

Development and Analysis of Finned Brake Drum Model Using Solidworks Simulation

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ABSTRACT: A brake is a friction device for converting the power of momentum or kinetic energy of a moving vehicle into heat energy by means of friction, thereby decelerating the motion of the vehicle. The heat energy is to be dissipated rapidly in order to control brake fade and brake failure. This can be subdued on brake drums, by providing cooling fins (extended surface) on the outer surface of the brake drums. This paper presents the development and analysis of a modified brake drum model having extended surface (fins) along its circumference. The fins or extended surface are designed to improve the heat dissipation rate from the surface of the brake drums which are convectively cooled by the streams of air flowing on its outer surface. One-fourth of the overall height thickness of the original brake drum model was converted into fins. The simulation carried out on the original and the modified models, shows that the modified brake drum model has a higher circumferential strength and better heat dissipation than the original brake drum model.

KEYWORDS: Brake Drum Development and Analysis.

I. INTRODUCTION

The brakes are energy conversion system which converts the kinetic energy of a moving vehicle into thermal energy. The systems are designed to decelerate the vehicle wheels movement through friction, thereby absorbing the kinetic energy at the wheels. The drum brakes are mainly used at the rear wheels of the passengers' cars and truck while the disc brakes are extremely used for the front brakes because of their greater directional stability. In brake drum, friction is caused by a set of shoes that presses against the inner surface of a rotating brake drum. Within the drum are shoes lined with friction material. The brake shoes move against the inner surface of the brake drum by the action of the piston inside the wheel cylinder. The hydraulic fluid under pressure in the wheel cylinder moves the pistons which forces the brake shoes against the brake drum. The wheel cylinder and the shoes are mounted on the back plate. The brake drum is the large critical part of the braking system that rotates round the brake shoes. When the drum is heated by hard braking, the diameter of the drum increases and the brake pedal must be further depressed to obtain an effective braking action. This is known as brake fade and it has led to drivers panic and brake failure in extreme circumstance. This paper also aimed at tackling this problem. Fins are widely used to enhance the heat transfer from a surface. The use of the fins (extended surfaces) is a thermal management technique used to augment heat transfer by increasing the available surface area and the total heat dissipation. Fins can be found in most electronics, engines, industrial equipment, and a variety of other mechanical devices. The ability of an object to reject excess heat is a required task to ensure operability, and if not accomplished sufficiently, can result in device malfunction or even failure (Dannelley 2013). Therefore, the convective removal of heat from the surface of the brake drum can substantially be improved by introducing extension (fins) on its surface. This is done in this paper, by maintaining the same weight of the two models and converting one-fourth (1/4) of the overall height thickness of the original model into extended surface (fins) on the modified and stimulating the two models to investigate the impact of forces and temperature on them.

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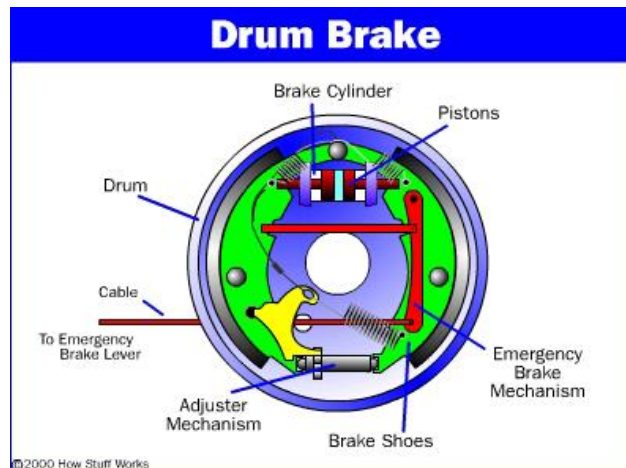


Fig 1. Drum Brake Assembly (Karim 2015)

II. MATERIALS AND METHODS

The materials used in this analysis include; solidworks (2913) package, an original and a modified brake drum model developed with the help of Kicreyco brake drum catalogue. The properties of the brake drum material (gray cast iron) are shown in table 2 below. In the analysis, solidworks modelling and simulation methodology has been employed to develop and study the impact of forces and thermal stress acting on the original and modified brake drum model.

A. Properties of the Brake Drum

1. Must have a hard wear-resistant rubbing surface and surface finish must not damage the lining.
2. Must be strong enough to withstand the hardest braking while at high temperature.
3. Must be stiff and resistant to distortion and warping
4. Must dissipate heat rapidly and withstand excessive temperature.

B. Brake Drum Nomenclature

1. A-Overall Diameter
2. B-Dust Shield Recess Diameter/ Outer Diameter
3. C-Brake Face Diameter/ Inside Diameter
4. D-Brake Face Width
5. E-Overall Height
6. F-Squealer Band Thickness
7. G-Depth of Dust Shield Recess
8. H-Hub Pilot
9. I-Bolt Hole Diameter/Number
10. J-Bolt Circle Diameter.

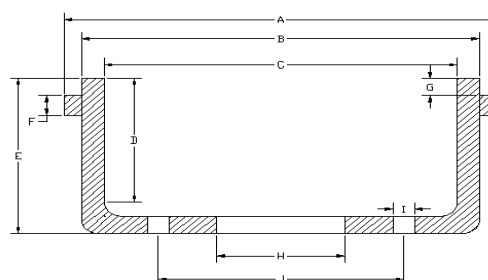


Fig 2. Brake Drum Nomenclature

III. BRAKE DRUM DEVELOPMENT

In this paper, one-fourth of the overall height thickness of an original brake drum model was converted into extended surface. The modified brake drum model was developed in such a way to maintain the same mass as the original model, but to exhibit better brake drum properties than the original model.

A. To Calculate the Fins Spacing s ,

For the purpose of this paper, the distance between the fins s , is considered to be twice the thickness (t) of the fins,

$$\text{Thus } s = 2t \quad (1)$$

The brake drum is design to have the fin thickness (t) of 10mm.

$$t = 10\text{mm}$$

$$s = 2 \times 10 = 20\text{mm}$$

Therefore the fins are 20mm apart,

B. To Calculate the Number of Fins N , on the Modified Brake Drum Model

The number of fins (N) round the circumference of the brake drum is given by;

$$N = \frac{W}{t + s} \quad (2)$$

Where W = fins Width.

For the purpose of this design the fin width is considered as the width of the brake shoe acting on the surface of the brake drum.

$$W = 180\text{mm}$$

$$N = \frac{180}{10 + 20} = \frac{180}{30}$$

$$N = 6$$

Therefore 6 fins are to be developed on the outer surface of the modified brake drum model.

C. To Calculate the Outer Radius of the Modified Brake Drum r_2

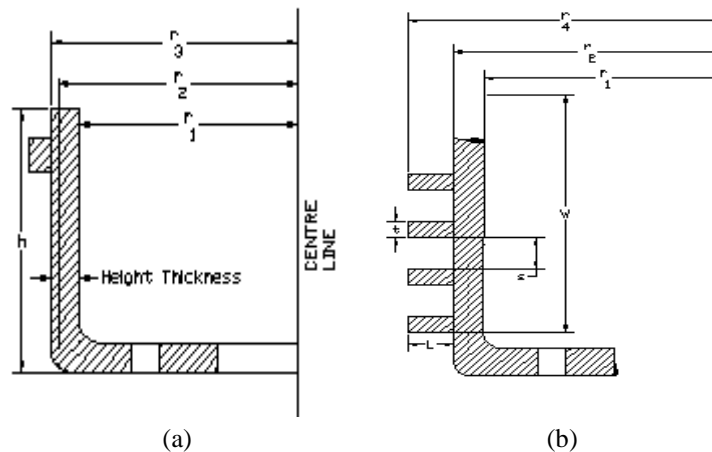


Fig 3. (a). A Section of the Original Model, (b). A Section of the Modified Model

Since the overall height thickness of the original brake drum is reduce by one-fourth (1/4) of its original size. Therefore the new outer radius r_2 is given by;

$$r_2 = r_3 - \left(\frac{r_3 - r_1}{4}\right)$$

$$r_2 = \frac{3r_3 + r_1}{4} \quad (3)$$

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Where, r_1 = Brake face diameter = 230mm
 r_3 = Dust shield recess diameter/ outer diameter = 240mm

$$r_2 = \frac{3 \times 240 + 230}{4} = 238mm$$

$$r_2 = 238mm$$

Therefore the outer radius of the proposed brake drum is 238mm

D. To Calculate the Radius of the Fins r_4

To determine the value of r_4 , we find the volume V_1 , of the brake drum that is deducted from the original model. The volume V_1 is given by;

$$V_1 = \pi(r_3^2 - r_2^2)h \quad (4)$$

Where, h = Overall Brake drum height = 210mm.

The volume of one circular fin V_f is given by;

$$V_f = \pi(r_4^2 - r_2^2)t$$

Where t = Fin thickness.

The total volume of the 6 fins V_{6f} is given by;

$$V_{6f} = 6\pi(r_4^2 - r_2^2)t \quad (5)$$

Since this design involves converting the volume V_1 into extended surface (fins) of equal volume V_{6f} . Therefore the volume V_1 deducted from the original model is equal to total volume of the fins V_{6f} . Thus,

$$\pi(r_3^2 - r_2^2)h = 6\pi(r_4^2 - r_2^2)t$$

$$r_4^2 - r_2^2 = \frac{\pi(r_3^2 - r_2^2)h}{6\pi t}$$

$$r_4 = \sqrt{\frac{(r_3^2 - r_2^2)h}{6t} + r_2^2} \quad (6)$$

$$r_4 = \sqrt{\frac{(240^2 - 238^2)210}{6 \times 10} + 238^2}$$

$$r_4 = 245mm$$

Therefore the fins have the outer radius of 245mm from the centre of the brake drum.

E. To Calculate the Length of the Fins L

The length of the fins L , is given by;

$$L = r_4 - r_2 \quad (7)$$

$$L = 245 - 238 = 7mm$$

The length of the fin is 7mm from the dust shield recess radius/ outer radius

F. To Calculate the Total Surface Area of the Fins A_{fin}

$$A_{fin} = 2\pi(r_4^2 - r_2^2) + 2\pi r_4 t \quad (8)$$

$$A_{fin} = 2 \times 3.142(245^2 - 238^2) + 2 \times 3.142 \times 245 \times 10$$

$$A_{fin} = 36642mm^2$$

The total surface area of the six fins = $6 \times 366542219852mm^2$

This is the total surface area added to the outer surface of the brake drum for heat dissipation.

IV. BRAKE DRUM MODELLING

The first step in this analysis was to prepare a solid model of the original and the modified brake drum model. The models were developed with the help of Kicreyco brake drum catalogue and modelled using solidworks (2013) package.

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The modified brake drum model has 6 fins of 10mm thickness and 7mm length; the two models are shown in figure 4. The brake drum models have the following specification.

Table 1. Models Specification

S/N	PARAMETER	VALUE	UNIT
1	Dust Shield Recess diameter	480	mm
2	Brake Face Diameter	460	mm
3	Brake Face Width	180	mm
4	Overall Height	210	mm
5	Squealer Band Thickness	10	mm
6	Depth of Dust Shield Recess	10	mm
7	Hub Pilot	280	mm
8	Bolt Hole Diameter	20	mm
9	Number of Bolt Hole	6	
10	Bolt Circle Diameter	280	mm
11	Weight of Brake drum	79	N

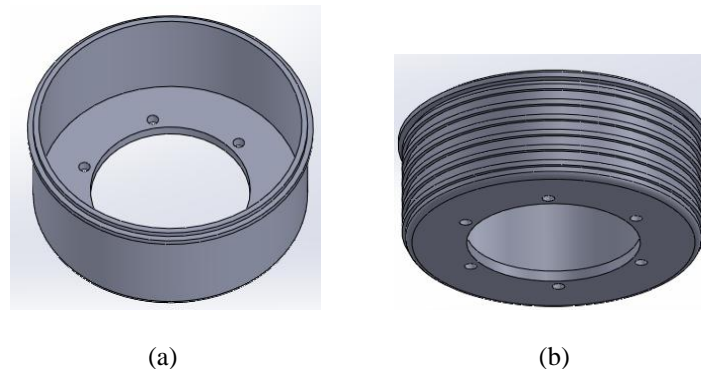


Fig 4. (a). Original Model, (b). Modified Model

V. SIMULATION AND ANALYSIS

In acceleration, heat energy of the fuel is converted by the engine into kinetic energy to move the vehicle. In braking, the kinetic energy is converted into heat by means of friction produced between the two mating surface of the brake drum. The amount of friction developed between the two surfaces in contact is independent of the area of the surface in contact. However the magnitude of the force of friction or retarding force created between the brake lining and the brake drum depends upon the pressure or force exerted on the shoes by the retarding mechanism and the coefficient for the two materials (Narang 1977). For the purpose of this paper, a retarding force of 150N was considered to be acting between the brake lining and the brake drum.

Since the brake shoes lining are poor conductor of heat, most of the heat remains inside the brake drum during braking. Under severe condition, brake drum may reach 590K temperature (Giri 2012). This is also because lining covers a large portion of the inner surface of the brake drum, so that a little cooling space is available. This shows that the inner surfaces of the brake drums are exposed to intense heating. This heat needs to be dissipated rapidly to prevent brake failure.

During the simulation, the exterior and the interior temperature of the brake drums were assigned to be 20°C and 120°C respectively. In simulating the models, the following specifications and properties of the brake drum material (Gray Cast Iron, shown in table 2) were taken into account.

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Table 2. Material Specifications and Properties

S/N	PROPERTY	VALUE	UNIT
1	Elastic Modulus	6.61781e+010	N/m ²
2	Poissons Ratio	0.27	N/A
3	Shear Modulus	5e+010	N/m ²
4	Density	7200	Kg/m ³
5	Tensile Strength	15165800	N/m ²
6	Compressive Strength	578572165000	N/m ²
7	Thermal Expansion Coefficient	1.2e-005	/K
8	Thermal Conductivity	45	W/mK
9	Specific Heat	510	Kg.K
10	Brake Shoe Force	150	N
11	Brake Drum Exterior Temperature	20	◊C
12	Brake Drum Interior Temperature	120	◊C

A. Analysis Results of the Original Model

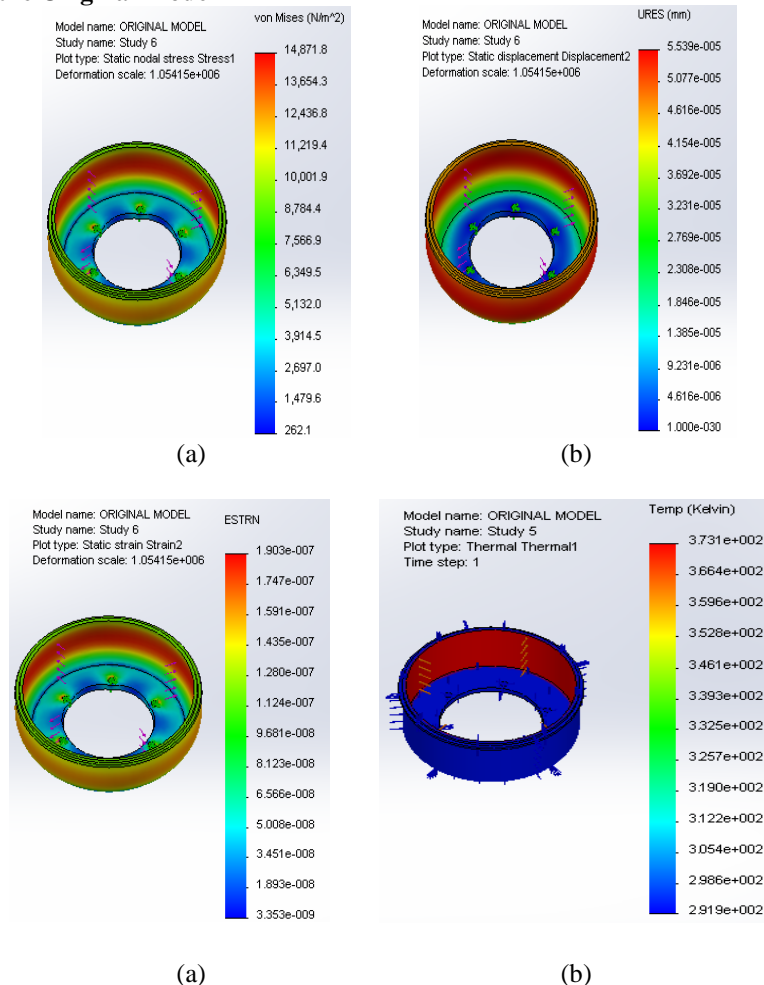


Fig 5. (a). Stress Plot for Original Model, (b). Displacement Plot for Original Model, (c). Strain Plot for Original Model, (d). Thermal Plot for Original Model

B. Analysis Results of the Modified Model

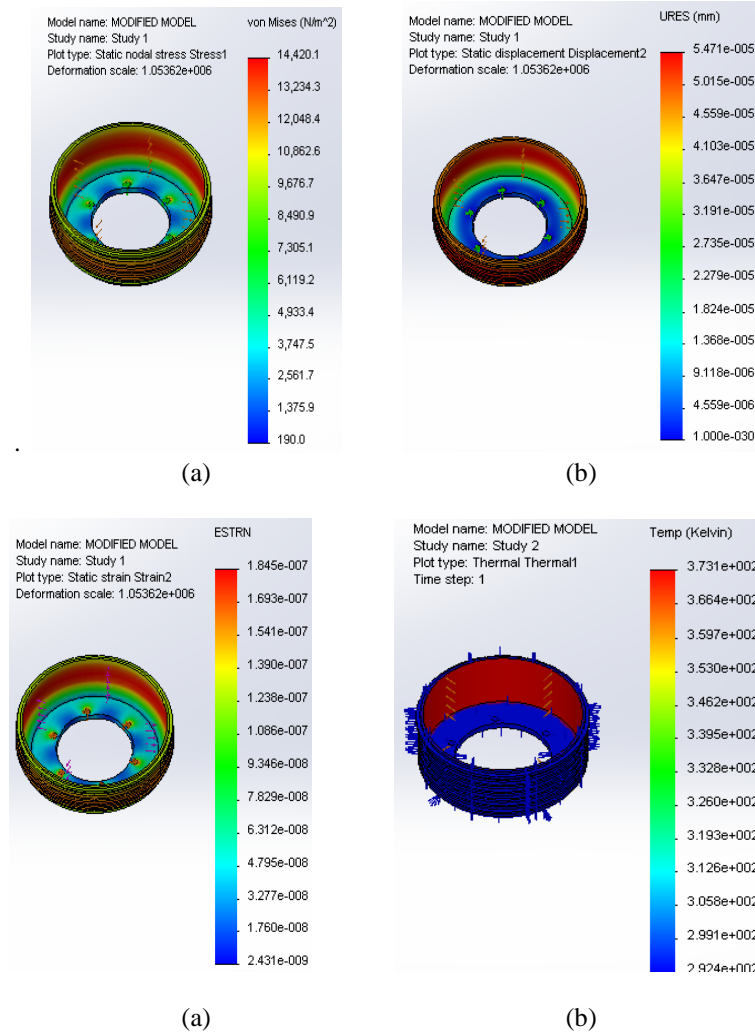


Fig 6. (a). Stress Plot for Modified Model, (b). Displacement Plot for Modified Model, (c). Strain Plot for Modified Model, (d). Thermal Plot for Modified Model

VI. DISCUSSION OF RESULTS

This simulation results states the prediction of stress, displacement and thermal stress of the two models by stimulating them with the brake shoe force of 150N and the exterior and interior temperature of 20°C and 120°C respectively. The minimum von mises stress and displacement are located at the adjacent side of the inner part of the two brake drum models. This is due to absence of forces acting directly on these surfaces. While the maximum von mises stress of the two models are located on the walls of the brake drums. This is due to the action of the brake shoes on the brake drum. The modified brake drum model shows a lower value of stress, strain and displacement than the original model. This indicates that the fins have added more circumferential strength on the brake drum. This circumferential strength has increased the circumferential resistance of the brake drum to the action of the brake shoe force. This has also makes the brake drum to be more rigid. This helps to reduce hoop or circumferential stress acting at the inner wall of the brake drum. This circumferential stress is produce when the brake drum is under pressure by the action of the brake shoes during braking.

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It was observed from the thermal analysis, that the initial temperatures of the two models are the same, but the original model shows a lower rate of decreasing in temperature than the modified model. This indicates that the rate of heat transfer is lower in the original model than in the modified model. Therefore some amounts of heat energy are retained inside the original brake drum as the result of the low heat removal from the inner surface to the outer surface of the brake drum. This retained heat energy is the major causes of brake fade and drum brake damages in the drum brake system.

The higher rate of change in temperature of the modified model from the maximum to the minimum temperature shows that the modified model has a higher rate of heat transfer compared to the original model; therefore much heat is removed from the inner surface to the outer surface of the brake drum at a faster rate. Also the minimum temperature of the modified model is higher than the minimum temperature of the original model. This shows that much heat is available at the outer surface of the modified model for heat dissipation by the action of the moving air stream on the outer surface of the brake drum. This indicates that the fins (extended surface) have improved the rate of heat dissipation and conductivity from the inner surface to the outer surface of the modified brake drum.

VII. CONCLUSIONS

By comparing the simulation results of the two brake drum models, the following conclusions were drawn;

1. The small von mises stress and displacement shown by the modified model; indicates that the modified model is stronger and rigid than the original model. With equal mass as the original model, the modified model has higher circumferential strength. This is due to the circumferential arrangement of the fins round the outer wall of the brake drum. Therefore the last three (2-4) properties of the brake drum (stated above) have been improved.
2. The high temperature of the outer surface of the modified model shows that more heat is transferred and dissipated from the brake drum. This is enhanced by the extended surface (fins) on the surface of the brake drum. Therefore the conversion of one-fourth of the overall height thickness of the original model to fins (extended surface) has also improved the heat dissipation of the modified brake drum.

However, this simulation shows that the drum brakes are prone to structural and thermal failure due to hard braking force, if the detailed design and material properties are not correctly specified. This analysis can assist Automotive Engineers to design a more effective and reliable brake drums.

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