International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Structural and Thermal Analysis of Disc Brake With Drilled Holes Of Various Materials

K. Viswanath Allamraju, Arrola Ravikumar

Abstract**:** ***The design of braking system of a vehicles is very important in order to minimize the accidents and increase the life span of vehicle, with this motto, in this paper presented the structural analysis, fatigue analysis and thermal analysis of disc brake with drilled holes(DBDH) was done by considering various materials of DBDH such as carbon alloy, steel and carbon steel. The comparison of those materials is studied in various mechanical and thermal properties such as deformation, strain, stress, factor of safety, number cycles under cyclic loading and heat flux. Simulation studies were done in Ansys 14.5 version. It is observed that the heat flow rate is high in carbon alloy and low in carbon steel material of DBDH model. Maximum stress is observed in steel in structural analysis.***

Index Terms**:** ***Cabon alloy, Carbon steel, DBDH model, Steel , Thermal analysis.***

I. INTRODUCTION

Braking system is one amongst the vital safety parts of a vehicle. It's primarily wont to decelerate vehicles from AN initial speed to a given speed. A friction based mostly braking system is a typical device to convert mechanical energy into thermal energy through a friction between the restraint and also the rotor faces. as a result of high temperatures will result in heating of the brake fluid, seals and different parts, the stopping capability of a brake will increase with the speed at that heat is dissipated because of forced convection and thermal capability of the system [6].Brake disc convective cooling has been traditionally studied by suggests that of experimental and theoretical strategies [11, 12] and also the improvement was solely boosted with the arrival of contemporary procedure resources within the late Eighties [13]. Currently, though of not easy usage and requiring previous understanding of the fundamentals of hydraulics and warmth transfer plus the information of numerical flow modeling, procedure fluid dynamics (CFD) has signifi-cantly gained preference within the automotive trade style method as a tool for the prediction of advanced flow and warmth transfer behavior in regions, wherever otherwise terribly heavy and time overwhelming experimental originated work would be required. As a result, brake disc convective cool- ing analysis and improvement is these days principally allotted victimization CFD business codes, see, e.g., [10]. Many investigations of warmth flow through aired disc brakes square measure reportable within the literature. Wallis et al. [16] distributed a numerical study exploitation the software package Fluent on disc rotor blades to look at the results of native heat and mass transfer of the axial gap distances for one co-rotating disc. The study of the one rotating disc showed that heat and mass transfer coefficients square measure increased significantly by decreasing the hub height. The friction heat generated between two slippery bodies causes thermoelastic deformation that alters the contact pressure distribution. This coupled thermo-mechanical method is referred to because the frictionally-excited thermoelastic instability [10]. Different works have studied the transient brake analysis [1-5]. Zhu et al. established the theoretical model of a three-dimensional (3D) transient temperature field to predict the modification of brake shoe's temperature field throughout hoist's emergency braking [14]. Voldˇrich postulated that the extraordinary of the essential slippery speed in brake discs causes formation of hot spots, non-uniform contact pressure distribution, vibration, and permanent harm of the disc [15]. Zagrodzki analyzed slippery systems with resistance heating, that exhibit thermoelastic instability (TEI) in friction clutches and brakes once the slippery speed exceeds a essential price [13]. Archangel and Roland mentioned the flowing patterns within the disc rotors [11]. The analytical model of TEI development was revealed by Lee and Barber [12]. In this paper presented the fatigue and thermal analysis of DBDH model with various materials such as carbon, steel and carbon steel.

II. STRUCTURAL ANALYSIS OF DBDH MODEL

Geometric properties of DBDH model are shown below.
Rotor disc dimension = 240 mm
Pad brake area = 2000 mm^2
Pad brake material = asbestos
Coefficient of friction (wet) = 0.07
Coefficient of friction (dry) = 0.3
Maximum temperature = 350 ^{0}c
Maximum pressure = 1 MPa

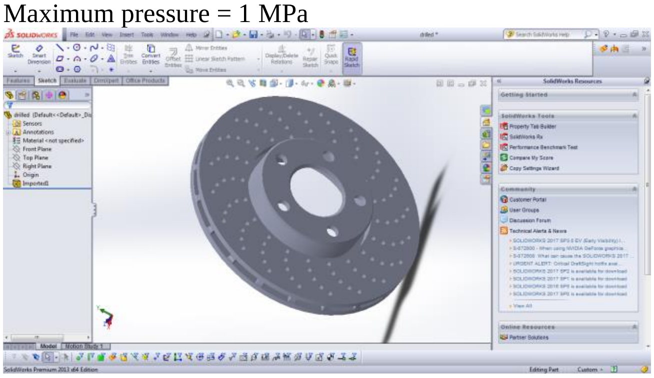

Fig.1Disc brake with drilled holes model(DBDH)

Structural analysis, fatigue and thermal analysis are done in Ansys 14.5 Simulation tool but the modeling of plane disc rotor brake was modeled in Solid Works. Fig.1 presents the 3D model of DBDH model.

Manuscript published on 30 August 2019.
*****Correspondence Author(s)
K.Viswanath Allamraju, Mechanical Engineering, Institute of Aeronautical Engineering, Hyderabad, India
Arrola Ravikumar, Mechanical Engineering, Institute of Aeronautical Engineering, Hyderabad, India.

Fig 2, 3 and 4 shows deformation, stress and strain of DBDH model made of carbon alloy. Data from structural analysis is required for doing Fatigue analysis, therefore, in this paper; structure analysis is done as a prerequisite for fatigue analysis.

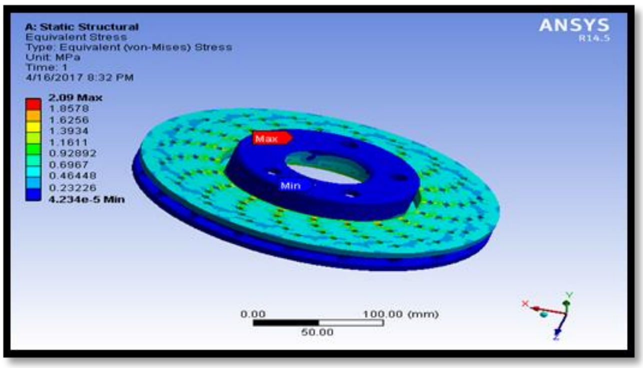

Fig.2. Stress Diagram Of DBDH Model Of Alloy

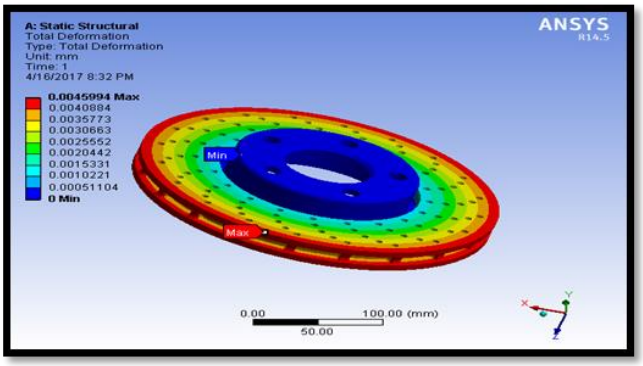

Fig.3. Deformation Of DBDH Model Of Carbon Alloy

Maximum stress was observed at inner side and minimum stress was observed at outer side of disc.

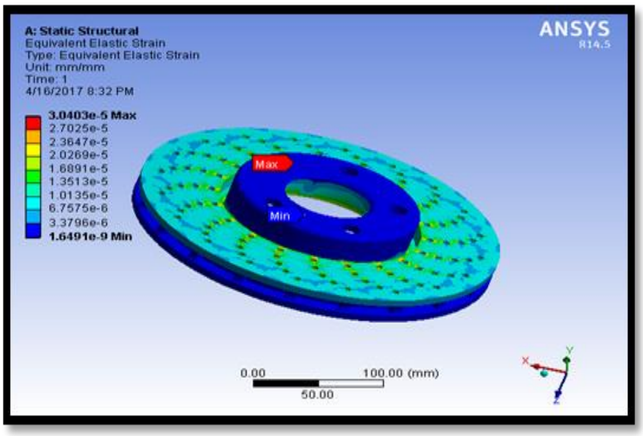

Fig.4. Strain Diagram Of DBDH Model Of Carbon Alloy Material

Fig. 5 to 7 describe the deformation, stress and strains of DBDH made of steel material. Fig. 8 to 10 describes the deformation, stress and strains of DBDH made of carbon steel material.

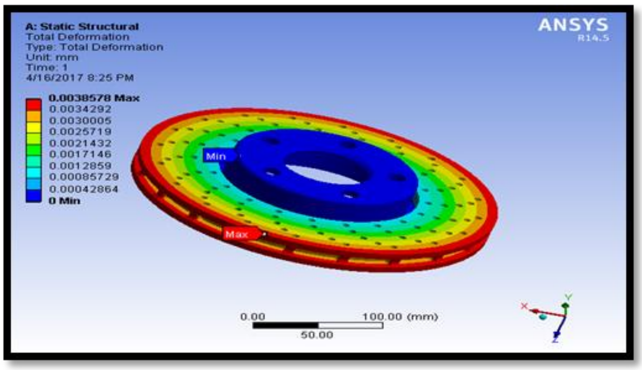

Fig.5. Deformation Diagram Of DBDH Model Of Steel Material

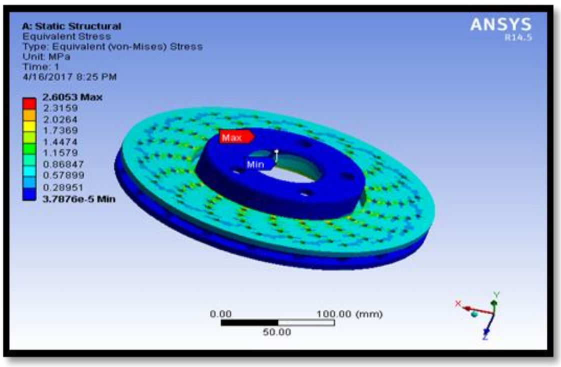

Fig.6. Stress Diagram Of DBDH Model Of Steel Material

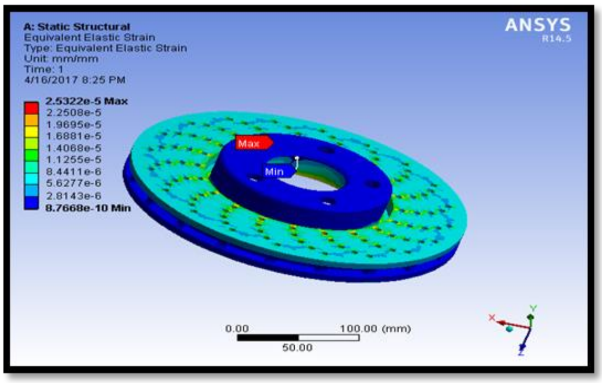

Fig.7. Strain Diagram Of DBDH Model Of Steel Material

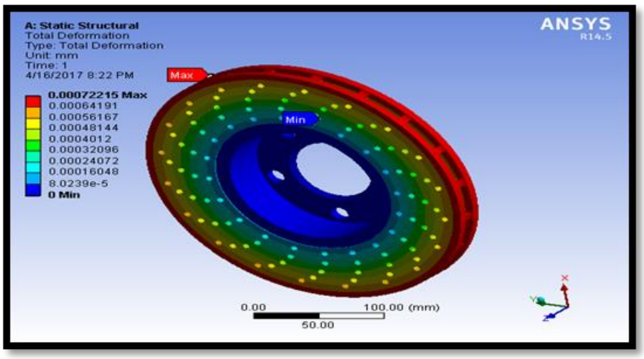

Fig.8. Deformation Diagram Of DBDH Model With Carbon Steel Material

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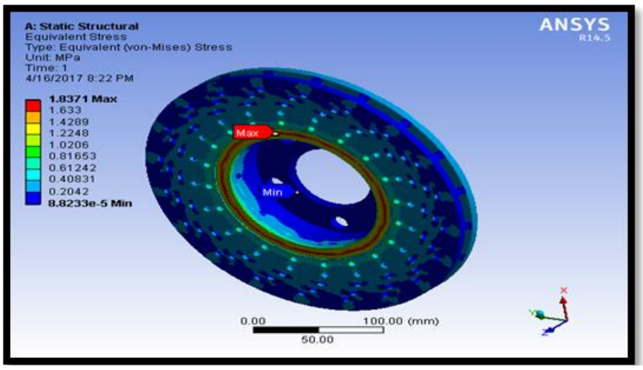

Fig.9. Stress Diagram Of DBDH Model With Carbon Steel Material

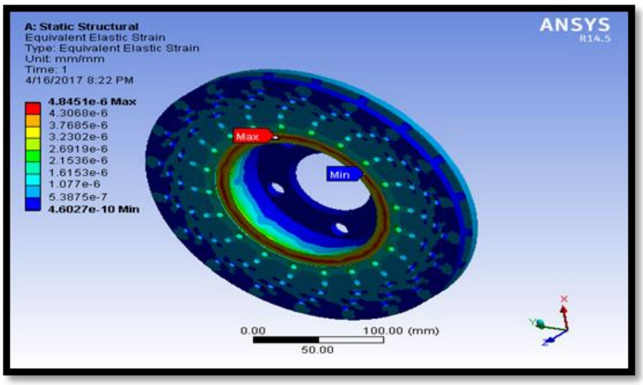

Fig.10. Strain Diagram Of DBDH Model With Carbon Steel Material

III. RESULTS AND DISCUSSION

Table 1, 2 and 3 gives the simulation values of plane disc with carbon alloy, steel and carbon steel materials during structural analysis, fatigue analysis and thermal analysis. Steel refers to the material of stainless steel. Fig.11 and 12 describes the values of deformation and maximum stress in structural analysis and its relation. It is observed that the maximum deformation in carbon alloy and minimum value in carbon steel under constant load. The maximum stress is observed in steel and minimum value in carbon steel. These values are depended on modulus of elasticity of materials. The working stress and the life of DBDH can be predicted by using fatigue analysis.

Table1. Values Of Static Analysis Of Disc Brake With Drilled Holes Model With Various Materials.

Models	Materials	Deformation(mm)	Stress (MPa)	Strain
DBDH model	Carbon alloy	0.0044994	2.07	3.03E-05
	Steel	0.0037578	2.5053	2.52E-05
	Carbon steel	0.0007022	1.7371	4.84E-06

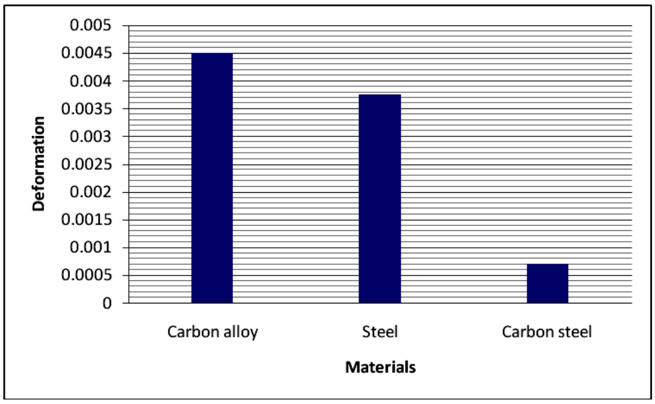

Fig.11. Deformation of CA,S and CS

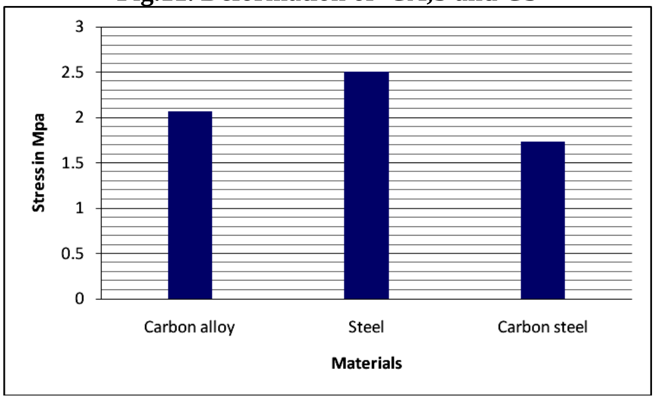

Fig.12. Stress values of DBDH model with CA, S and CS

Table 2: Values of fatigue analysis of DBDH model with various materials.

	Materials	Life in cycles		Damage	Safety factor
DBDH model		Max	Min		
	Carbon alloy	1×e6	20812	43847	0.40244
	Steel	1×e6	10174	96095	0.31086
	Carbon steel	1×e6	34019	26563	0.45922

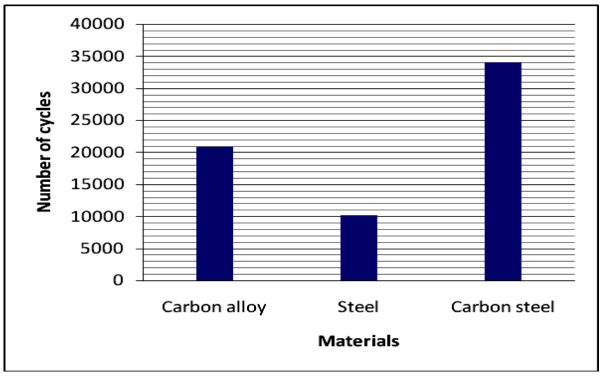

Fig.13. Number of cycles of CA, S and CS

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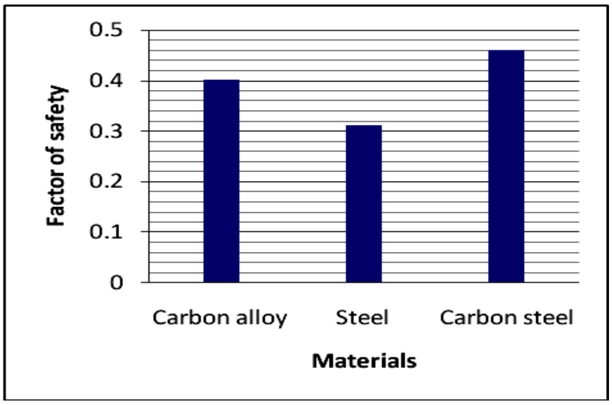

Fig.14. Factor of safety of DBDH model of CA,S and CS

Factor of safety is observed in carbon alloy, steel and carbon steel by doing fatigue analysis. The maximum values are observed in carbon steel and minimum value in steel (Fig.14). The number of cycles of operation under cyclic load, maximum for carbon steel material and minimum for steel material (Fig.13). If the factor of safety is high, the working cycles under fatigue load is in proportional.

Table 3 : Values Of Thermal Analysis Of DBDH Model With Various Materials

Models	Materials	Temperature (^{0}C)		Heat flux (w/mm^2)
		Max	Min	
DBDH model	Carbon alloy	350	228.2	1.0695
	Steel	350	115.39	0.67639
	Carbon steel	350	19.872	0.051472

Thermal analysis is done in order determine the heatflux values of DBDH made of various materials such as carbon alloy, steel and carbon steel. When the brake is applied to control the speed, the heat will be generated due to contact. Fig.15 describes the heat flux values of carbon alloy, steel and carbon steel. The maximum heat flux values is observed for carbon alloy and minimum for carbon steel material of DBDH.

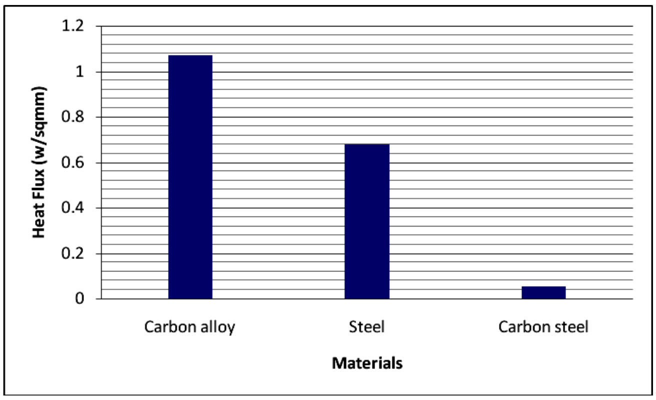

Fig.15. Heat flux of CA,S and CS

IV. CONCLUSION

Structural analysis, fatigue analysis and thermal analysis of DBDH model, which was made of carbon alloy, steel and carbon steel is done in order to design the robust disc brake for minimizing the cost and damage. And also fatigue analysis predicts the life of brake under cyclic loads. Carbon steel material could withstand more cycles in comparison to other materials such as carbon alloy and steel under constant load. Heat flow rate is high in carbon alloy material in comparison to steel and carbon steel materials, which was observed from thermal analysis. The conclusion is that simulation of DBDH with carbon alloy, steel and carbon steel helps to get optimized design under both cyclical and normal loads.

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International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

AUTHOR PROFILE

K Viswanath Allamraju, completed his M-Tech from **MANIT Bhopal** and PhD from **NIT Warangal**. His research areas are finite element method, neural networks, material characterization of metals and composite materials, vibration analysis and machine design. He has published more than 50 articles in various International journals (Scopus indexed). He had participated 60 International conferences at various IITs and IISC.

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