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Transient Thermal Analysis of Materials for Disc Brake of a Light- Weight Aircraft

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***Abstract*— This paper is a comparative study between the conventionally used brake materials and the advanced materials. The prime objective of this paper is to suggest the best material that can be used as a disk brake of a light- weight aircraft. There are five properties that have been considered in the selection of the candidate materials: Compressive strength, Friction coefficient, Wear resistance, Thermal conductivity and specific gravity. The cost of the material is also considered as a primary factor. A transient thermal analysis has been carried out over the disk brake of a light- weight aircraft. The landing velocity, landing distance, mass of the aircraft and braking time were considered in order to find out the brake pressure on the disk and the heat generated while braking. The analysis has been done in two sub steps: one at the landing velocity and the other at halt. The project compares the maximum temperatures obtained during braking in each of the candidate material disk and also the amount of stress produced in each disk. The temperature distribution pattern of each disk has been studied to make comparisons. The results obtained suggest that the best material to be used as a disk brake of a light- weight aircraft is Aluminium Composite reinforced with Silicon Carbide. This material showed the best performance during the analysis and can withstand high brake pressure.**

***Keywords*—Disc brake,Thermal Analysis,temperature distribution, stress, Metal Matrix Composite (MMC), braking, meshing**

I. INTRODUCTION

A composite is a combination of two or more materials combined on a microscopic scale to give superior properties than original materials which include strength, fatigue life, stiffness, temperature dependent behavior, corrosion resistance, thermal insulation, wear resistance, thermal conductivity, attractiveness, acoustical insulation and weight. The composites also possess high specific strength, high specific strain, low thermal coefficient of expansion, low weight, wear and corrosion resistance etc. Composites find its applications in Aerospace, Defense, Automobile, Machine tools, Marine, Construction Industry, Chemical Industry and Biomedical equipment etc. While designing a disk brake, the following properties are taken into consideration: compressive strength, friction coefficient, wear resistance, thermal conductivity and specific gravity as well as cost. It is often observed that disk brakes wear off easily with time and require a replacement. For a long run, the disk brake has to be designed with low wear rate and good friction coefficient. The disk brake has to exhibit excellent thermal properties in order to withstand extreme temperatures, such as in a case of aborted takeoff in an aero plane. In order to meet these property requirements, composite materials are used.

This paper deals with the use of a Metal Matrix Composite (MMC) in order to find out if the material can satisfy the requirements for a high- performance disk brake. A transient thermal analysis is done over the model of the disk brake using ANSYS 12.0, by applying pressure over the disk brake at two different speeds.

Aluminium-Metal matrix composites have lower density and high thermal conductivity. But, repeated braking causes lowering of friction coefficient and significant wear of brake pad. An addition of abrasive particles can help prevent the decrease in friction coefficient. Silicon Carbide (SiC), also known as Carborundum, is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral, Moissanite. Silicon Carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as brakes, clutches and ceramic plates in bulletproof vests. Silicon carbide is also used as a reinforcement to provide high strength to the resultant material. It has high thermal conductivity and high strength.

Aluminium Metal matrix composite reinforced with Silicon carbide in the required volume can be used to get the desired properties to withstand high temperatures in a disk brake and to overcome the drawbacks of conventionally used disk brake materials.

II. SOLUTION APPROACH

The structural model of the disc brake is modeled using the modeling software CATIAV5R19. The model is then transferred to the analysis software i.e., ANSYS 12.0. The heat generated at the disc is calculated using the relevant formulae. The thermal analysis is done using ANSYS 12.0 by taking time and speed into consideration. By changing the material properties, the thermal stresses in all the candidate materials are found and a comparative study is done.

III. TRANSIENT THERMAL ANALYSIS

In order to perform a transient thermal analysis of the disc brake employed for stopping an aircraft, a virtual model of the disc is created using CATIA V5R19. Pressure is applied at varying speeds of the aircraft over the part of the disc which is in contact with the brake pad. During the analysis, which is done using ANSYS 12.0, the time period for stopping the aircraft is also considered. Pressures are applied with respect to time. The pressure values are derived by calculating the values of Kinetic Energy at every stage, which is equal to the amount of heat generated. The applied load values are then found out and are used to attain the pressure values.

For calculating the Kinetic Energy at every wheel, the following expression is used:

$$K.E. = \frac{1}{2}mv^2$$

m = Landing Mass of the Aircraft
v = Velocity of the Aircraft

Also,

$$K.E. = Heat\ Generated = \mu F v$$

μ = Coefficient of Friction
F = Force applied
V = Velocity of the Aircraft

Now,

$$Pressure = Force / Area$$

IV. DIMENSIONS OF THE MODEL

Thickness of the disc = 11.2mm

Outer diameter of the disc = 254mm

Diameter at the hub = 76mm

Diameter of slot = 9mm

V. FINITE ELEMENT MODELING

Finite element modeling is done over the model of the disk brake created using CATIA V5R19 as per the dimension obtained. The model is then exported to ANSYS 12.0 for Analysis. Meshing is done over the model after giving the material properties.

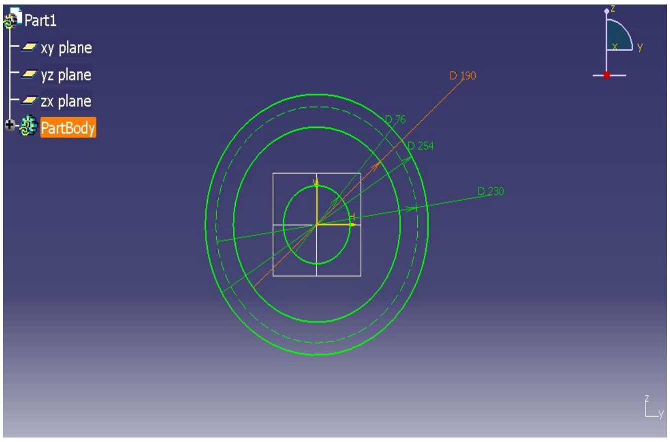

Fig. 1 Front view of the disk

VI. MATERIAL PROPERTIES OF CANDIDATE MATERIALS

The material properties of the candidate materials taken for study are given below.

ALUMINIUM METAL MATRIX COMPOSITE WITH SILICON CARBIDE REINFORCEMENT

Percentage of Silicon Carbide = 20

Longitudinal Young's Modulus = 108GPa

Transverse Young's Modulus = 102GPa

Poisson's ratio = 0.33

Specific Heat = 0.98 KJ/Kg K

ALUMINIUM

Young's Modulus = 69GPa

Poisson's ratio = 0.33

Specific Heat = 910 J/Kg K

Thermal Conductivity = 250 W/m K

VII. BOUNDARY CONDITIONS

The slots provided at the hub for fitting the disk to the wheel are provided insulation so that no heat is transferred through it. The slots provided for dust removal and heat dissipation are subjected to a convective temperature of 35 °C. The area of the disk which is in contact with the brake pad is subjected to the heat generated during braking.

VIII. MODELING AND ANALYSIS

The model is imported to ANSYS 12.0 software, after being created in CATIA V5R19 as per the dimensions obtained. *Fig.2* shows the model of the disk brake. *Fig.3* shows the disk brake model after being imported to ANSYS software.

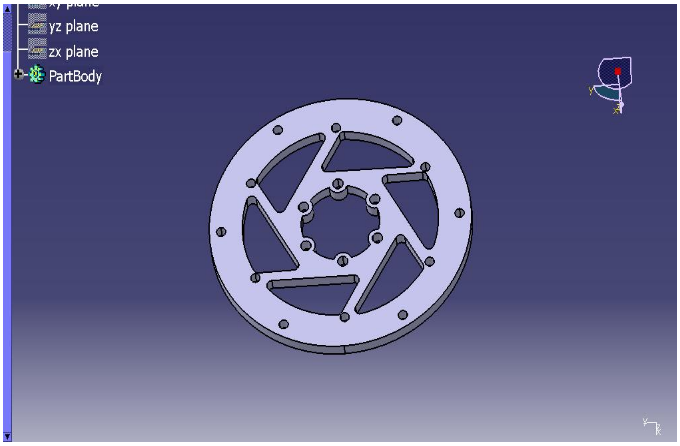

Fig.2 Isometric view of the disk in CATIA

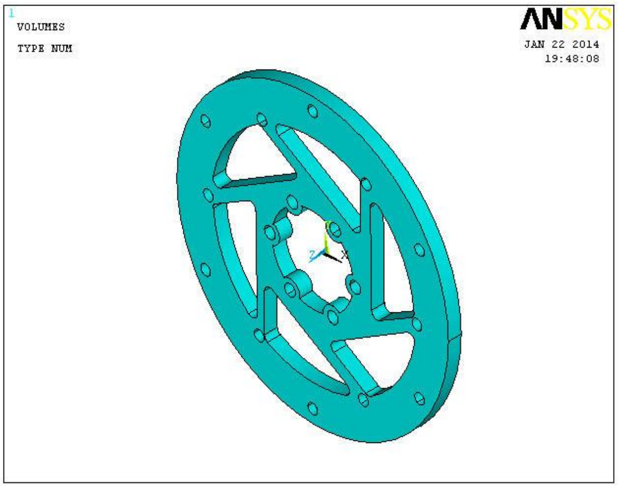

Fig. 3 Isometric view of the disk brake in ANSYS

The model of the brake disc is meshed according to the disc dimensions, in order to obtain a fine mesh and accurate results. The pressures are applied once meshing is completed. *fig. 4* shows the model under mesh.

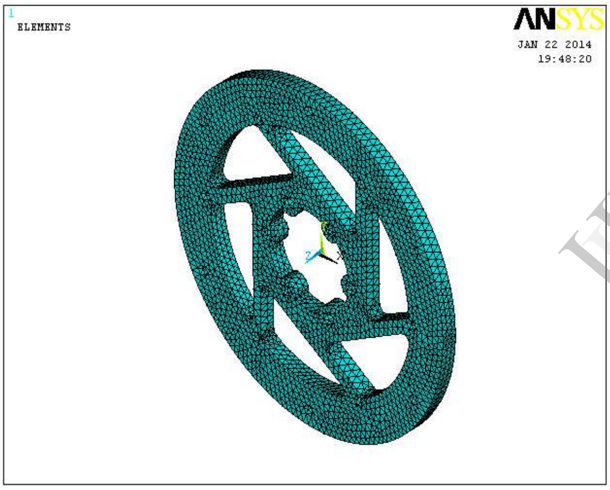

Fig. 4 Isometric view of the meshed disc

IX. RESULTS

ALUMINIUM COMPOSITE DISK BRAKE REINFORCED WITH SILICON CARBIDE

As it can be seen from *Fig. 5*, a maximum temperature of 1372°C is reached during braking at a landing velocity of 80 mph. The next figure depicts the condition of the brake disk at halt position after a braking time of 23.07 seconds, from a velocity of 80mph to 0mph. The picture shows that the complete disk attains a convective temperature of 35°C.

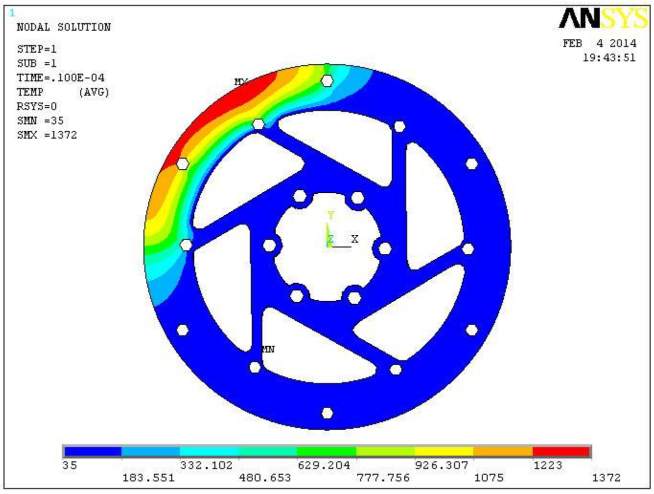

Fig. 5 Temperature distribution pattern in an Aluminium Composite disk reinforced with Silicon Carbide

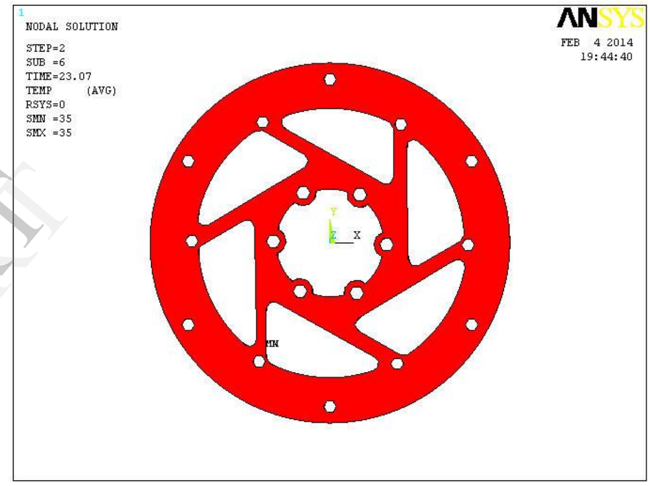

Fig. 6 Temperature distribution pattern of the Aluminium composite disk with Silicon Carbide reinforcement at halt

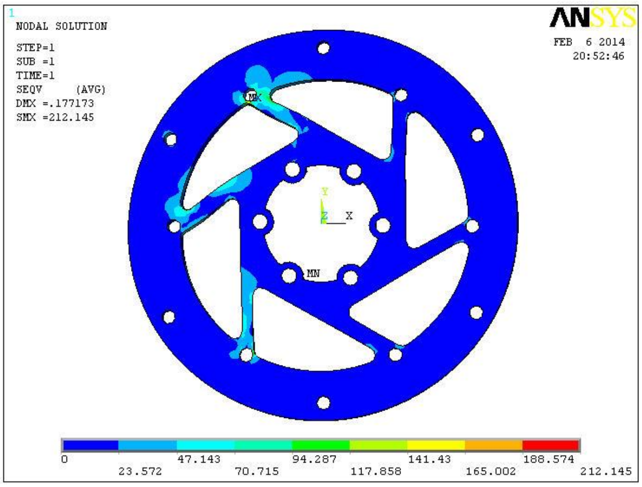

Fig. 7 Structural analysis of Aluminium composite disk with Silicon Carbide reinforcement showing Von- Mises stresses on application of the brakes

ALUMINIUM DISK BRAKE

In the Aluminium disk, a maximum temperature of 1150°C is obtained at the landing velocity. The temperature variation over the disk is shown in *Fig. 8.*

Fig. 9 depicts the condition of the brake disk at halt position after a braking time of 23.07 seconds, from a velocity of 80mph to 0mph. The picture shows that the complete disk attains a convective temperature of 35°C.

X. COMPARATIVE STUDY OF THE CANDIDATE MATERIALS

The temperatures reached during braking, lie within a range of 1100-1400 °C. The maximum temperature of 1372 °C is obtained in the Aluminium composite disk reinforced with Silicon Carbide while the lowest temperature is obtained in the Aluminium disk at 1150 °C.

It is quite visible that the Aluminium composite disk reinforced with Silicon Carbide is safe for use in the aircraft at a landing velocity of 80 mph. This is possible since the maximum temperature obtained during braking is under the melting point limit of the material. In case of Aluminium composite disk, the factor of safety is very less and cannot be risked for use in the aircraft taken for study.

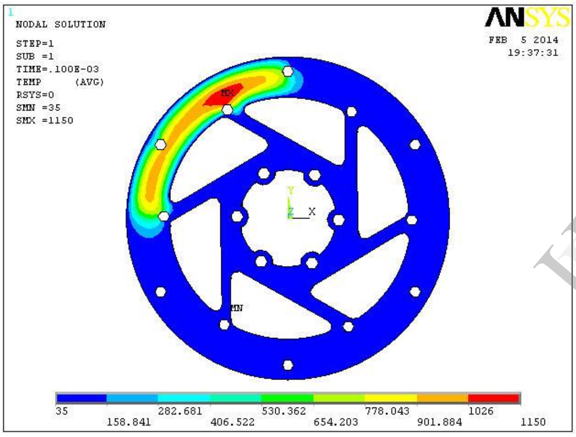

Fig. 8 Temperature distribution pattern in the Aluminium disk

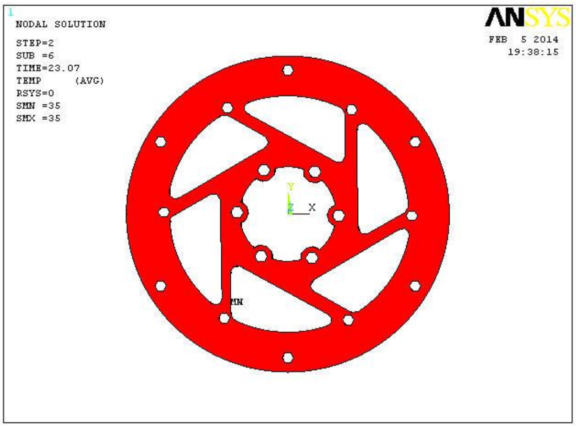

Fig. 9 Temperature distribution pattern of the Aluminium disk at halt

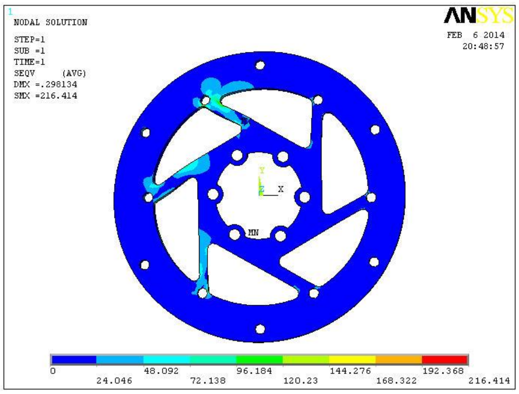

Fig. 10 Structural analysis of Aluminium disk showing Von- Mises stresses on application of the brakes

XI. CONCLUSIONS AND FUTURE SCOPE

From the analysis carried out over the candidate materials, the following conclusions have been drawn:

1. The best candidate material to be used as a disk brake of a light- weight aircraft is Aluminium composite reinforced with Silicon Carbide
2. Aluminium disk brakes do not withstand the heat generated since they have lower melting points compared to Aluminium composite reinforced with Silicon Carbide
3. Silicon Carbide provides enough strength to the disk so that it can withstand higher brake pressure, as shown in structural analysis in *Fig. 7.*
4. Aluminium composite disk brake reinforced with Silicon Carbide can withstand and perform well at higher thermal stresses and higher temperatures.

This project suggests the best material for manufacturing disc brakes for light weight aircrafts and sports cars. This project is considered to be a forward step in the field of brake material development and the results can be used for further references.

REFERENCES

1. Transient temperature analysis of airplane carbon composite disk brakes Ahmet Sahin, Ahmed Al-Garni, 32nd Thermophysics Conference, 1997
2. Thermo-Mechanical Analysis of Airplane Carbon-Carbon Composite Brakes Using MSC Marc: ZbigniewWolejsza, Adam Dacko, TomazZawistowski, Jerzy Osinski
3. Development of carbon brake discs for light combat aircraft Dr. R. K. Jain, Dr. J. Gururaja Rao, K H Sinnur National Conference on Recent Advances in Composites (NCRAC-2012)
4. Development of materials for automotive disk brakes**,** Omar Maluf, MaurícioAngeloni, Marcelo Tadeu Milan, DirceuSpinelli, WaldekWladimir Bose Filho
5. Material Selection Method in Design of Automotive Brake Disc, M. A. Maleque, S. Dyuti, M.M.Rahman ,Proceedings of the World Congress on Engineering 2010 Vol III WCE 2010, June 30 - July 2, 2010, London, U.K.
6. Evaluation of materials and design modifications for Aircraft brakes, by T.L. Ho, F.E. Kennedy, and M.B. Peterson , January 1975, Prepared for Aerospace Safety Research And Data Institute Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio
7. Metal Matrix Composites by K .K. Chawla, University of Alabama at Birmingham and N. Chawla, Arizona State University