*International Journal of Engineering & Technology*, 3 (2) (2014) 201-207
©Science Publishing Corporation
www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v3i2.1822
Research Paper

# Weight reduction of a standard brake drum: A design approach

**D. Rambabu [1]*, R. Gopinath [2], U. Senthil rajan[1], G.B. Bhaskar[1]**

[1] Department of Mechanical Engineering, Tagore Engineering College, Chennai – 127
[2] Department of Mechanical Engineering, Bharath University, Chennai – 73
*Corresponding author E-mail: rambabu.deva@gmail.com



**Abstract**

A Brake drum is specialized brake that uses the concept of friction to decelerate the vehicle speed. The deceleration is achieved by the assistance of the friction generated by a set of brake shoes or pad, when operator presses against a rotating brake drum. The material generally preferred for making the brake drum is grey cast iron or vermicular cast iron. The drum brake is highly efficient for hand brake and service brake applications. During the operation of drum brake excessive heating of brake drum may occur. This excessive heating occurs due to repeated or frequent contact of the brake shoes against the drum. This causes the drum to crack, oversize, extreme wear, out of round drums and also leads to vibration which while braking will leads to reduced brake drum life and braking efficiency. The Un-laden weight of the vehicle will result in increased fuel consumption, reduced payload and ride handling characteristics. The objective of the paper is to improve the thermal characteristics by incorporating fins in the brake drum and to reduce the un-laden weight of the vehicle by changing the rib thickness, wall thickness and base flange thickness. The design is done by using 3D CAD Modelling software and Hexahedral finite element model prepared by using CAE pre-processing software and Stiffness analysis. Design iterations are carried out by using Linear/Non-linear Finite Element Solvers, Stress Displacement and Temperature is post-processed for design validation. Optimized design solution obtained based on the comparison study between the iteration with rib thickness 75 mm, star shaped removal and wall thickness 17 mm has been chosen. 1.8Kg of weight is being reduced from the brake drum including fins.

***Keywords***: *Drum Brake, 3D CAD Modelling, Para Metric Matrix, Structural Analysis, Fins.*

## 1. Introduction

Drum brakes, like most other brakes, convert kinetic energy into heat by the frictional contact between parts. When the brake is applied, the lining pushes against the inner surface of the drum, generating friction heat that can surrounding air, but can just as easily transfer to other braking system components. Reach as high as 500 °C. This heat should dissipate into the Brake drums must be large enough to cope with the massive forces exerting by adjacent components, and must be able to absorb and dissipate a lot of heat. However, excessive heating can occur due to heavy or repeated braking, which can cause the drum to distort, leading to vibration under braking. The other consequence of overheating is brake fade this is due to one of several processes or more usually an accumulation of all of them. When the drums are heated by hard braking, the diameter of the drum increases slightly due to thermal expansion, so the brake shoes must move farther and the driver must press the brake pedal farther. The properties of the friction material can change if heated, resulting in less friction. The loss of friction is usually only temporary and the material regains its efficiency when cooled, but if the surface overheats to the point where it becomes glazed the reduction in braking efficiency is more permanent. We are planned to reduce the un-laden weight of the brake drum which will leads to increased torque and reduced over heating by parameter matrix analysis, in addition to that we add the fins over the outer side of the brake drum which will leads to increased thermal efficiency and brake drum weight. The parameter matrix is formed by varying base flange thickness, wall thickness and rib thickness by nine iteration will be formed for each iteration analysis is done among which the best iteration is selected in-terms of stress, displacement and weight.

## 1.1. Brake drum –geomentry

1) Major dimensions of the brake drum are shown in Figure1 & Figure2.
2) Brake Surface Diameter (ø D)
3) Width of Braking Surface (L1)
4) Overall Depth of the drum (L2)
5) Pilot Diameter (ØD1)

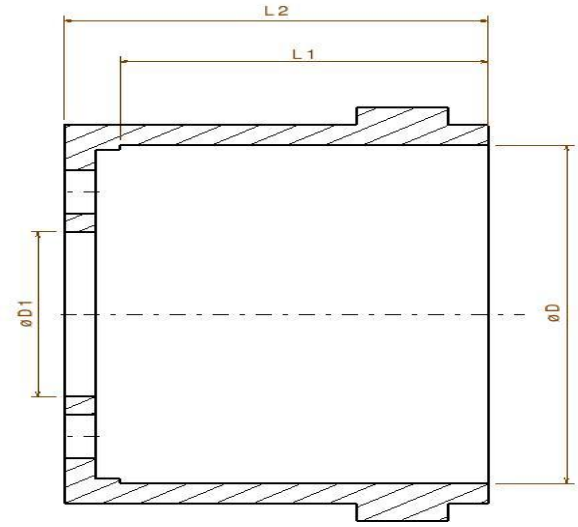



**Fig. 1:** Brake Drum

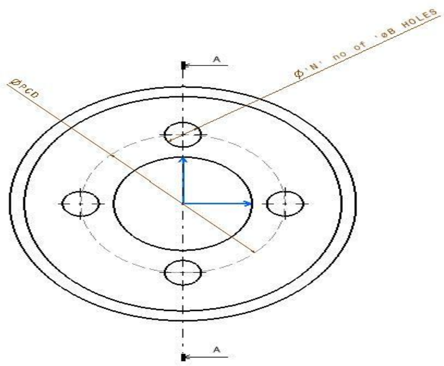



**Fig. 2:** Brake Drum Dimensions

Drum nomenclature will be given as D x L1. In our project scope, we are taking ø15.5” (ø393.7) x 8” (202.4) Brake drum is considered for weight optimization.
The material considered for the brake drum made of Grey Cast iron with tensile strength of 250N/mm2.

**Table 1:** Thermal Conductivity of Cast Iron Brake Drum [8]

| Temperature(°K) | Thermal Conductivity (W/mm/K) |
|---|---|
| 373 | 0.048 |
| 473 | 0.047 |
| 573 | 0.046 |
| 673 | 0.045 |
| 773 | 0.044 |

**Table 2:** Thermal Properties of FG260 Cast Iron Brake Drum [2]

| Thermal Properties | Values |
|---|---|
| Specific Heat | 515 J / Kg K |
| Thermal Expansion | 12.5E-06 /K |
| Ambient Temperature | 313 K |
| Convection Coefficient | 5 W/mm$^2$ K |

**Table 3:** Mechanical Properties of Cast Iron Brake Drum [7]

| Component | Material Name | Young's Modulus (G Pa) | Poisson's Ratio | Density (Kg/mm$^3$) | 0.1% Proof Stress (M Pa) |
|---|---|---|---|---|---|
| Drum | Cast iron | 145 | 0.26 | 7.20E-06 | 169 |

# 2. Boundary conditions

To do the structural analysis of the brake drum, Load condition is Variable pressure loading for five zones of leading and trailing shoe. Constraints on mounting holes will be arrested in all directions
Vehicle weight = 16200 Kg, Declaration = 0.6g,
Braking Ratio = 0.5, SLR: 0.508m,
Tire Drag = VW * Deceleration* BR: 4860kgs Brake Torque (T) = Tire drag * SRR/2:1235Kg-m [5]
With this brake torque and brake geometry variables, Variable Pressure is derived from Cosine theory for leading and trailing side.

# 3. Parameter matrix

To optimize the weight of the brake drum, three major contributors for weight of the brake drum have been identified for parameterization. Those variables are rib width, flange thickness, wall thickness [3]. By varying those three parameters by a predefined range a parameter matrix has been arrived as shown in Figure.3 and Table.4.
A-Rib width, B-Base flange thickness,
C-Wall thickness

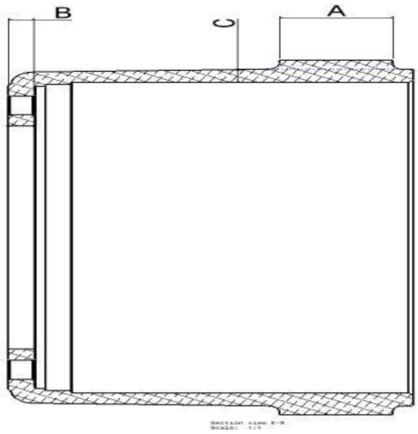



**Fig. 3:** Basic Parameters

## 3.1. Parameter matrix work method

Totally 9 Iterations are conducted for structural analysis. Based on the comparison between first stress and displacement results with acceptable limit, final option should be chosen for further optimization.

**Table 4:** Parameters for Iterations

| Iterations | A | B | C |
|---|---|---|---|
| Iteration-1 | | 17 | |
| Iteration-2 | 85 | 16 | 17 |
| Iteration-3 | | 15 | |
| Iteration-4 | | 17 | |
| Iteration-5 | 70 | 16 | 17 |
| Iteration-6 | | 15 | |
| Iteration-7 | | 17 | |
| Iteration-8 | 55 | 16 | 17 |
| Iteration-9 | | 15 | |

A is varied between 50-85mm and B is varied between 15-17mm, C- is kept as constant with17mm [6].

## 3.2. Star- shaped material removal in the flange

Once the Final choice has been made among the above 9 iteration, instead of varying the complete flange thickness (B), star shaped material removal (Figure 4& 5) has been proposed in the final iteration which will have a impact on weight reduction as well as it will facilitate the temperature reduction.

# 4. Cad model

The cad model is drawn through 3D design software is shown in Fig 4 & Fig 5. [Brake drum 3-D model is performed in pro-e wild fire 4.0].

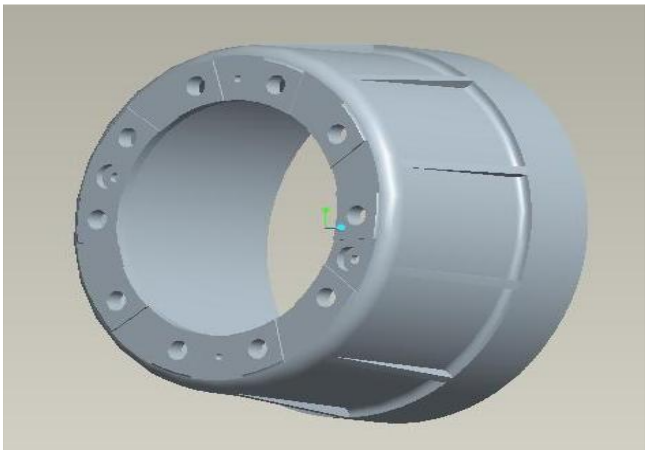


**Fig. 4:** 3-D Model

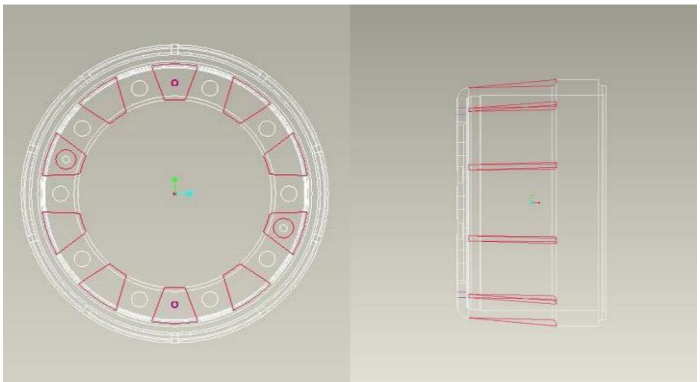


**Fig. 5:** Wire frame model

## 4.1. Meshing

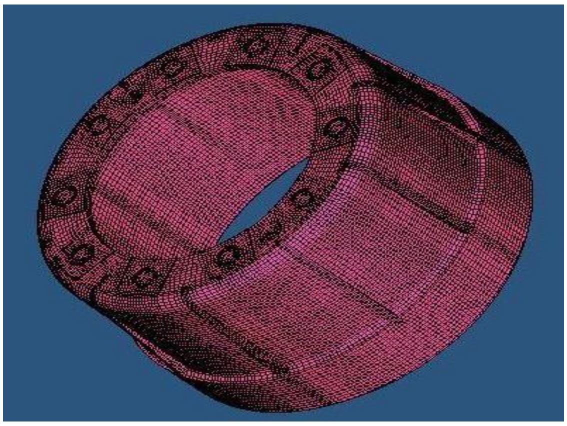


**Fig. 6:** Mesh Diagram

Finite Element Model prepared using Pre-processing tool Hyper- mesh is shown in Fig 6A. Hexahedral meshing technique is used to mesh 3-D mode

# 5. Analysis

Principal stress, Displacement and Thermal Properties are analyzed using Ansys is shown in Fig 7 & Fig 8 and Thermal analysis in Fig 9. The various load conditions are applied for respective analysis with required boundary condition

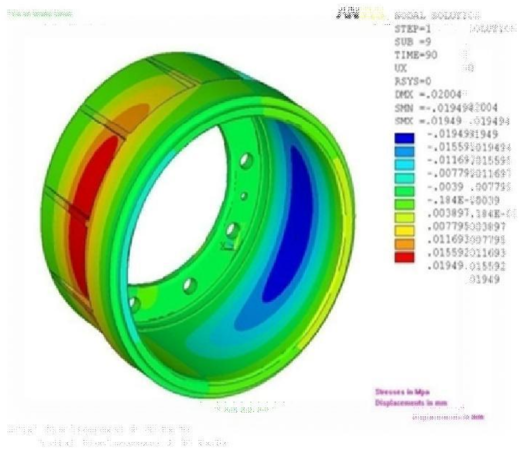


**Fig. 7:** Displacement Analysis

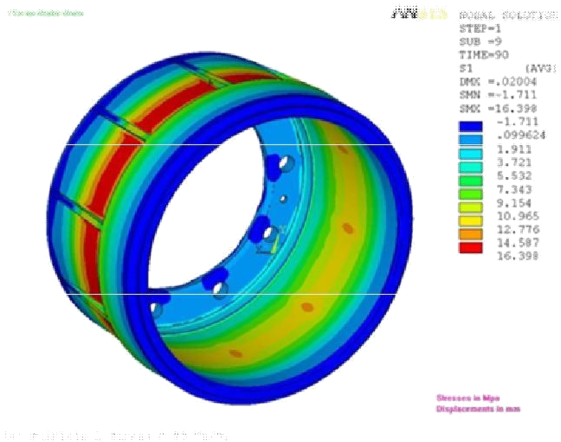


**Fig. 8:** Stress Analysis

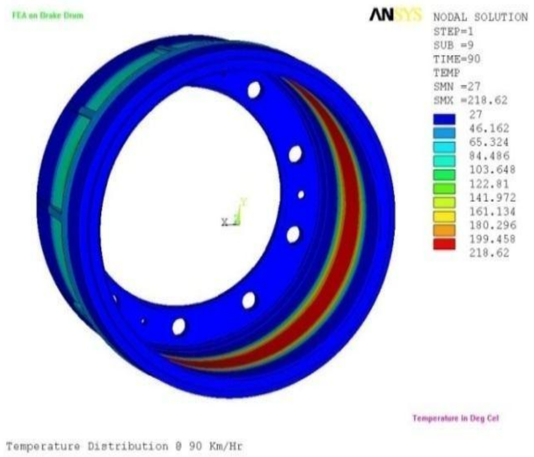
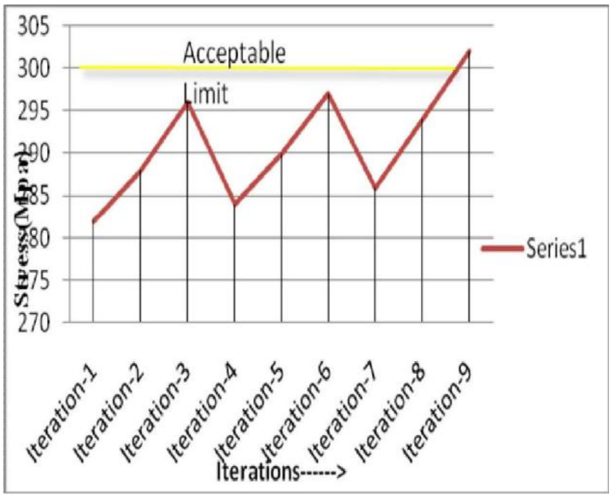


**Fig. 9:** Thermal Analysis

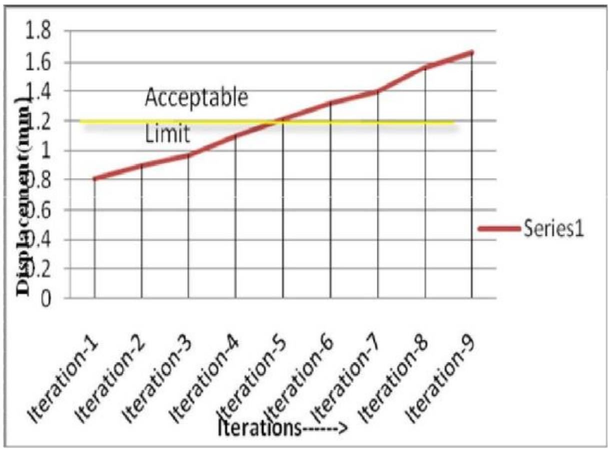
# 6. Parmeter matrix –results overview

As per the parameter matrix, 9 CAD models had been made and those models were meshed with Hexahedron elements. All mounting holes were clamped in all directions. Friction materials contact area has been divided in to five zones in both leading and trailing shoe. Variable pressure boundary condition has been applied in those zones. First stress and displacement has been obtained for all iterations and checked for braking condition

Inference of the above plot by keeping the variable A and C as constant and if we vary the parameter B, increasing trend will be there in first principal stress. Based on the past field results, acceptable limit for first principal stress for brake drum will be 300Mpa [4].Inference of the above plot by keeping the variable A and C as constant and if we vary the parameter B, increasing trend will be there in displacement. Based on the past field results, acceptable limit for displacement for brake drum will be 1.1mm [4]. Based on the acceptable limit of stress and displacement, Iteration.No-6 has been chosen for further optimization. In the Iteration-6 displacement is very high than the acceptable limit to reduce the displacement, Parameter "A" had been modified to 75mm instead of 70mm. Instead of varying the parameter B, star shaped removal has been proposed to reduce the weight further and improves the thermal behavior. After modifying the above things, final results obtained. The displacement and stress variation for each iteration is obtained and the result's has been plot in Graph.1 & Graph.2. The final iteration-10 has shown in Table.




**Graph. 1:** Strees vs. iterations




**Graph. 2:** Displacement vs. Iterations

# 7. Conclusion

Based on the various design iterations, 10th iteration has been chosen best in terms of optimized weight, stress and displacement results, the weight has been reduced 2.4kg with acceptable stress of 303 Mega Pascal and displacement of 1.136mm. Finite Element model of Brake drum has been developed to evaluate the drum behavior with respect to temperature, pressure and displacement parameters. Analysis is carried out with different proposals in brake drum construction. Fins are placed to reduce over-heating and improves brake drum life Based on the proposals carried out for brake drum, iteration-10 is yielding optimized results for the required displacement and stress values. I.e., the iteration with rib thickness 75 mm, star shaped removal and wall thickness 17 mm. 1.8Kg of weight is being reduced from the brake drum including fins. This is leads fuel efficiency and longer life. Further study can be done for fatigue and fracture toughness study with different materials like aluminum, steel alloys, etc., without compensating the base performance

# References

[1] Dr.Ramesha , " Temperature distribution analysis of Aluminum composite and cast iron brake drum using ANSYS" International Journal of Emerging trends in Engineering and Development ISSN 2249-6149 , Issue 2,Vol.3, 2012

[2] Zhen-caizhu, "Three dimensional transient temperature field of brake shoe during hoist emergency braking", Applied thermal engineering, Vol-29, Pageno-932, 2009.

[3] Jinchun Huang, Charles M. Krousgrill, Anil K. Baja, January, "Modelling of Automotive Drum brakes for Squeal and parameter sensitive analysis" Journal of Sound and Vibration Pages 245–263, 2006.

[4] Amorim, G, "Thermal fatigue life analysis of Brake drums made with Gray cast iron and Vermicular Cast iron Via FEM Simulation," SAE Technical Paper, 2005.
[5] Morshed. MM, "Physical & chemical characteristics of commercially available brake shoe lining materials a comparative study", Material processing technology, Vol-155, Page-1422, 2004.
[6] S.S.Rao, "Optimum Design of Mechanical System Involving Interval Parameters", 2002.
[7] Cuvea.G, "Wear resistance of cast iron used in brake disc rotors", Wear Vol-255, Page no-515, 2003.
[8] John. P, "The Transient Temperature Distribution in a Heavy Duty Brake System during Fatigue crack Testing". SAE – Paper No: 2000-529534, 2000.