Design and Static Structural Analysis of Disc Brake Rotor

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ABSTR ACT

The main objective of the presented work is to analysis about the mechanical behavior during braking phase when the brake is in dry contact. Static structural analysis done to determine the stress and deformation established in the disc for solid and ventilated discs. Three different materials have been taken into consideration to enhance the performance of the rotor. A comparison of structural analysis obtained from FEM for all the design. ANSYS 16.0 and SOLID WORKS 16.0 have been used for the modeling and analysis of disc brake rotor. Finally best suitable material and design suggested on the basis of obtained results.

Keywords: Disc Brake, Structural Analysis, FEM, ANSYS, SOLID WORKS.

1. INTRODUCTION

For a vehicle braking system is the important safety components which is used to retards vehicle from an initial speed to given speed. It is a friction based system and converts the kinetic energy into thermal energy when friction occurs between the brake pads and rotor faces. Due to high temperature, overheating of brake fluid, seal and other components results an increment in stopping capabilities brake. This increment depends on the heat dissipation rate due to forced convection and thermal capacity. The most common materials used to make a disc brake are cast iron or ceramic composites which include carbon or silica. Brake pads used as a friction material which is forced mechanically against both side of discs. As two surfaces come in contact with each other frictional forces developed. In a solid body disc brake the heat transfer rate is low also area of contact is more. In case of ventilated disc the area of contact remains same as that of solid body but the cooling rate is improved. For this reason ventilated discs are used widely in automobile sector.

In the current time CFD (computational fluid dynamics) gained preference as a tool in automotive industry which is used to predict the complex flow and behavior of heat transfer in different regions. Nowadays convective cooling analysis and optimizations has been carried out using CFD codes.

2. ROTOR MODELLING AND DESIGNING

2.1 Designing

Present work used a reference design of disc brake rotor of Honda City (Car) and made several changes in the design keeping the shape and geometry of the disc constant (Four different designs are used including the reference design). Also three different materials used for each design and evaluated the results of structural analysis.

Design	Rotor Thickness	Rotor Diameter (Outer)	Rotor Diameter (Inner)	Hub Bolt Diameter	Blind Vents	Hole Diameter	No. of Holes

Reference Design	25 mm	288 mm	165 mm	13.5 mm	25*10*12 mm	–	–
Design 1	25 mm	288 mm	165 mm	13.5 mm	25*10*12 mm	8 mm	100
Design 2	25 mm	288 mm	165 mm	13.5 mm	25*10*12 mm	10 mm	40
Design 3	25 mm	288 mm	165 mm	13.5 mm	25*10*12 mm	6 mm	126

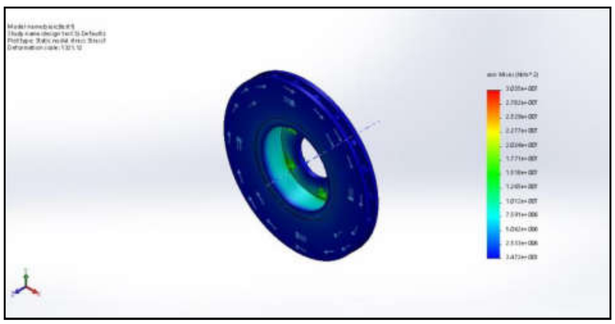
Table 2.1. Design Parameters

3. RESULT AND DISCUSSIONS

The following results are obtained using ANSYS workbench 16.0 and SOLID WORKS 16.

3.1 Static Structural Analysis for Basic (Reference) Design

3.1.1 for Grey Cast Iron



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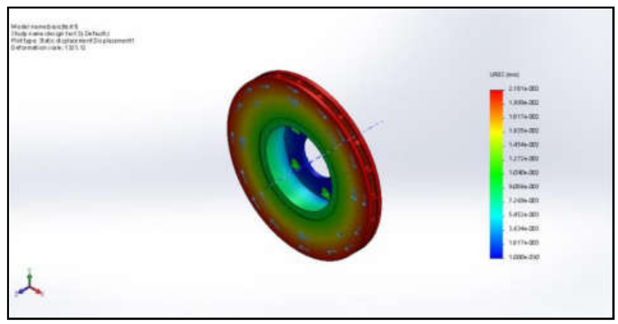

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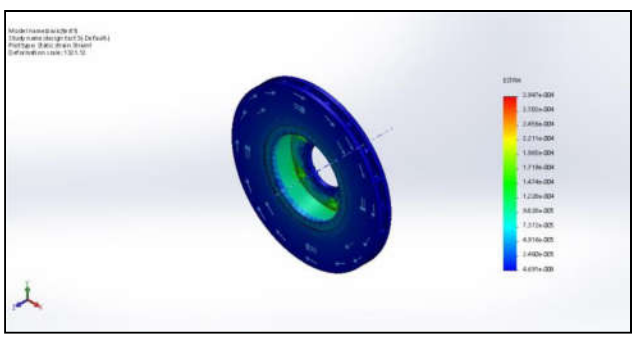

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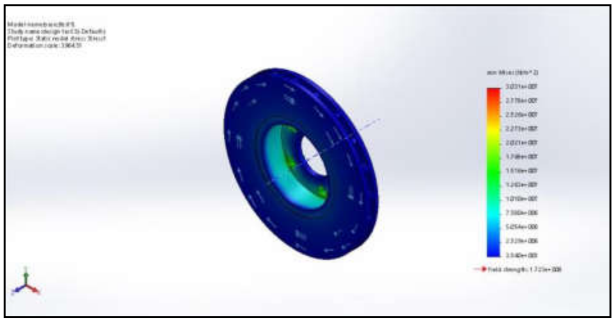
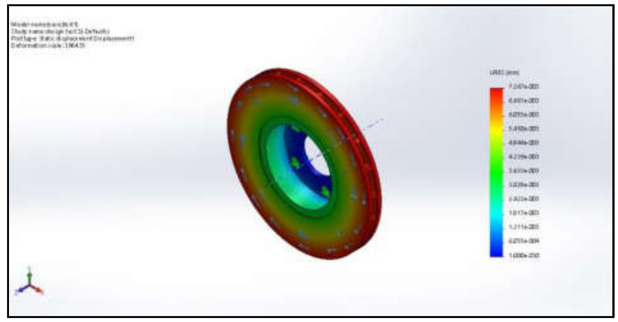
Fig 3.1.1 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

3.1.2 for Chrome Steel





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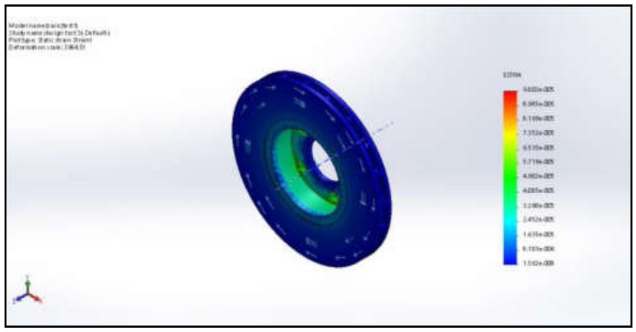

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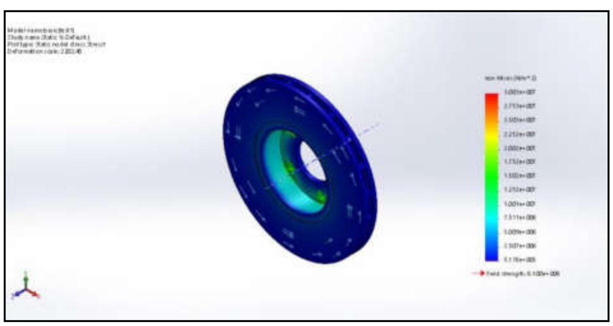
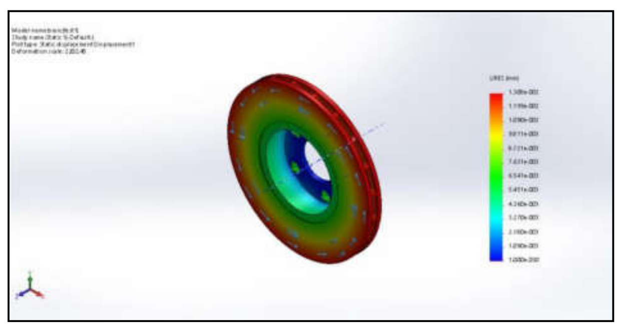
Fig 3.1.2 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

3.1.3 for Titanium Alloy





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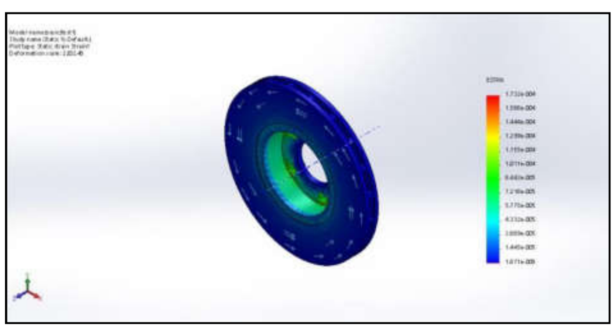


(c)

Fig 3.1.3 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

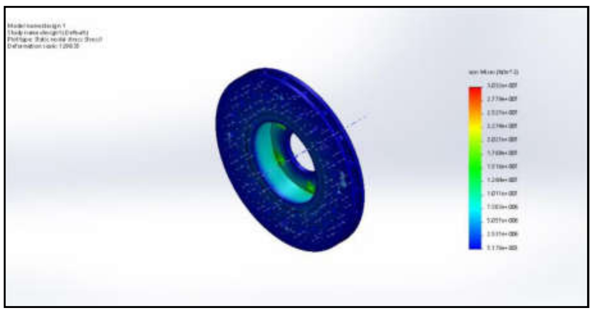
Material	Stress (in N/m^2)	Strain	Displacement (in mm)	Weight (in kg)
Grey Cast Iron	3.035×10^7	2.947×10^{-4}	0.02181	9.082
Chrome Steel	3.031×10^7	9.802×10^{-5}	0.007267	9.83
Titanium Alloy	3.003×10^7	1.72×10^{-4}	0.01308	5.966

Table 3.1.1 Comparison of Structural Analysis (Basic Design)

Based on result obtained after analysis chrome steel disc has less strain and displacement produced on it.

3.2 Static Structural Analysis for Design 1

3.2.1 for Grey Cast Iron



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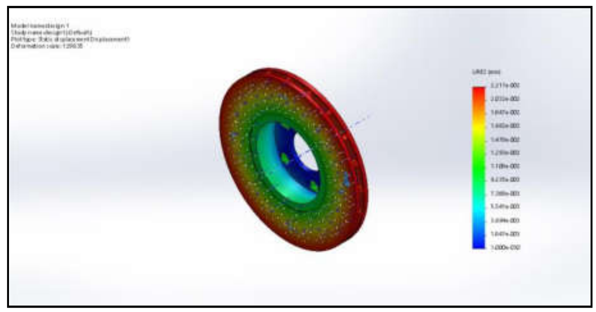

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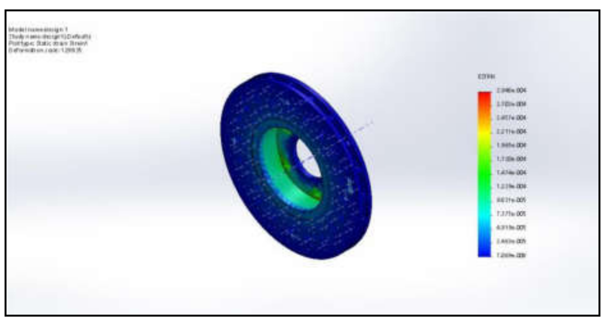

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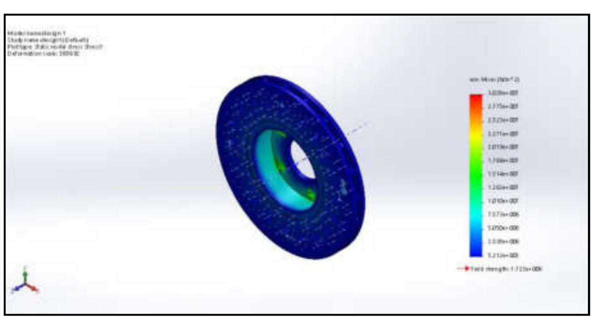
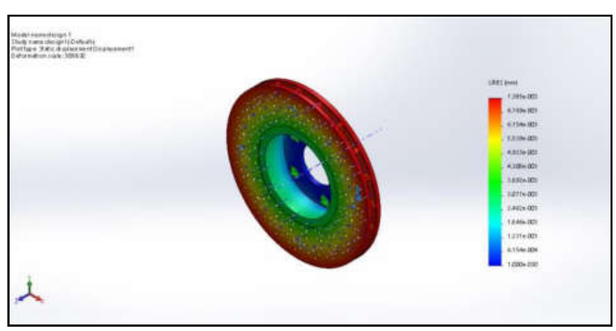
Fig 3.2.1 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

3.2.2 for Chrome Steel





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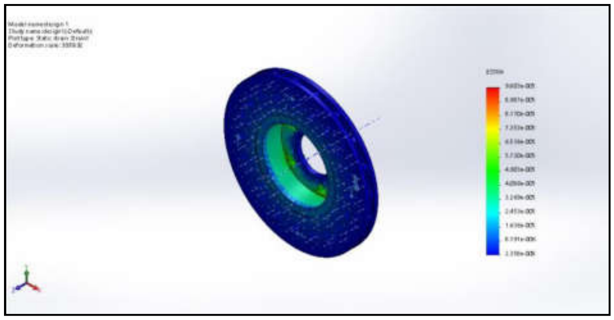

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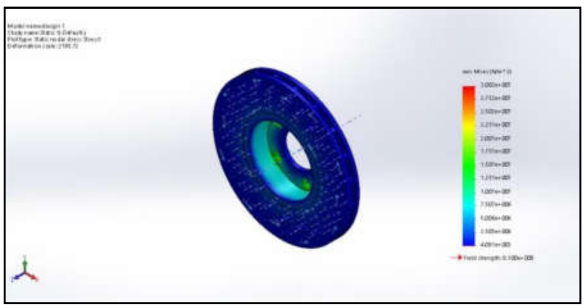
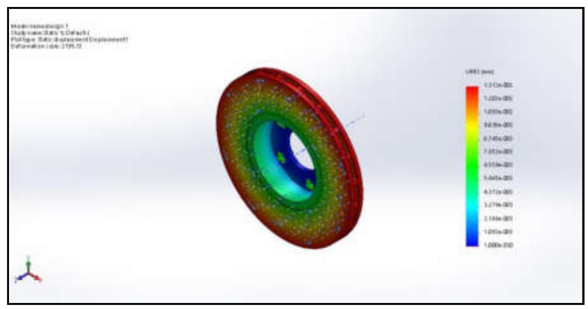
Fig 3.2.2 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

3.2.3 for Titanium Alloy





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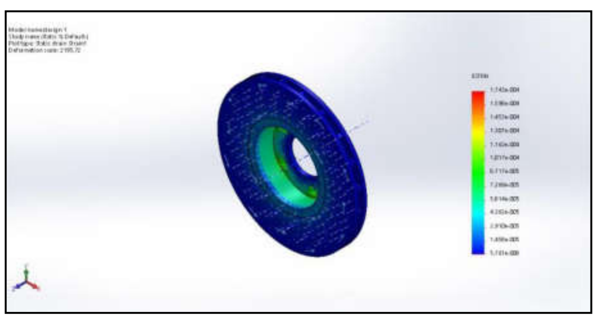


(c)

Fig 3.2.3 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

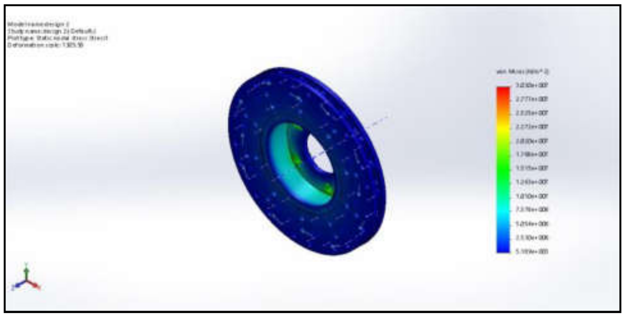
Material	Stress (in N/m^2)	Strain	Displacement (in mm)	Weight (in kg)
Grey Cast Iron	3.032×10^7	2.948×10^{-4}	0.02217	8.569
Chrome Steel	3.028×10^7	9.803×10^{-5}	0.007385	9.283
Titanium Alloy	3.002×10^7	1.713×10^{-4}	0.01312	5.63

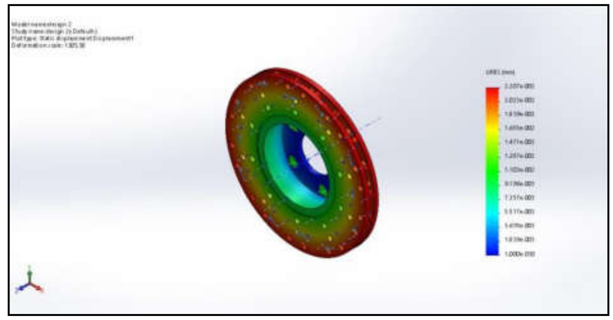
Table 3.2.1 Comparison of Structural Analysis (Design 1)

In the above table it is clear that the chrome steel has less strain and displacement.

3.3 Static Structural Analysis for Design 2

3.3.1 for Grey Cast Iron





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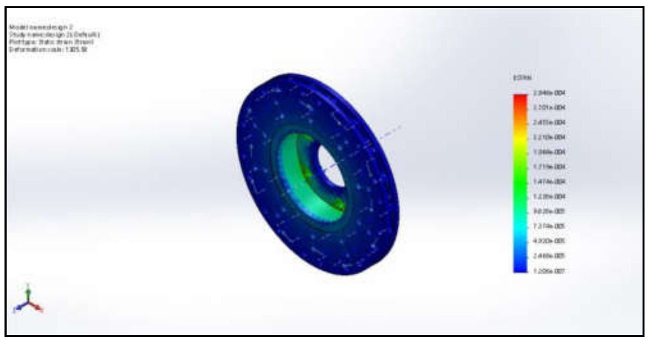

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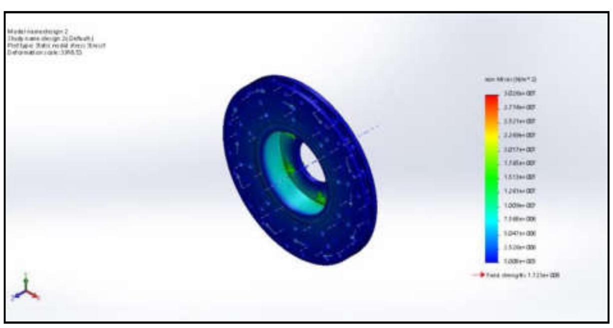
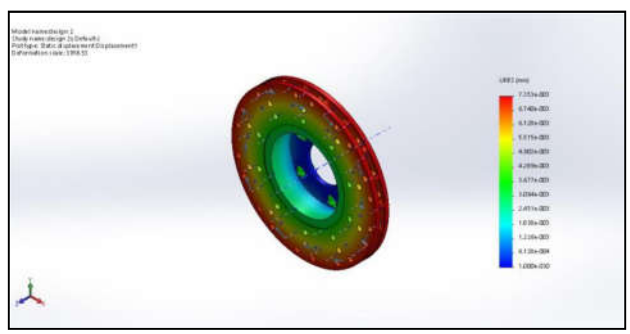
Fig 3.3.1 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

3.3.2 for Chrome Steel





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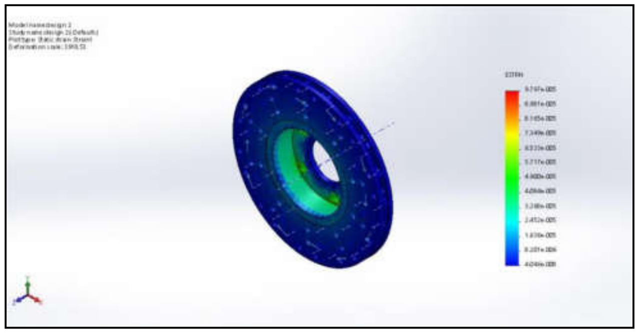

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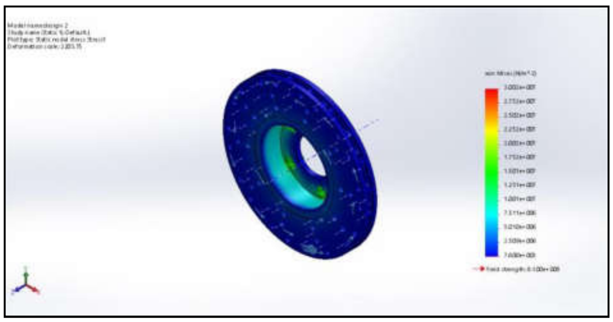
Fig 3.3.2 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

3.3.3 for Titanium Alloy



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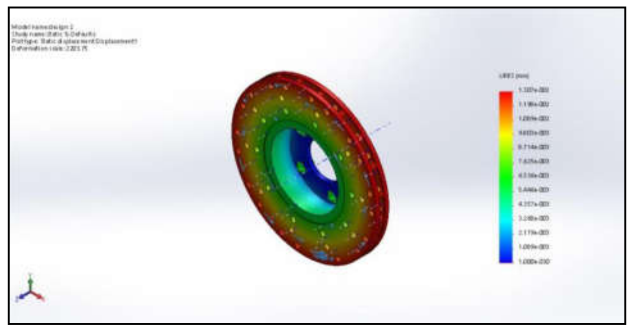

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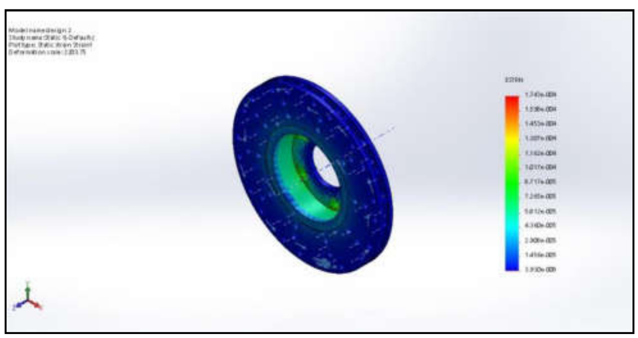


(c)

Fig 3.3.3 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

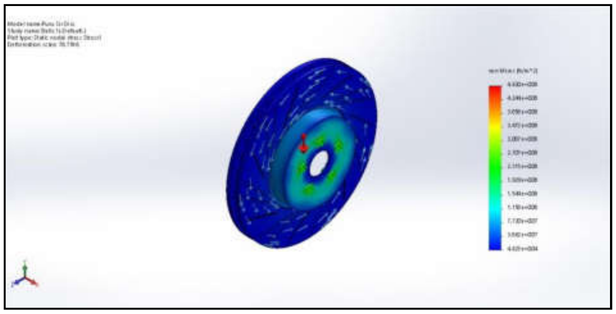
Material	Stress (in N/m^2)	Strain	Displacement (in mm)	Weight (in kg)
Grey Cast Iron	3.030 X 10^7	2.946 X 10^{-4}	0.022	8.58
Chrome Steel	3.026 X 10^7	9.797 X 10^{-5}	0.007353	9.29
Titanium Alloy	3.002 X 10^7	1.743 X 10^{-4}	0.01307	5.63

Table 3.3.1 Comparison of Structural Analysis (Design 2)

As similar to previous results chrome steel has less strain and displacement.

3.4 Static Structural Analysis for Design 3

3.4.1 for Grey Cast Iron



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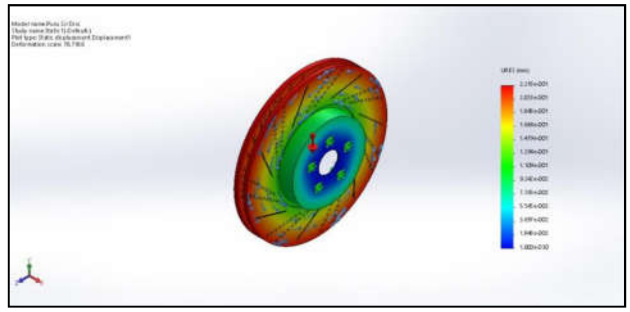

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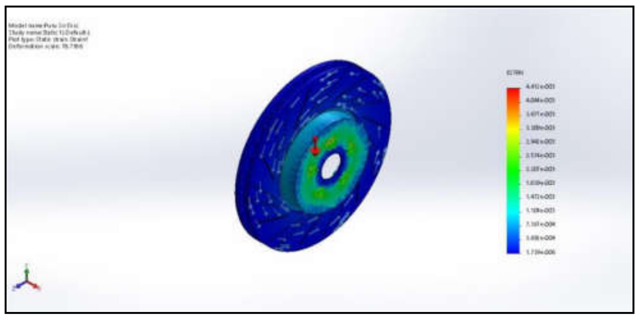
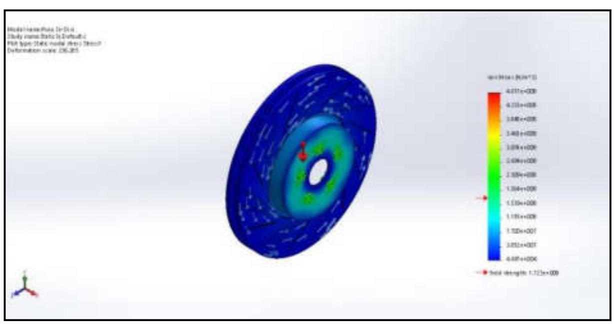


(c)

Fig 3.4.1 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

3.4.2 for Chrome Steel



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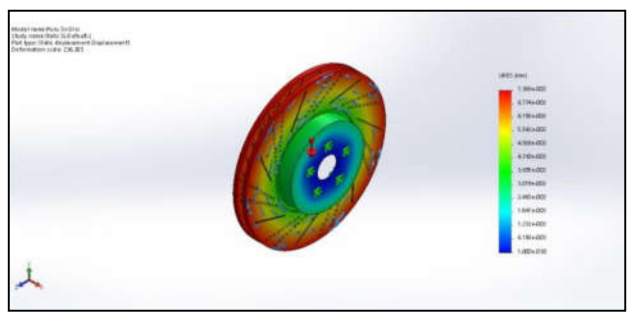

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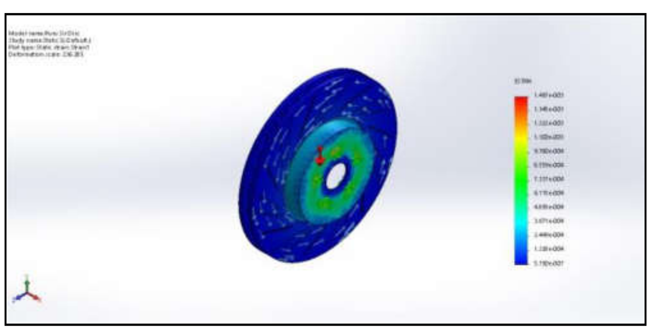
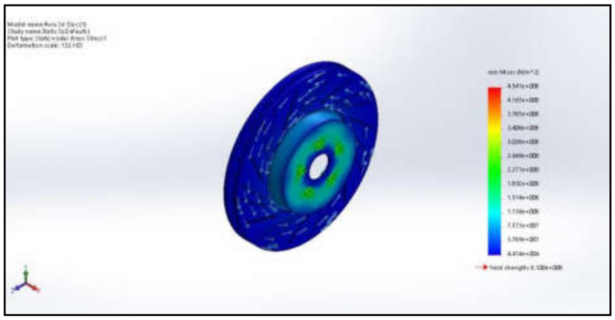


(c)

Fig 3.4.2 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

3.4.3 for Titanium Alloy



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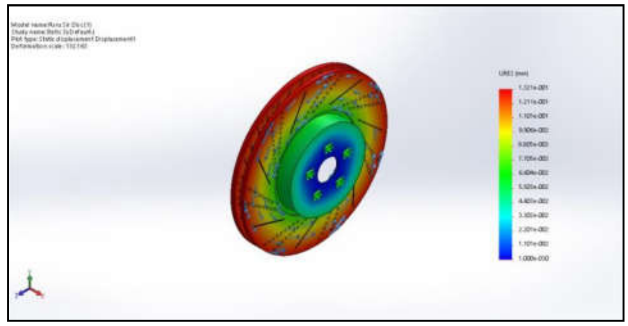

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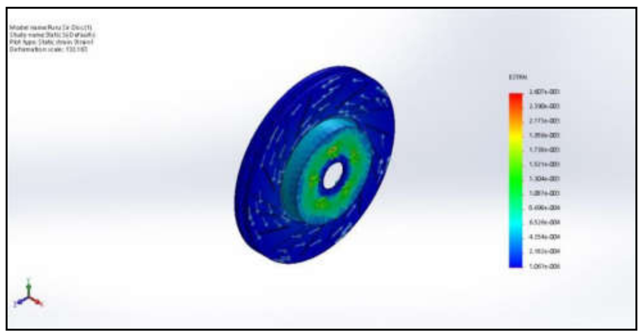

(c)

Fig 3.4.3 (a) Stress Analysis (b) Displacement Analysis and (c) Strain Analysis

Material	Stress (in N/m^2)	Strain	Displacement (in mm)	Weight (in kg)
Grey Cast Iron	4.629 X 10^8	0.0044	0.2218	2.62
Chrome Steel	4.617 X 10^8	0.001466	0.07389	2.84
Titanium Alloy	4.541 X 10^8	0.002607	0.132	1.92

Table 3.4.1 Comparison of Structural Analysis (Design 3)

Like other designs analysis, Chrome steel again shows the less displacement and strain for design 3.

4. CONCLUSIONS

Comparing the data obtained by structural analysis it is easy to decide that design 3 is the weakest when subjected to stresses. While design 1 and design 2 give approximately equal results that are better than the solid disc i.e. Basic design.

In comparison of the three materials chrome steel gives the best results when tested on stress, strain and deformation.

REFERENCES

1. Piotr GRZEŚ, "Finite Element Analysis of Disc Temperature During Braking Process", Faculty of

Mechanical Engineering, Białystok Technical University, ul. Wiejska 45 C, 15-351 Białystok.

2. Abd Rahim Abu-Bakar, Huajiang Ouyang, “Prediction of Disc Brake Contact Pressure Distributions by Finite Element Analysis”, Journal Teknologi, 43(A) Dis. **2005**: 21–36 © University Teknologi, Malaysia.

3. M. Nouby, D. Mathivanan, K. Srinivasan, “A combined approach of complex eigenvalue analysis and design of experiments (DOE) to study disc brake squeal”, International Journal of Engineering, Science and Technology Vol. 1, No. 1, **2009**, pp. 254-271.

4. P. Liu a, H. Zheng a, C. Cai a, Y.Y. Wang a, C. Lu a, K.H. Ang b, G.R. Liu, “Analysis of disc brake squeal using the complex eigenvalue method”, Science Direct, Applied Acoustics 68 (**2007**) 603– 615.

5. Rajendra Pohane, R. G. Choudhari, “Design and Finite Element Analysis of Disc Brake”, International J. of Engg. Research & Indu. Appls. (IJERIA). ISSN 0974-1518, Vol.4, No. I (February **2011**), pp 147-158.

6. H Mazidi, S.Jalalifar, J. Chakhoo, “Mathematical Model of heat conduction in a disc brake system during braking”, Asian journal of Applied Science 4(2): 119-136,2011, ISSN 1996-3343 / DOI: 10,3923/ajaps,2011,119,136.

7. V. M. M. Thilak, R. Krishnaraj, Dr. M. Sakthivel, K. Kanthavel, Deepan Marudachalam M.G, R. Palani , “Transient Thermal and Structural Analysis of the Rotor Disc of Disc Brake” , International Journal of Scientific & Engineering Research Volume 2, Issue 8, August-**2011** ISSN 2229-5518.

8. Prashant Chavan, Amol Apte, “Axis symmetric analysis of bolted disc brake assembly to evaluate thermal stresses”, TATA motors ltd. Pimpri, Pune-411018. India 91-20-5613 3159.

9. R.B. Gupta, “Brake Design Calculations”, Satya Prakashan- New Delhi, **2008**, 5th edition, Pg. No. 692.

10. Manjunath T.V, Dr Suresh P.M , “Structural and Thermal Analysis of Disc Brake Rotor of Disc Brake”, International Journal of Innovative Research in Science, Engineering and Technology, Volume 2, Issue 12, December **2013** ISSN 2319-8753.