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DESIGN AND NUMERICAL ANALYSIS OF A FOUR WHEELER DISC BRAKE USING CATIA AND ANSYS.

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Abstract

In the present scenario, weight reduction of an automobile play an important role in increasing the efficiency and performance of the vehicle. Brake is a mechanical device which can absorb both kinetic and potential energy and converts into heat energy which is dissipated to its surroundings. The present work is carried out by using titanium alloys in order to reduce the weight and increase the performance of the disc brake. As titanium alloys satisfies the material properties of a disc brake. Modeling is done using CATIA V5. The structural and modal analysis is carried out by using ANSYS. The results of the present work using titanium alloys are compared to the present used materials.

Key Words: Disc Brake, CATIA V5, ANSYS, Stresses, Titanium Alloys

I. INTRODUCTION

A brake is a mechanical device which is used to accelerate and decelerate the wheel of the vehicle. Brakes are classified into the following types:

1. Mechanical brakes: These are operated by mechanical means such as levers, springs and pedals. These depend upon the shape of the friction material. These are classified as block brakes, internal or external shoes brakes, disc brakes and band brakes. According to the direction actuating force these are classified as radial brake and axial brake. Radial brakes are the internal and external brakes. While disc brakes are axial brakes.
2. Hydraulic and pneumatic brakes: These are operated by fluid pressure such as oil and air.
3. Electrical brakes: These are operated by magnetic forces. These include magnetic particle brakes, hysteresis brakes and eddy current brakes.

A disc brake has calipers to squeeze the pair of pads against the disc to create friction that retards the rotation of a shaft, either to reduce its rotational speed or to hold it stationary. The effectiveness of the disc brake depends upon the material. The material should provide performance, cost effectiveness and easy manufacturability. The materials used for disc brake are:

- Grey cast iron GG-20
- Stainless steel 321
- Aluminium and aluminium matrix composites 2
- Ceramic composites

- Chromium

For the present work titanium is used for the disc brake. Titanium alloys like grade 5 (Ti 6Al 4V) and Ti 550 is consider for the study in the present work.
Titanium alloys have good properties like high corrosion resistant, high temperature resistant, high strength to light weight, formability, etc…

II. BACKGROUND INFORMATION

Design and modeling:

a) Design and calculations:

Part name	Dimensions
Weight of the vehicle	1385 Kg
Wheel base	2380mm
Top speed	160Kmph
Disc diameter	210mm
Disc thickness	24mm
Tyre radius R_t	235mm
Effective radius of rotor, R_r	110mm
Deceleration	12.9ms^{-1}
Stroke	56.4
Cylinder	4
Gears	5

b) Brake Distance:

Initial velocity (v) = 60 Kmph = 16.667m/s
Kinetic energy (K.E) = ½ mv^2 = 192368.8056 J
Rotational speed (W) = v/ R_t = 70.923 rad/sec
T_s= 4 sec
Stopping distance = v^2/2*a = 10.767m
Heat generated (Q) = m*$C_{p*}\Delta T$
Specific heat C_p for (Ti 550) = 586 JKg^{-1}K^{-1}
Specific heat C_p for (Ti6Al4V) = 565 JKg^{-1}K^{-1}
Mass of the disc brake (for titanium (Ti 550)) = 0.34 kg
Heat generated for (Ti 550) = 796.96 J
Heat generated for (Ti6Al4V) = 768.4 J
Area of the disc = π (R-r) = 0.4084m^2
Restoration energy (R.E) = 30% of K.E. = 57710.641 J
Total energy = K.E + R.E = 250079.447 J
Area of rubbing face = T.E (R-r) = 32510.328m^2
Force on disc (F_d) = R.E/ 2*$R_{r/}R_t$*(v*T_s*0.5(v* T_s) =136.995 N
Disc usable area = π/4 (R-r) = 0.1021 m^2

c) **Tangential force between pad and rotor:**

FTRI = Normal force between Pad and Rotor
µ = coefficient of friction = 0.3, A= area of the brake
FTRI = FRI * µ
FRI = $(P_{max})/2*A$
P_{max} = 2 Mpa
FTRI = 0.3*0.3*2e6*0.4084/2
= 14.8284 N

d) **Braking Torque:**

Considering uniform pressure theory:
R_f = friction radius = $2/3 *(R^3 - r^3)/ (R^2 - r^2)$ = 0.183 m
$M_t = \mu * P * R_f$
P = Actuating force
$P = P_{avg} * A$ = 329.52 N
M_t = 18.09 Nm

III. MAIN RESULT

a) **Material properties:**

Table 1: material properties of various material used.

Properties	Cast iron	aluminium	ceramics	Ti 550	Ti6Al4V
Density (δ)	7200	2700	5700	4600	4400
Poisson's ratio (ϒ)	0.25	0.3	0.3	0.31	0.31
Thermal conductivity w/m°c	52	209	2.0	7.5	7.1
Specific heat C_p	460	900	400	586	565
Coefficient of thermal expansion	8.1	1.4	0.75	8.8	7.1

e) **Modeling of the disc brake using CATIA V5:**

- **CATIA V5:**

CATIA provides a wide range of applications for tooling design, for both generic tooling and mold & die. A rich catalog of industry-standard components is provided to automate tooling definition. Specific tools are also provided to address the needs of mold tool injection designers.

- **Modeling:**

The following steps are followed in modeling the disc brake.

i. Using axis commands draw the axis in both horizontal and vertical directions.

ii. Using the profile command draw the side views of the disc brake and constraint it.

iii. Exit work bench select pad. Select sketch and draw circles.

iv. Exit work bench and select pockets.

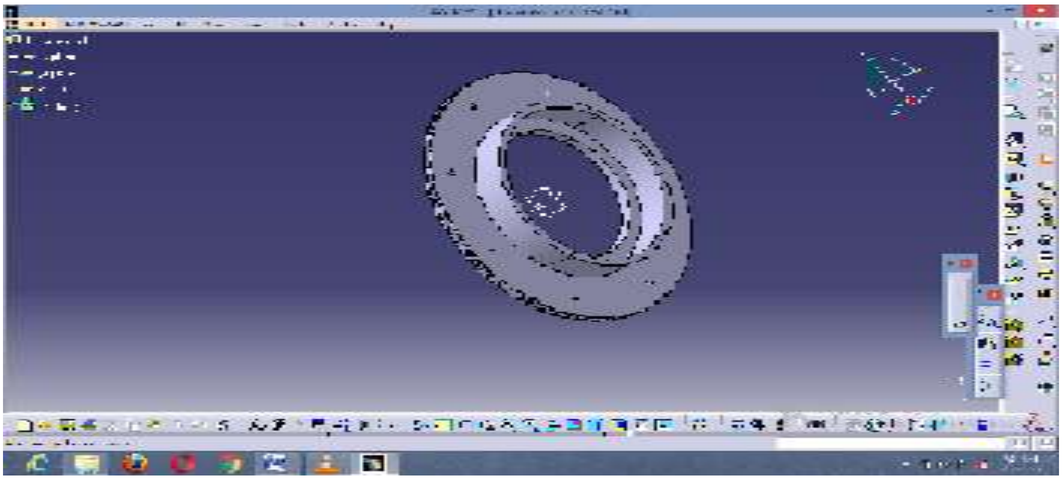
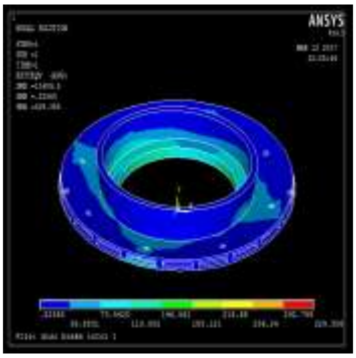


Fig 1: design of disc brake

IV. RESULTS

The analysis is carried out by using ANSYS 15. This software is used to analyze the stresses acting on the component. To reduce the cost of the piston different materials are considered and the results of their analysis are compared for the best solution.

a) **For Ti 550**:



I.

Fig 2:Vonmises stress

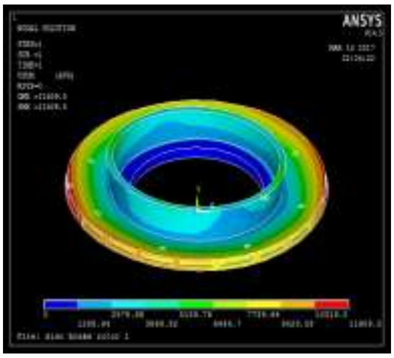


Fig 3: Displacement vector

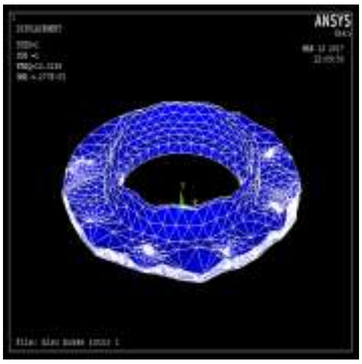


Fig 4:Model deformation

a) For Ti6Al4V:

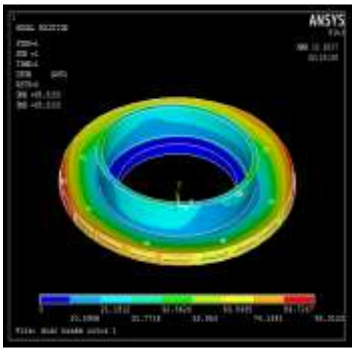


Fig 5: Displacement vector

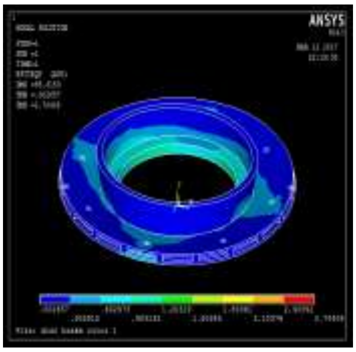


Fig 6: Vonmises stress

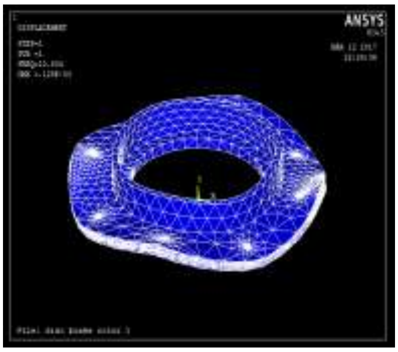


Fig 7: Model deformation

b) For ceramics:

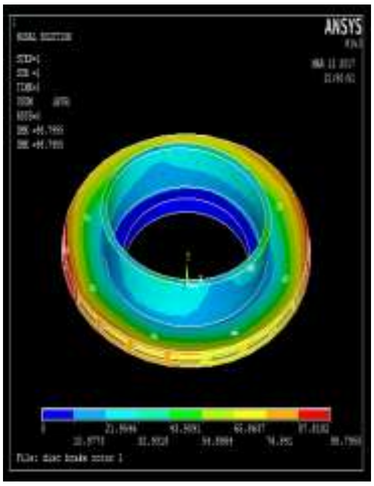


Fig 8: Displacement Vector

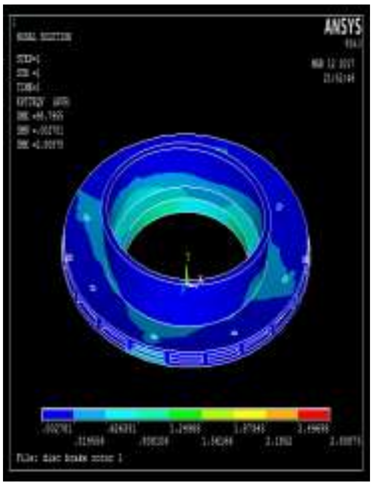


Fig 9: Vonmises stress

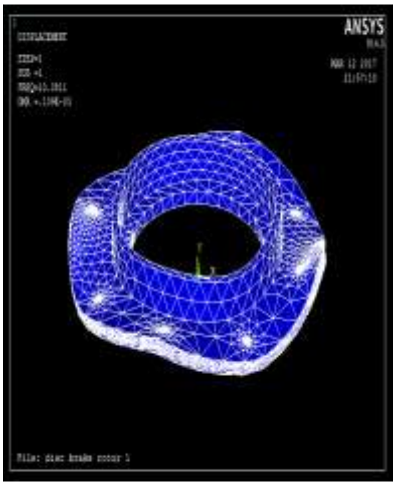


Fig 10:Modal deformation

c) For aluminium:

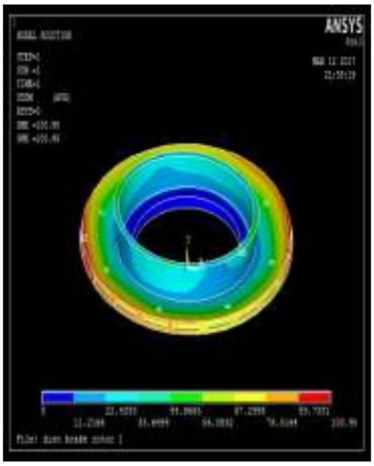


Fig 11:Displacement vector

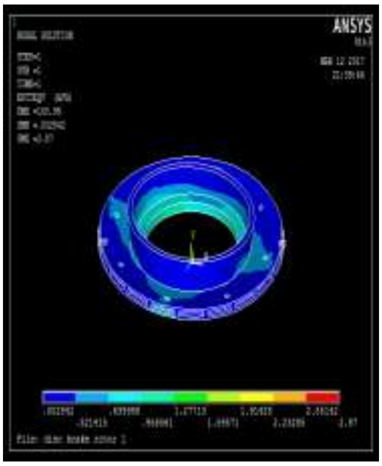


Fig 12: Vonmises stress

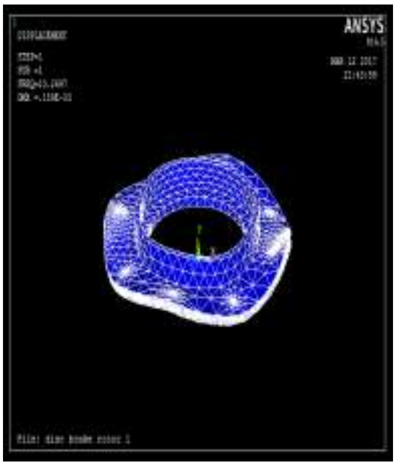


Fig 13: Model deformation

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a) **For grey cast iron:**

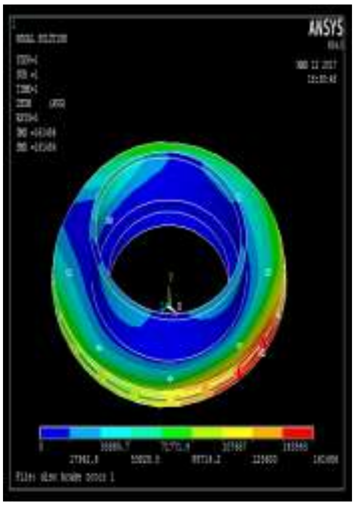

Fig 14: Displacement vector

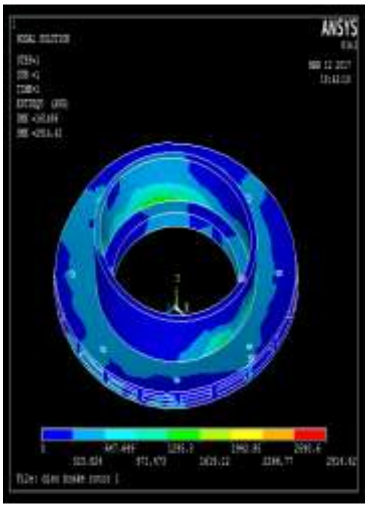

Fig 15: Vonmises stress

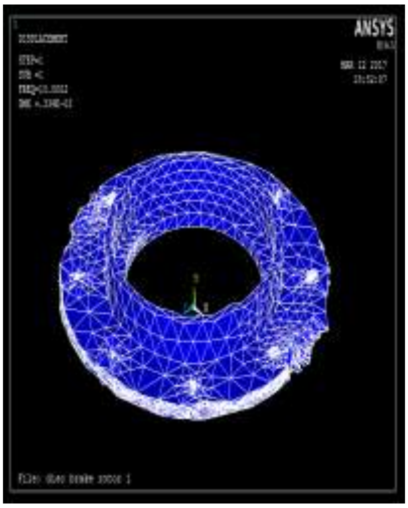

Fig 16:Modal deformation

V. CONCLUSION

There can be further study on different composites in order to reduce the weight and cost of the component. There can be design modification for the further development of the component which increases the braking efficiency of the vehicle.From the analysis these materials are the best suitable materials for a disc brake in reducing the weight and cost of the disc brake. These materials satisfy the required properties of the disc brake

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