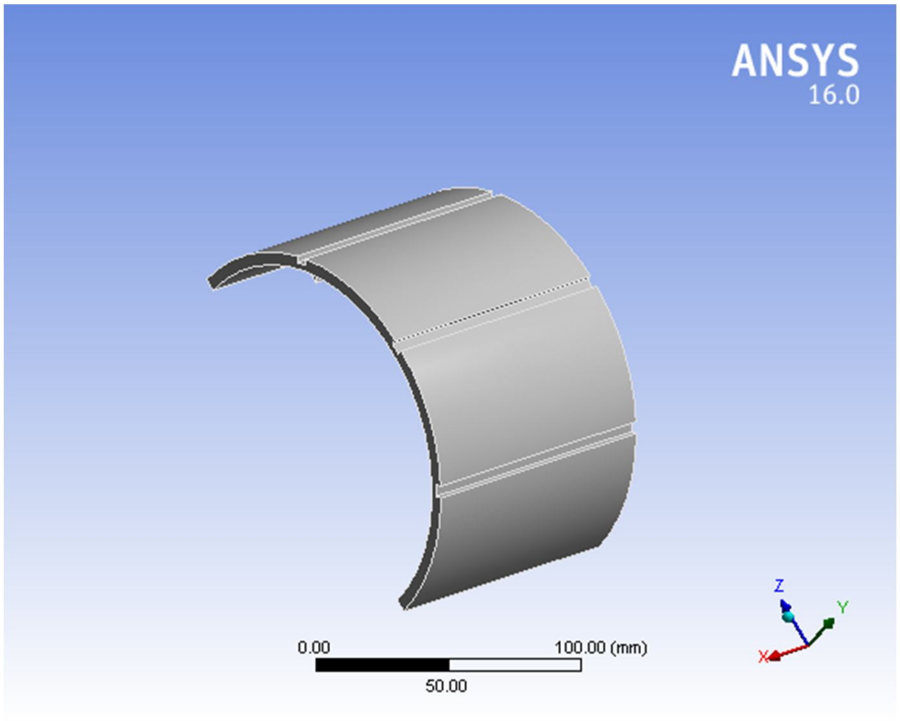

Fig: 1.2 3D Diagram of Brake Shoe

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	7.2	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

V. BOUNDARY CONDITION

From above literature review (1), pressure is applied on the internal surface of the brake drum.
The boundary condition of drum brake are given as follows,
Pressure generated on the brake shoe lining: 1.2 MPa
Ambient temperature: 22^0C
Maximum temperature generated: 90^0C

VI. Analysis Of Brake Shoe lining

Finite element analysis of brake shoe lining is done with the help of Ansys workbench 16.0 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 external surface of the brake shoe.

1) Aluminium Alloy

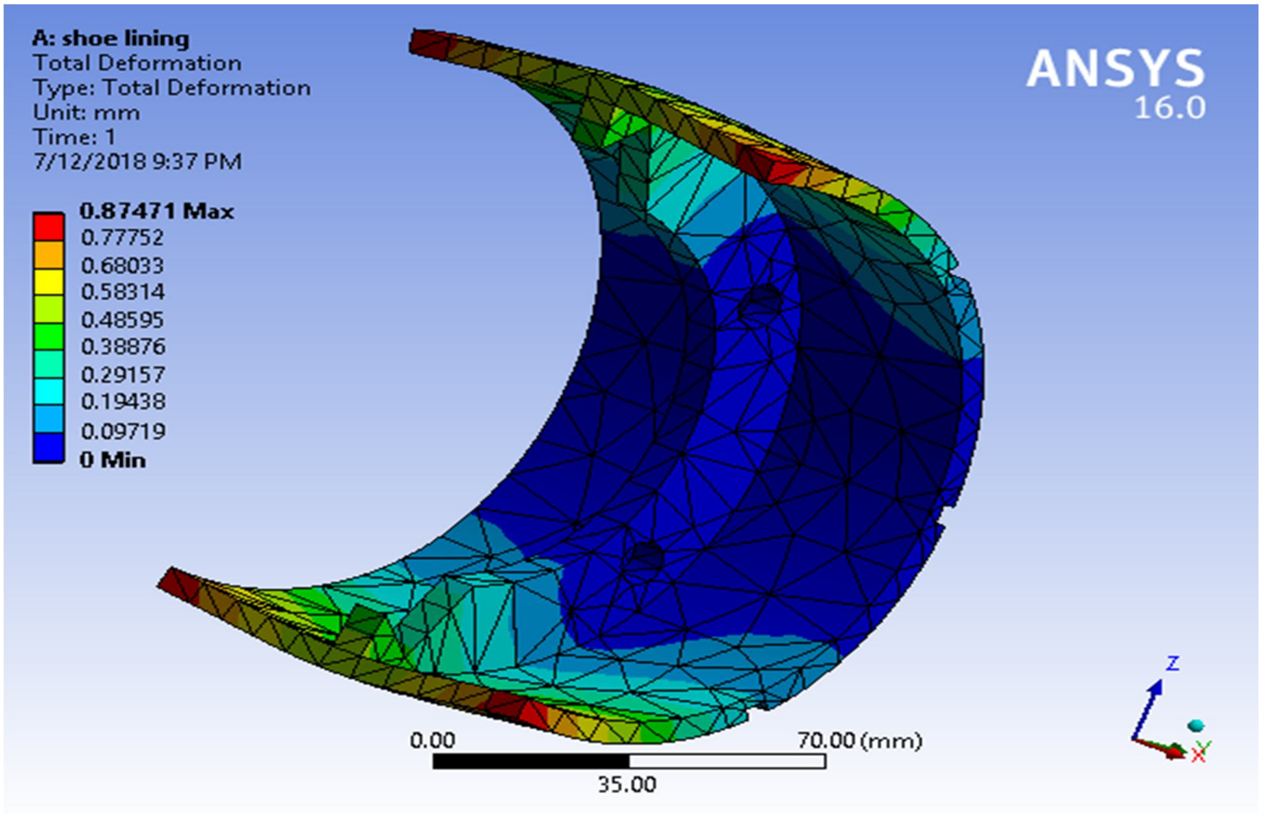

Fig: 2.1- Total deformation of aluminium alloy

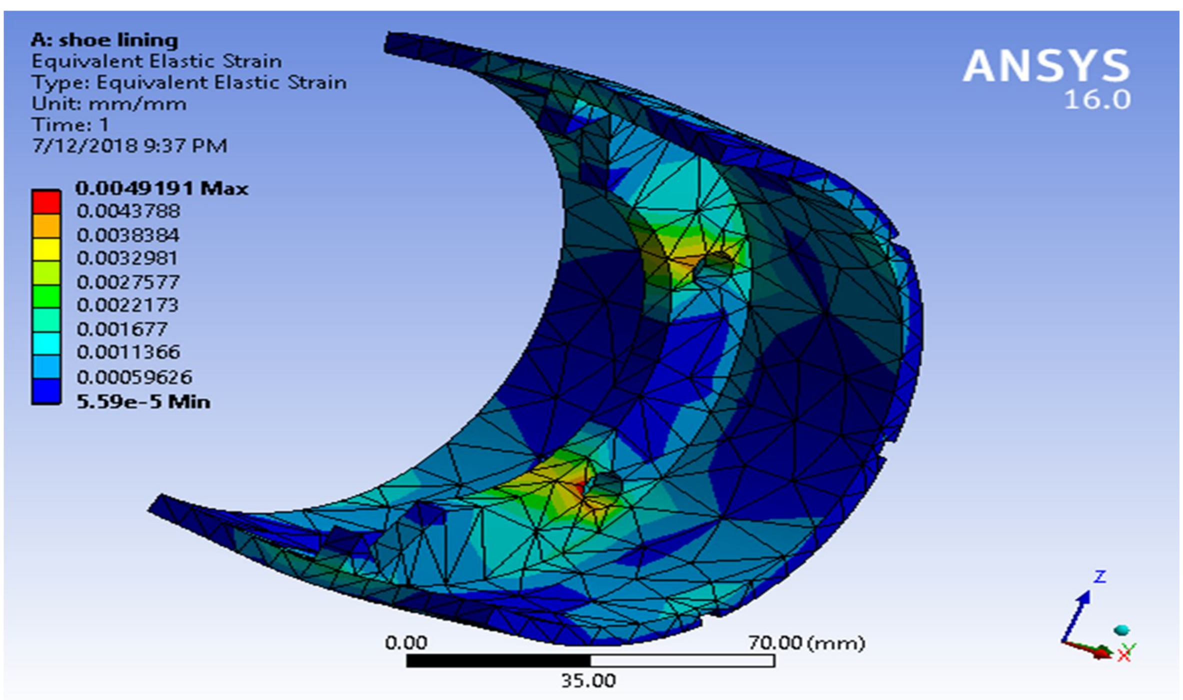

Fig: 2.2- Equivalent strain of aluminium alloy

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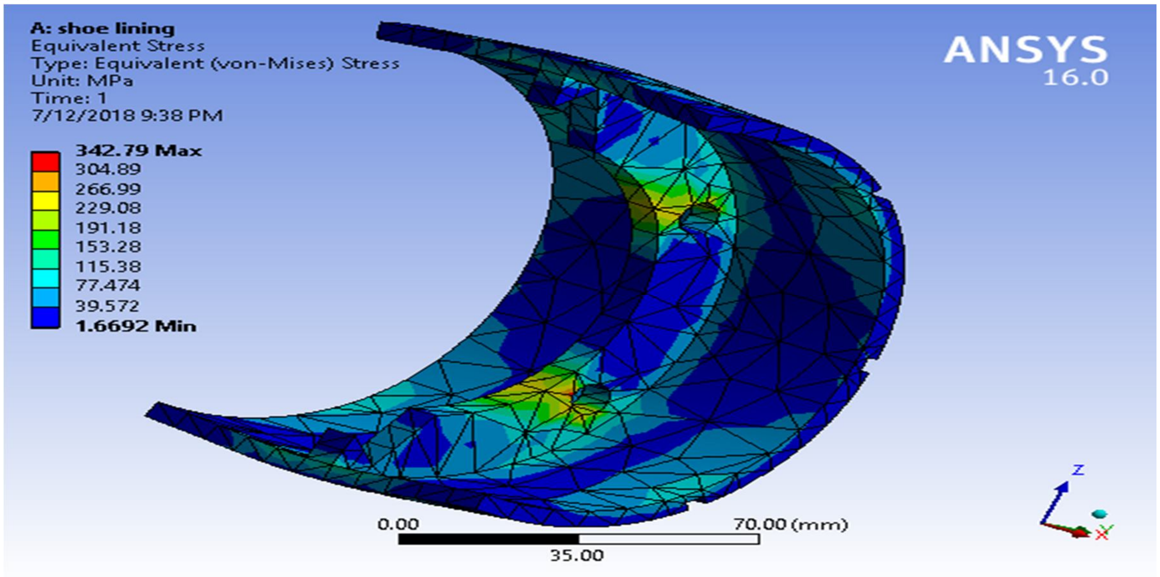

Fig: 2.3- Equivalent stress of aluminium alloy

2) *Titanium Alloy*

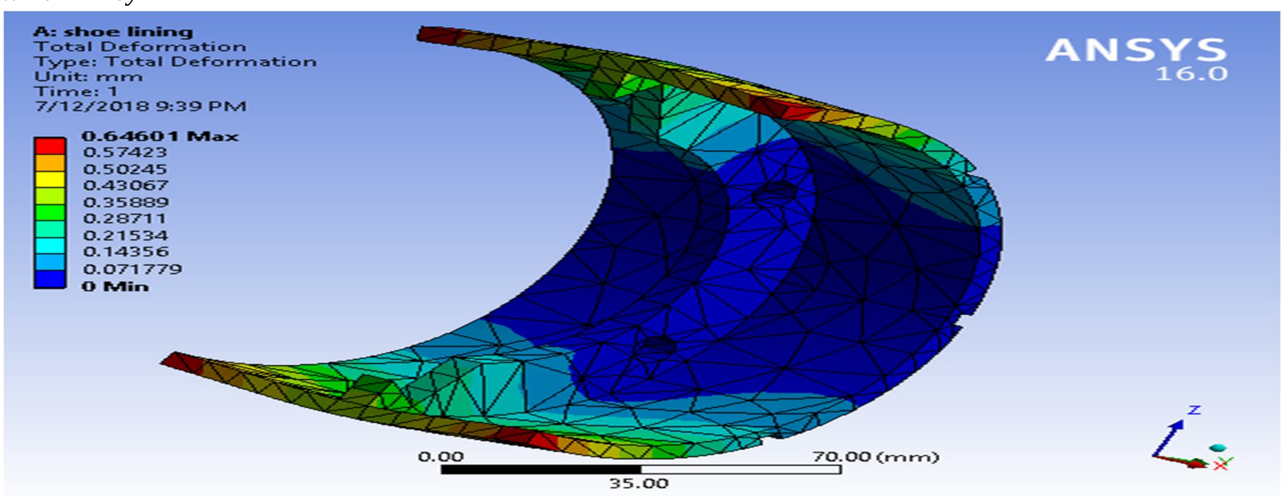

Fig: 3.1- Total deformation of titanium alloy

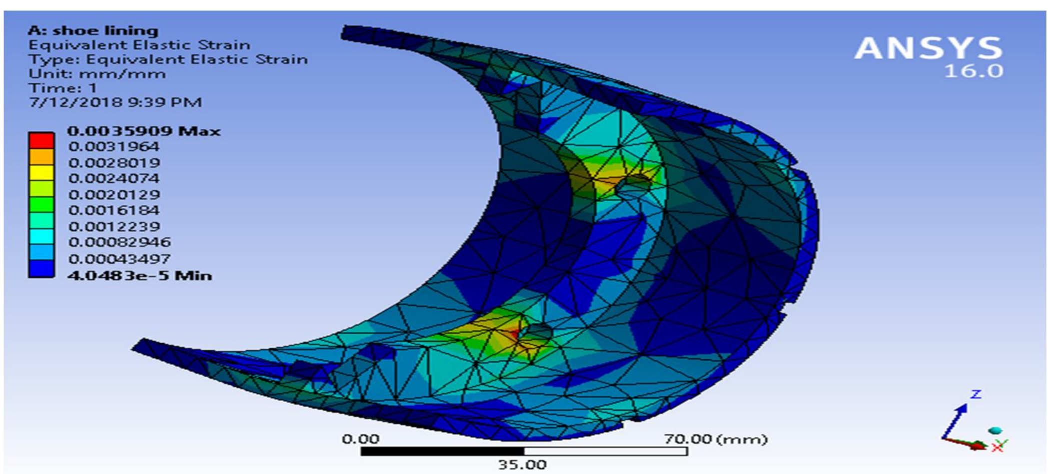

Fig: 3.2- Equivalent strain of titanium alloy

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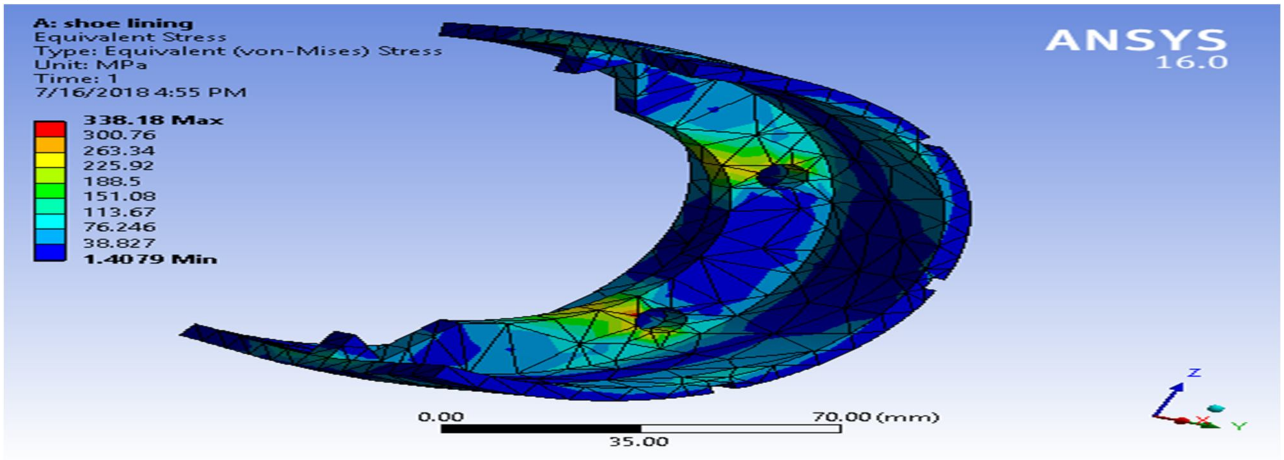

Fig: 3.3- Equivalent stress of titanium alloy

3) *Aluminium Metal Matrix 1.*

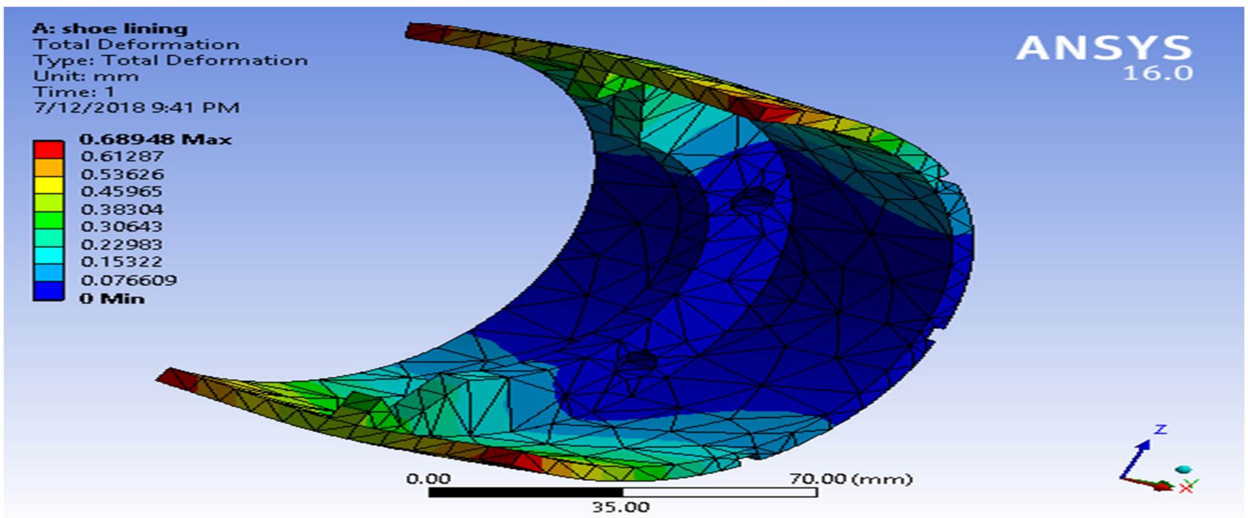

Fig: 4.1- Total deformation of aluminium metal matrix 1

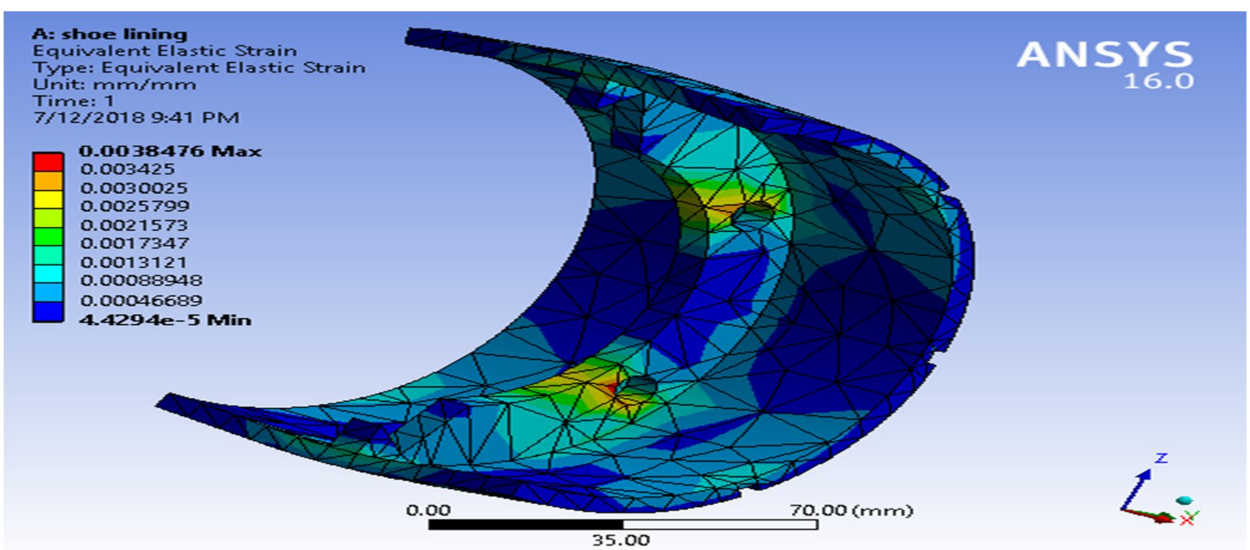

Fig: 4.2- Equivalent strain of aluminium metal matrix 1

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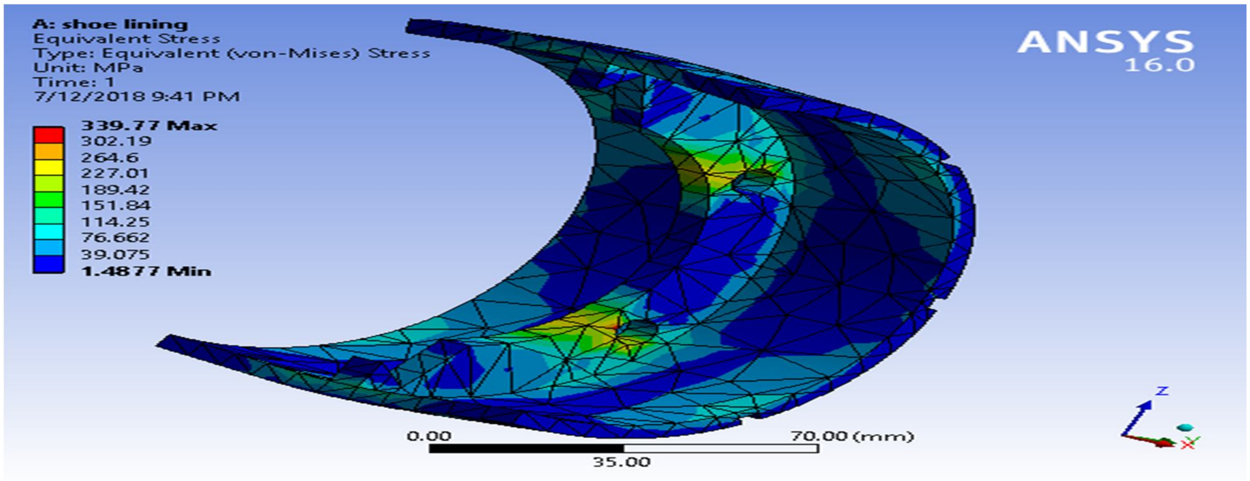

Fig: 4.3- Equivalent stress of aluminium metal matrix 1

4) Aluminium Metal Matrix 2

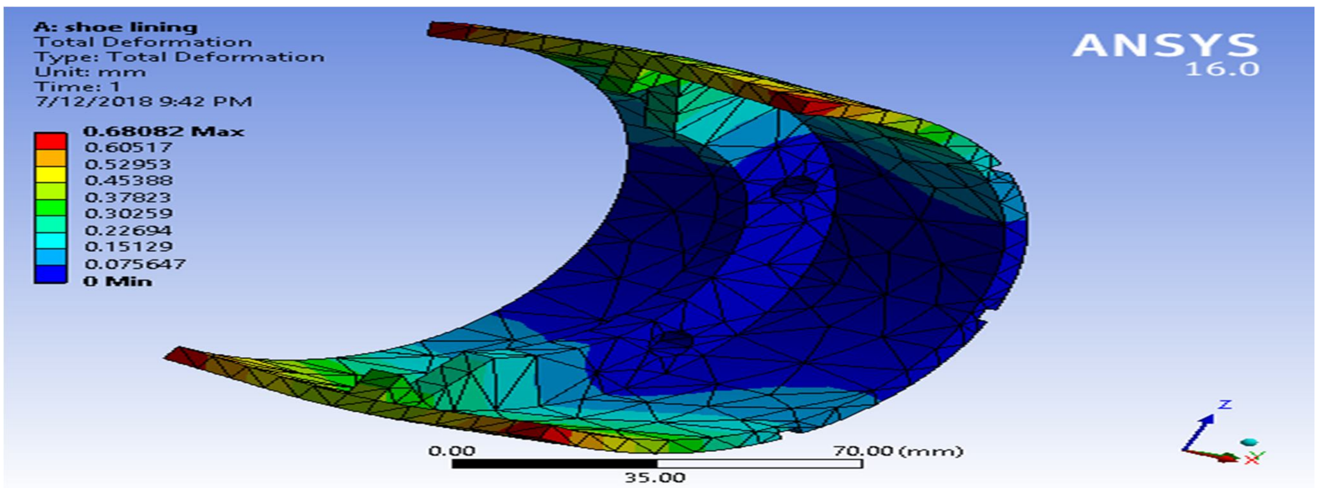

Fig: 5.1- Total deformation of aluminium metal matrix 2

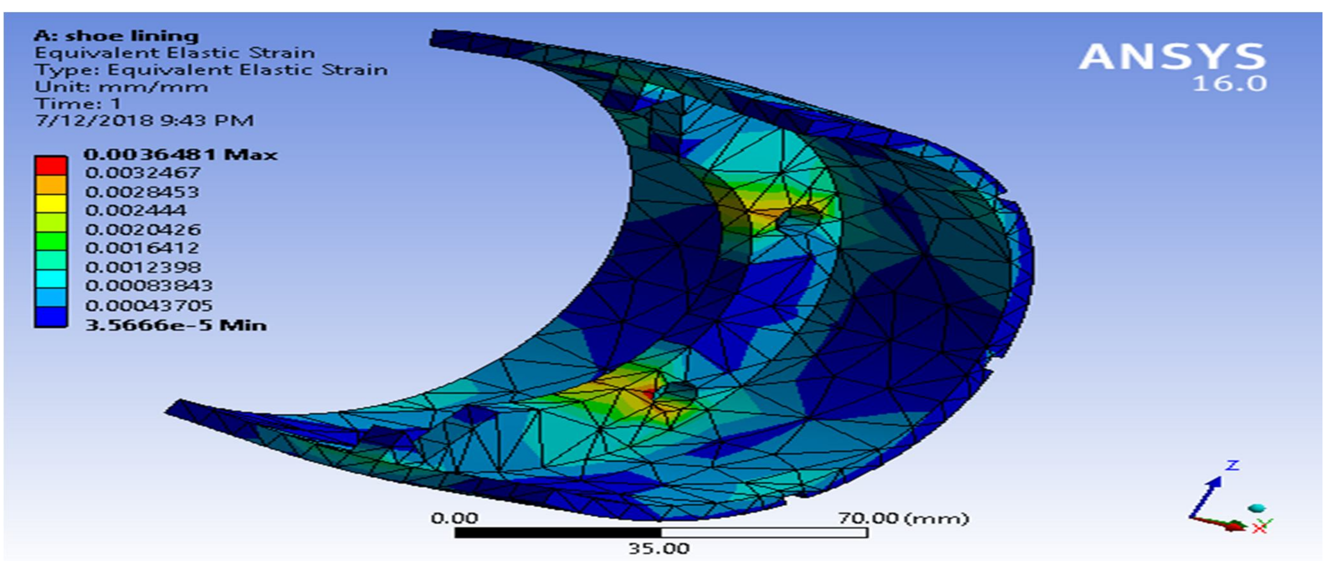

Fig: 5.2- Equivalent strain of aluminium metal matrix 2

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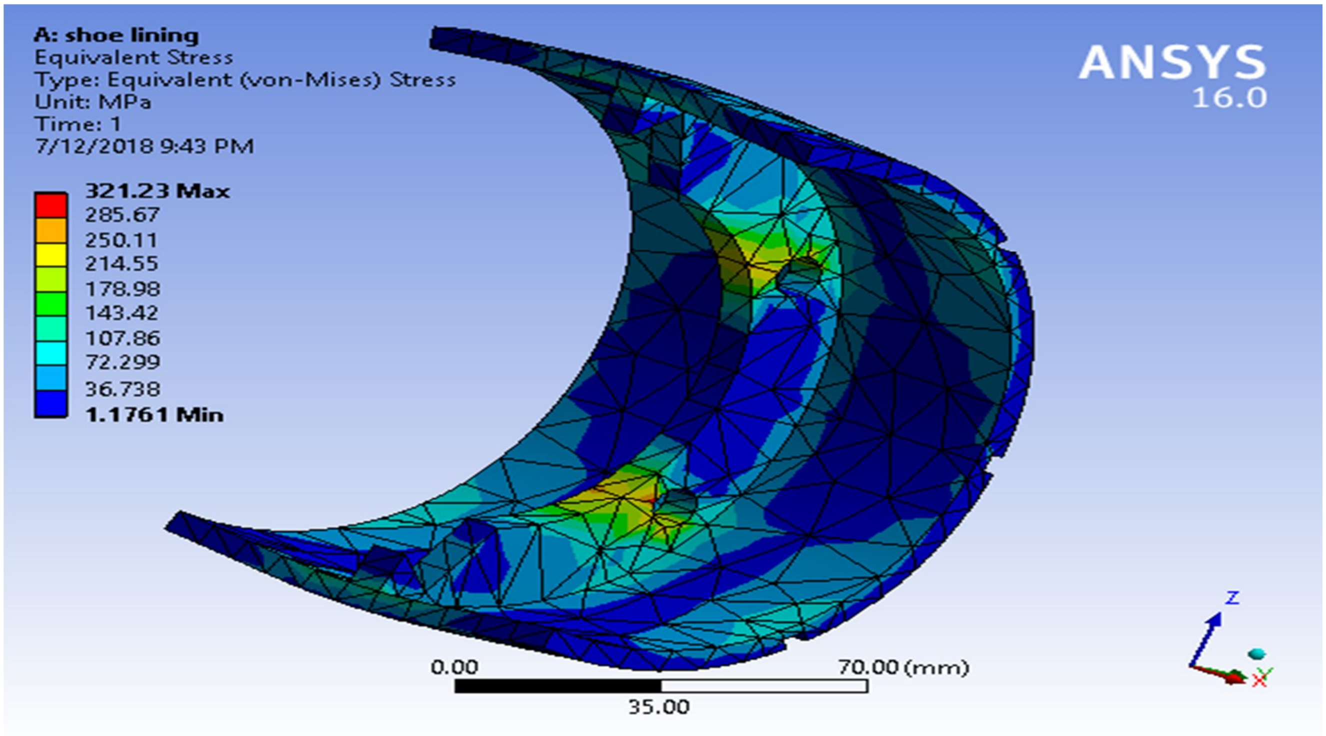

Fig: 5.3- Equivalent stress of aluminium metal matrix 2

B. Thermal analysis

For thermal analysis we apply the maximum temperature on outer surface of shoe lining.

1) Aluminium Alloy

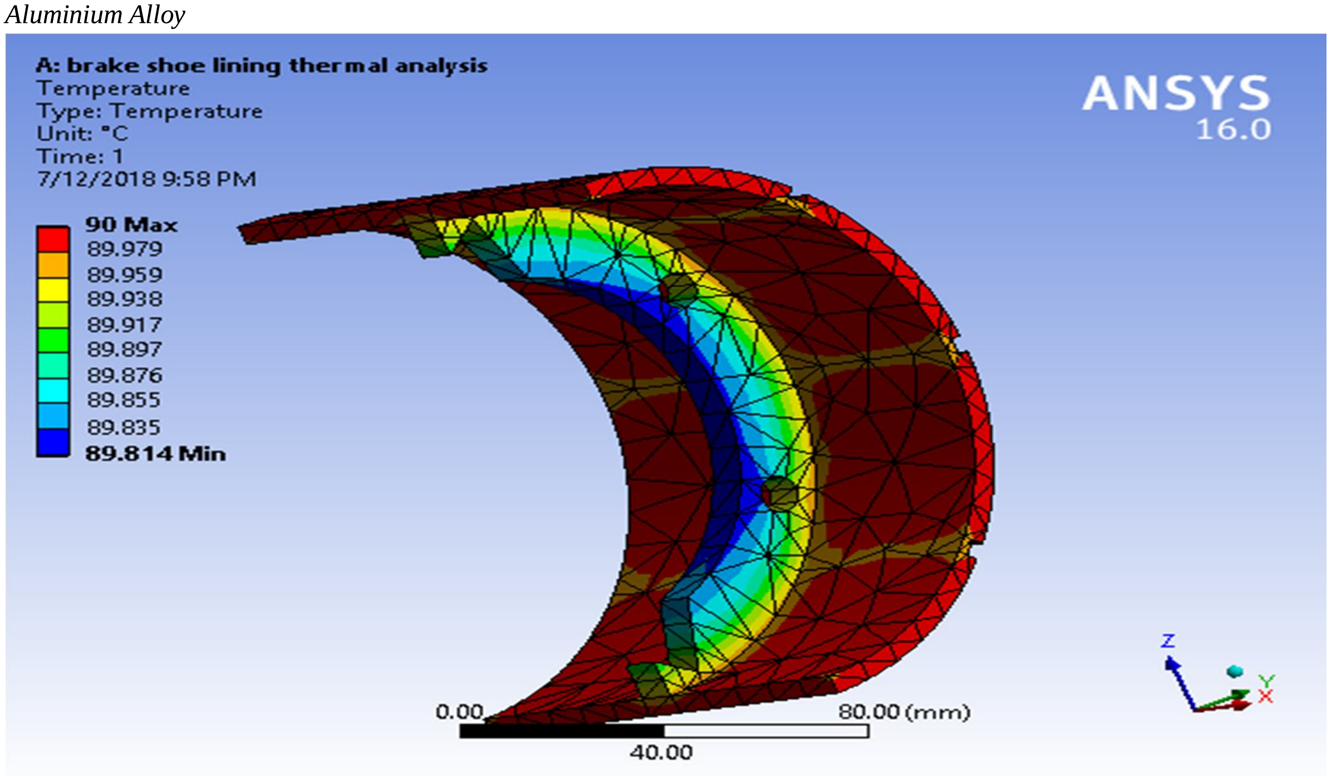

Fig: 6.1- Temperature distribution of aluminium alloy

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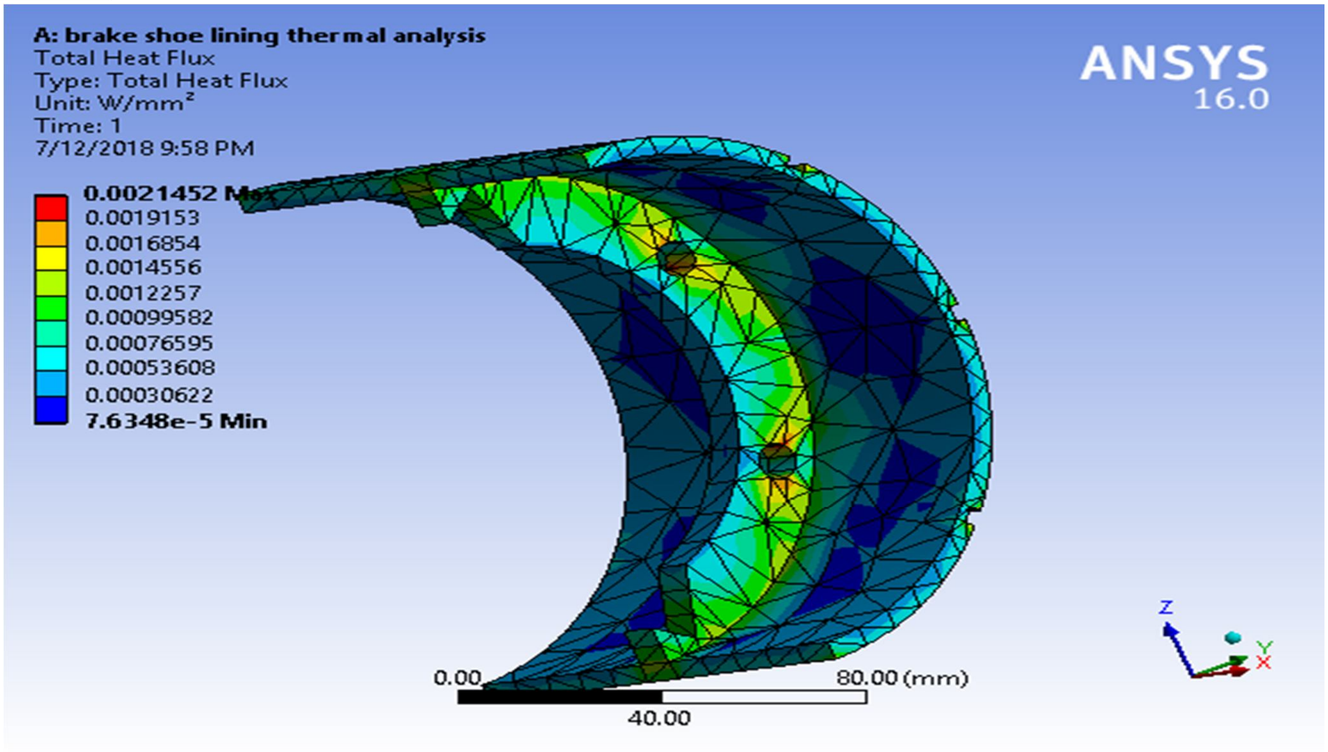

Fig: 6.2- Total heat flux of aluminium alloy

2) *Titanium Alloy*

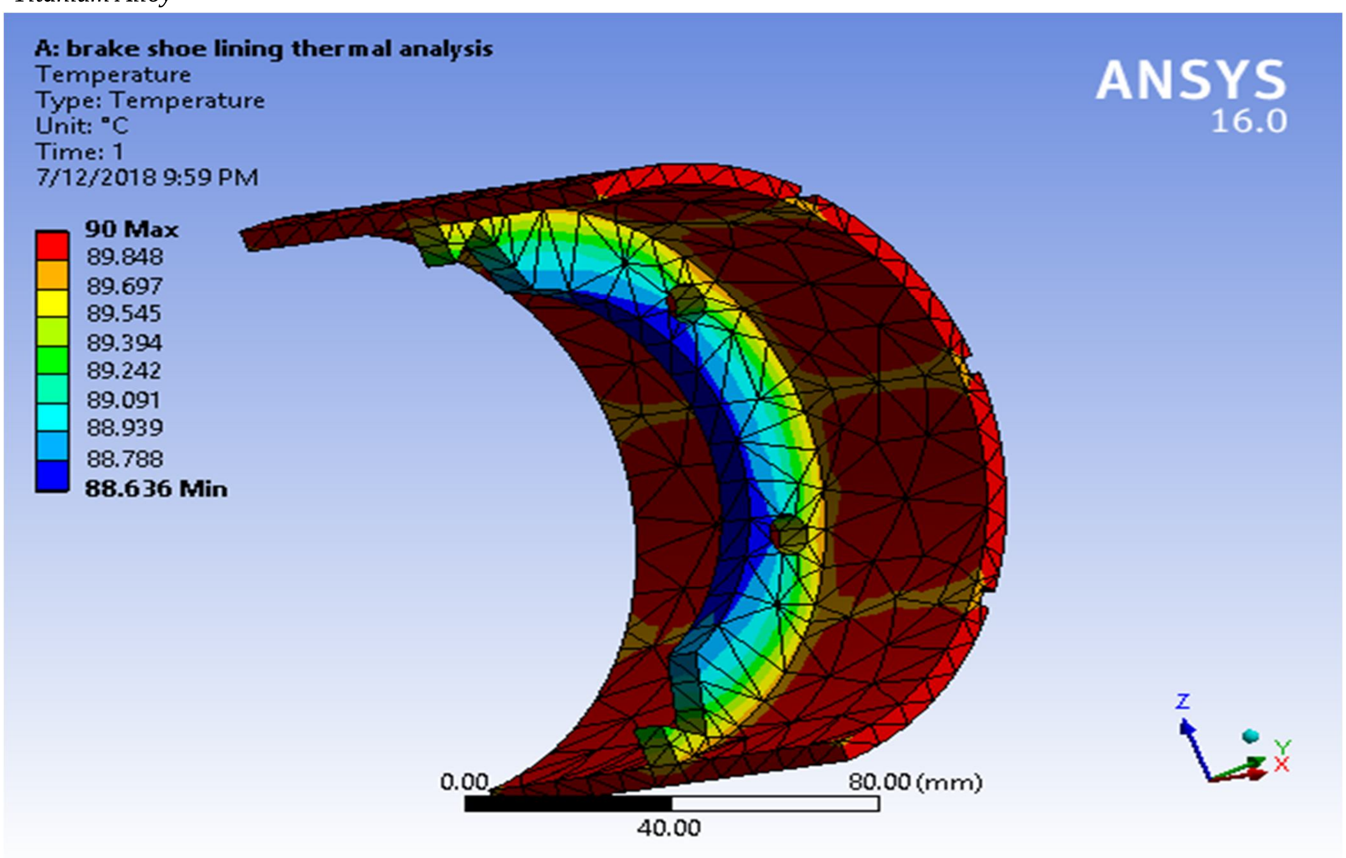

Fig: 7.1- Temperature distribution of titanium alloy

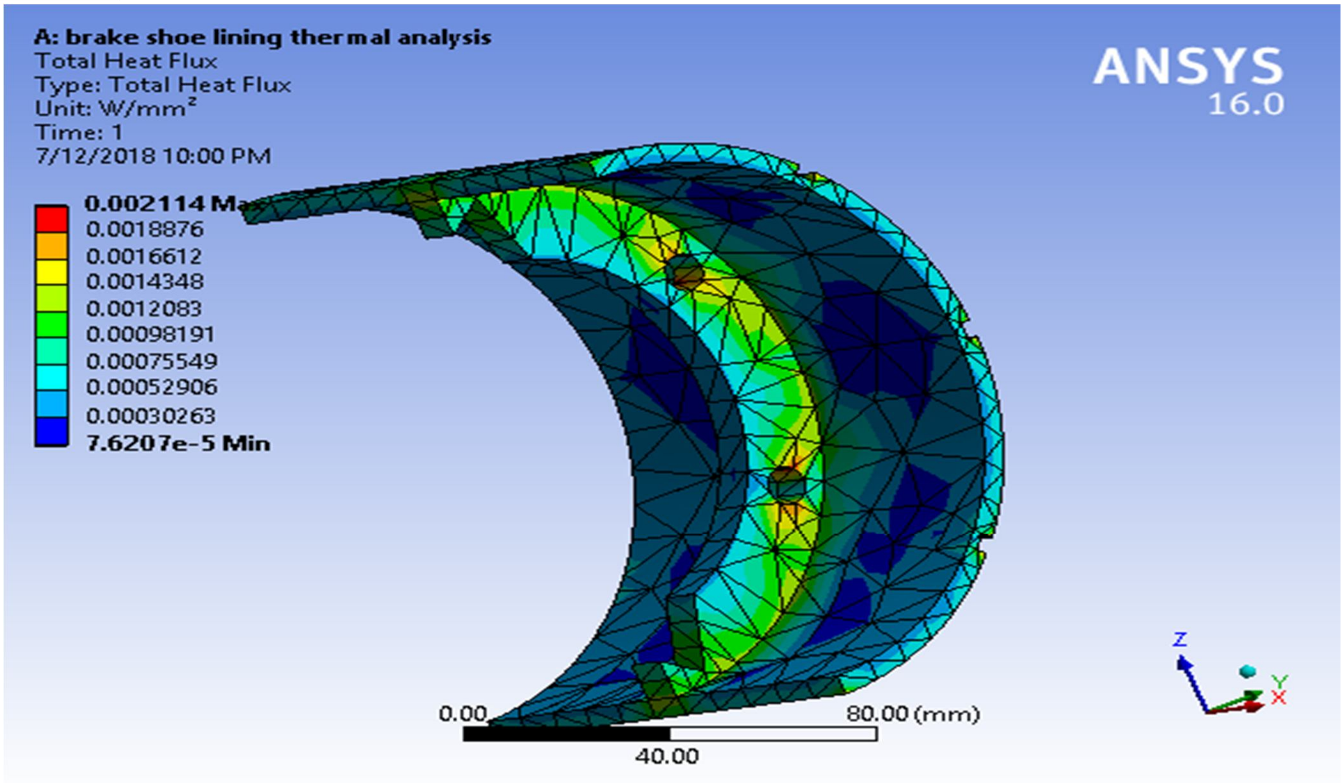

Fig: 7.2- Total heat flux of titanium alloy

3) *Aluminium Metal Matrix 1*

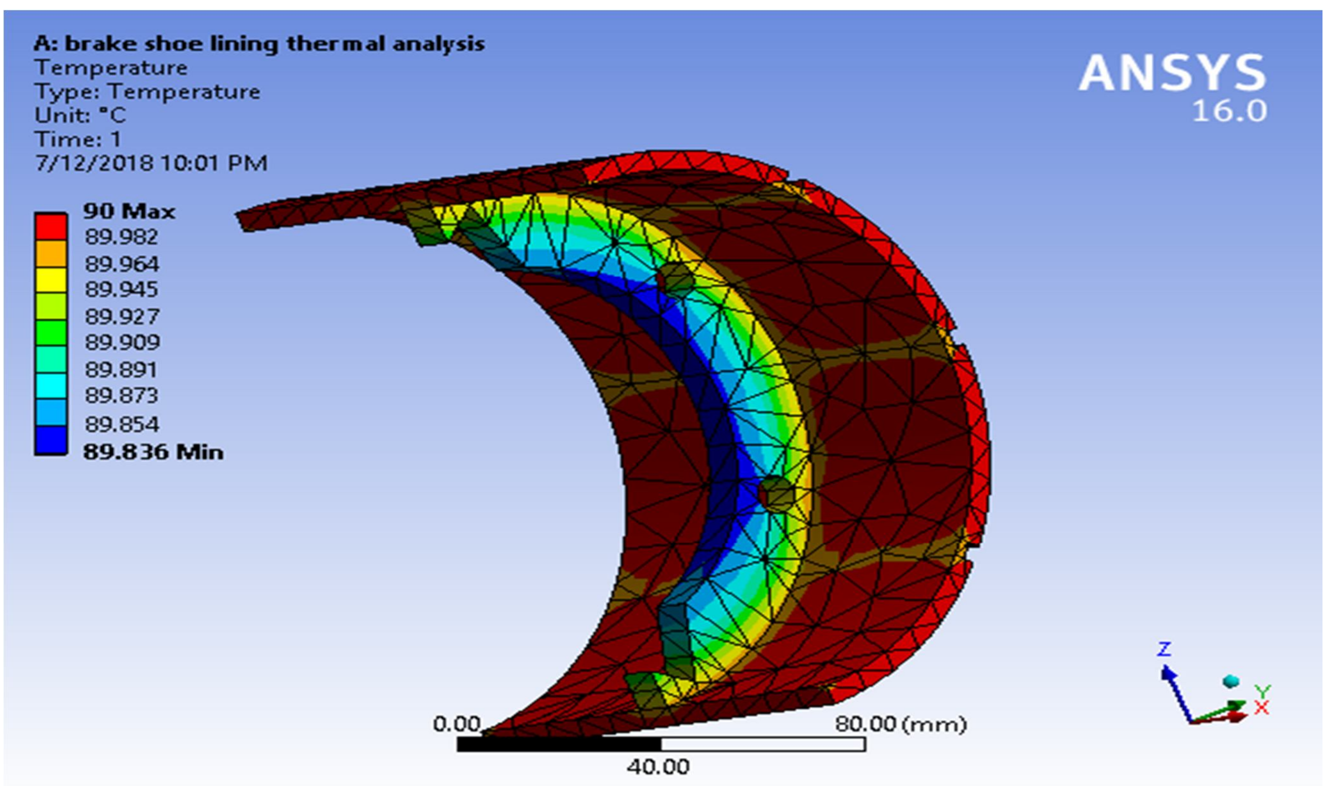

Fig: 8.1- Temperature distribution of aluminium metal matrix 1

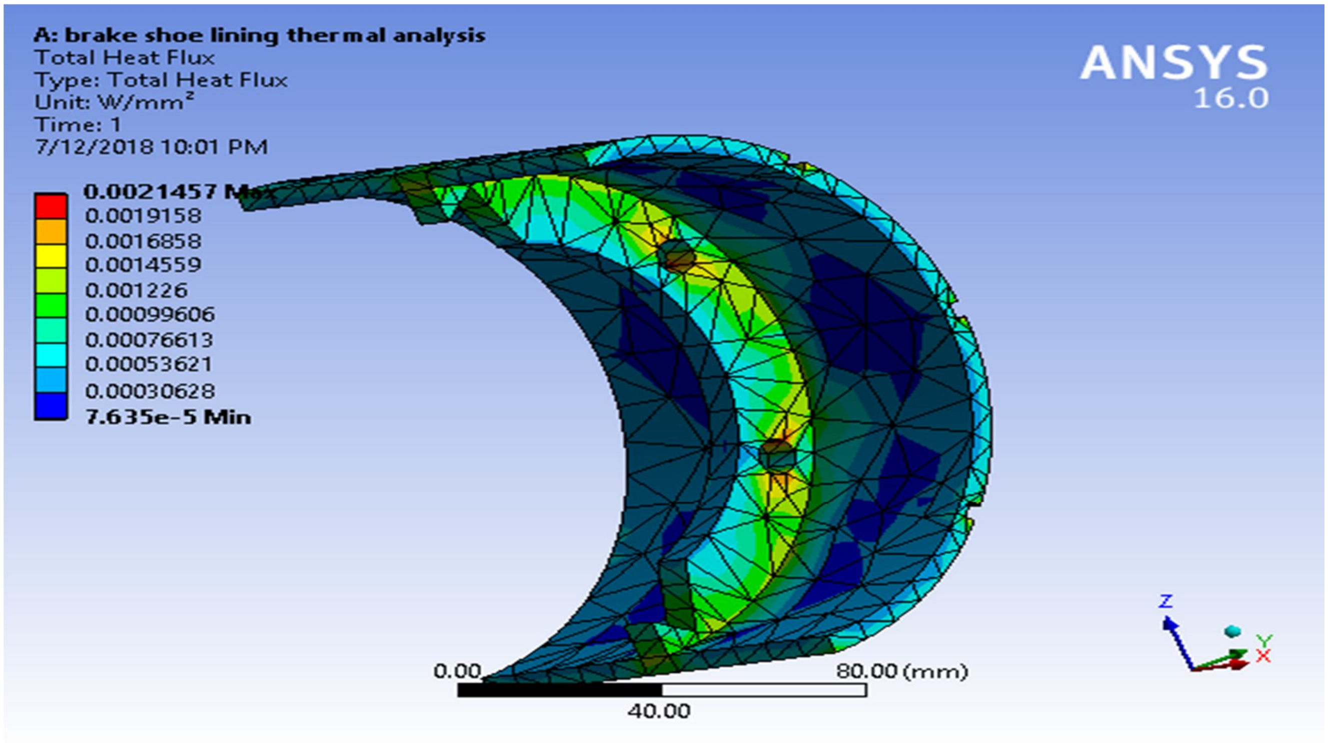

Fig: 8.2- Total heat flux of aluminium metal matrix 1

4) *Aluminium Metal Matrix 2*

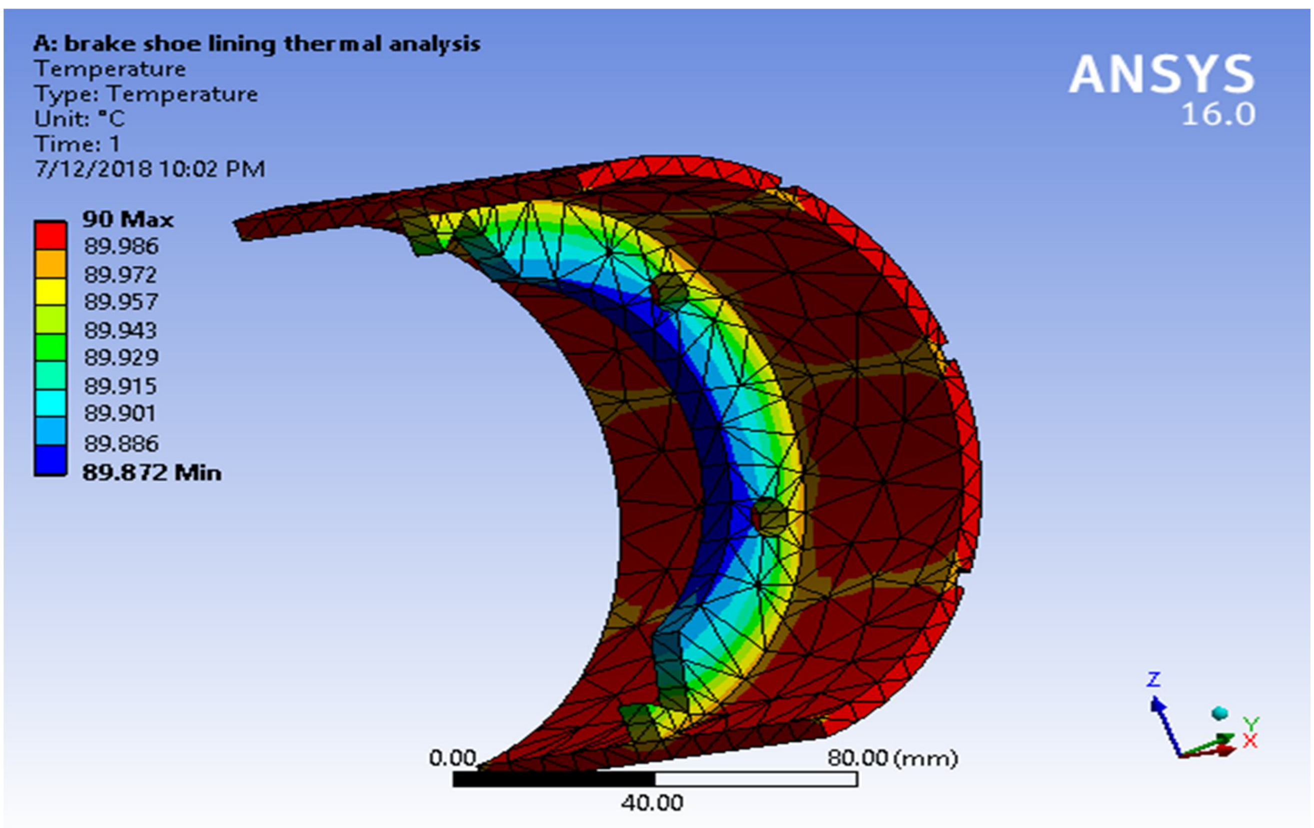

Fig: 9.1- Temperature distribution of aluminium metal 2

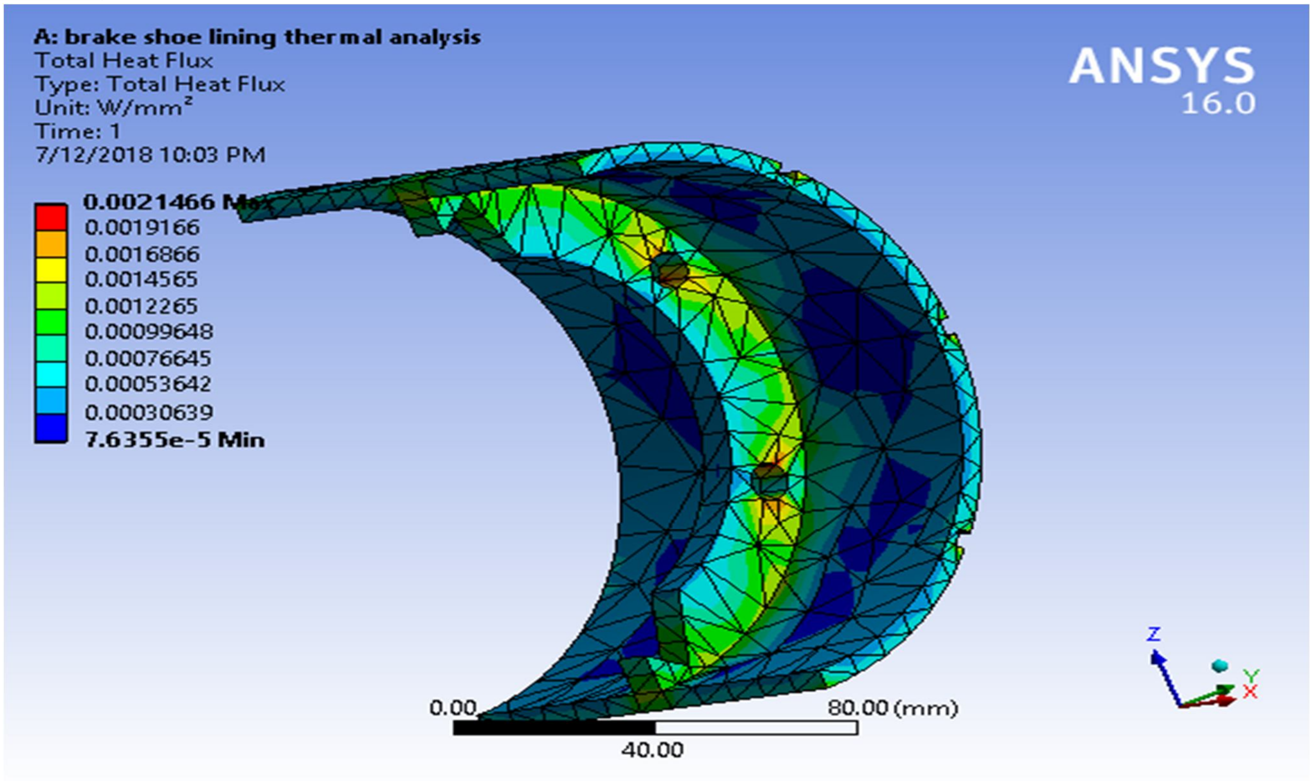

Fig: 9.2- Total heat flux of aluminium metal matrix 2

VII. RESULTS

A. *Static Structural analysis*

Parameters / Metal	Total deformation (mm)	Equivalent strain (mm/mm)	Equivalent stress (MPa)
Aluiminium alloy	0.87471	0.0049191	342.79
Titanium alloy	0.64601	0.0035909	338.18
Aluminium metal matrix 1	0.68948	0.0038476	339.77
Aluminium metal matrix 2	0.68082	0.0036481	321.23

B. *Thermal analysis*

Parameters / Metal	Temperature (^{0}C)	Total heat flux (W/mm^2)
Aluiminium alloy	90	0.0021452
Titanium alloy	90	0.0021140
Aluminium metal matrix 1	90	0.0021458
Aluminium metal matrix 2	90	0.0021466

VIII. CONCLUSION

From above result we can conclude that beside general materials such as aluminium alloy, 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. 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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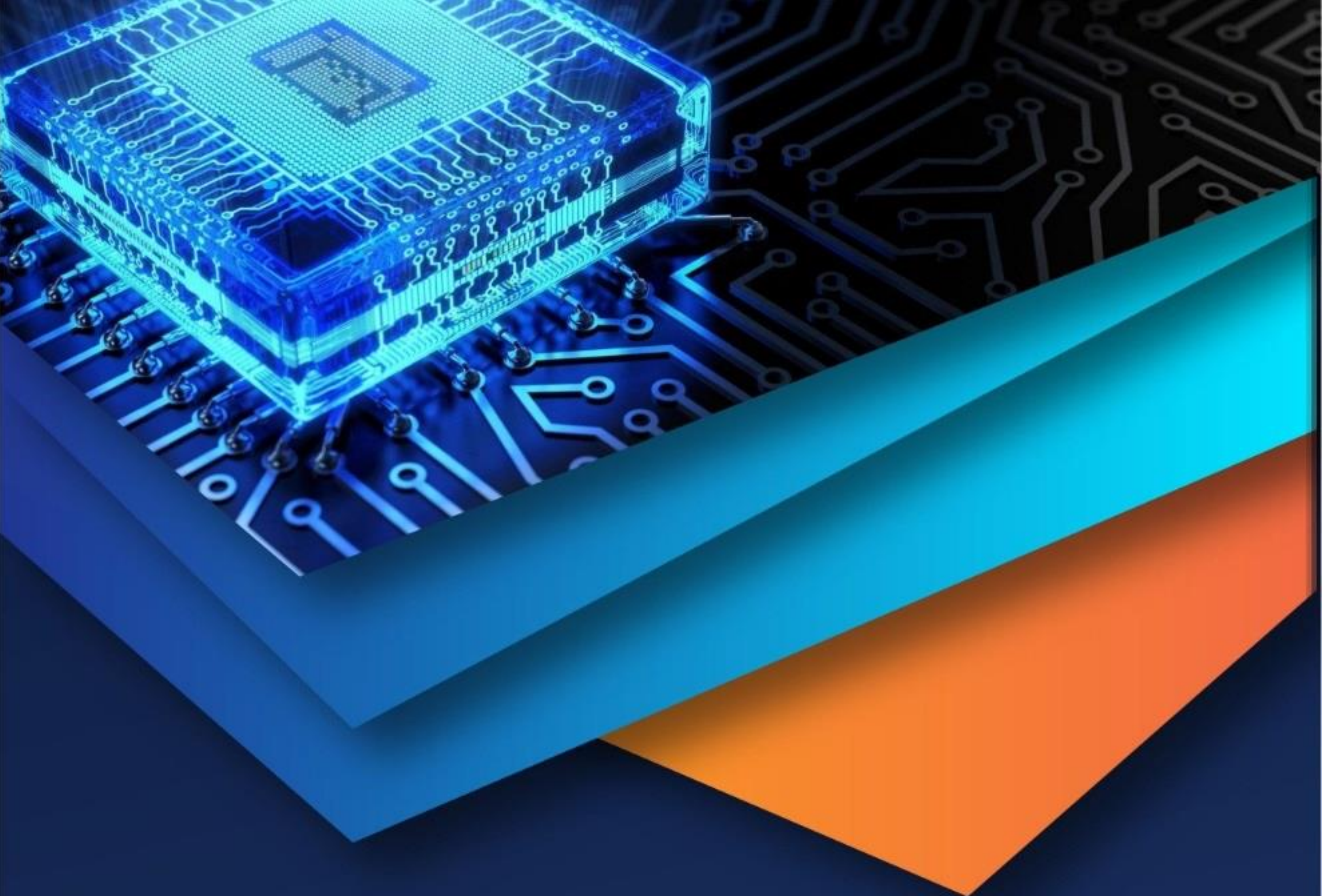

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