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Research Paper

DESIGN OF A BRAKE DRUM USING FINITE ELEMENT METHOD

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In the recent years the needs for heavy duty brakes have been increasing. Since the performance of a braking system has direct influence on the safety of an automobile, an accurate design of brake drum is very important at present. The Brake Drum of TATA INDICA car is working well under certain load conditions. The required size of the break drum to be used in newly introduced TATA NANO car, the adoptability of the brake drum is tested under different load conditions with the help of Finite element analysis. The analysis is carried out using a FEM package, ANSYS 10. The results shown that the size of the brake drum required for NANO car is smaller than the size that is being used in INDICA car with lesser brake load than the later one.

Keywords: Hoop stress, Longitudinal stress, Von miss stress, Speed, Pressure

INTRODUCTION

The modern Automobile Drum Brake was invented in 1902 by Louis Renault through a less sophisticated Drum Brake had been used by May batch a year earlier. In the first Drum Brakes, the shows were mechanically operated with levers and rods or cables. From the mid-1930 the shoe was operated with levers and rods or cables. From the mid-19300s the shoe was operated with oil pressure in a small wheel cylinder and pistons, though some vehicles continued with purely mechanical systems for decades. A Drum Brake is Brake in which friction is caused by a set of shoes or pads that press against the inner surface of a rotating Drum. The Drum is connected to a rotating wheel.

Drum Brakes with internal shoe have a particular problem that when the Drums are heated by hard breaking the diameter of the Drum increases due to expansion of the material and the Brakes must be further depressed to obtain effective braking action. For this reason Drum Brakes have been superseded in most modern automobiles and light trucks with at least front wheel disc Brakes. Drum Brakes are still used in some modern cars owing to weight and cost

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advantages and also easy to manufacturing. An advanced technology hybrid car using Drum rear Brakes is the Toyota Prisus.

PROBLEM DESCRIPTION

There is a difference between theory and practice of Brakes. To cover this gap, many factors have to be considered. These factors include of variation of interface pressure, temperature and wear. To solve with these factors Finite Element Method is the most helpful. Conventional method of Brake analysis does not give accurate results. So the design of Drum Brake by using Finite Element Method for more accuracy is very essential. In the present work we are designing the brake drum under different load and speed conditions.

DATA COLLECTION

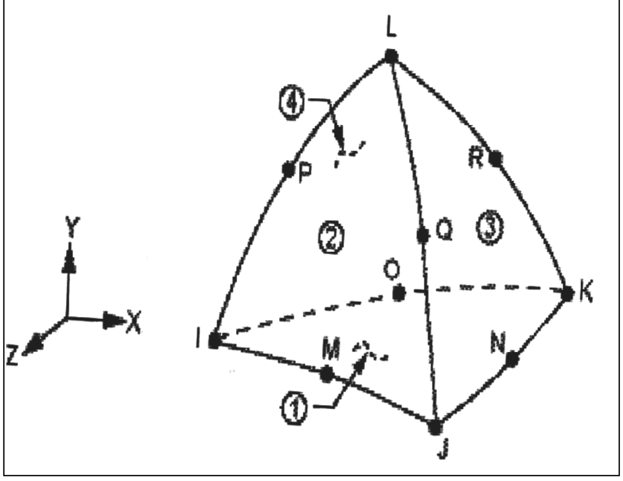
The data on Brakes have been collected from the published literature, data books, study and observation. The data contains the details of composition and mechanical properties of Drum Brake material and the specifications of Indica car and NANO car were collected. The data has been classified and presented in Table 1.

Table 1: Materials Properties

S. No.	Property	Value/ Composition
1.	Young's Modulus (GPa)	125
2.	Density (ρ) (Kg/m^3)	7110
3.	Poisson's Ration (μ)	0.25
4.	Thermal Conductivy (W/mK)	54
5.	Coefficient of Thermal Expansion (K^{-1})	12 × 10-06
6.	Grey Cast Iron	3.2 C, 2.5 Si wt%

For the analysis of present project work, the element type "SOLID 87" is chosen. The diagram of this element is shown in Figure 1.

Figure 1: Element Type "SOLID 87"



MESH GENERATION

For the analysis of the present brake drum is meshed and it is divided in to 86626 elements. The total number of nodes is 137971; Mesh generation refers to the generation of the nodes and Element connectivity (Figures 2 and 3). It also includes the automation, numbering of nodes and Elements based on a minimum amount of user supplied data. Before meshing the model, and even before building the model, it is important to think about whether a free or mapped mesh is appropriate for the analysis. A free mesh is one that has no restrictive in terms of Element shapes and has not specified pattern applied to it. Compared to a free mesh, a mapped mesh is restricted in terms of the Element shape it contains and the pattern of the mesh. A mapped mesh area contains either only quadrilateral or only triangular Elements, while a mapped volume mesh contains only hexahedron Elements.

Figure 2: Mesh Generation in INDICA Car Brake Drum

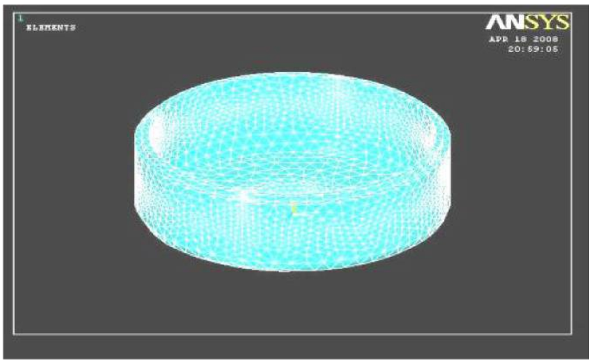
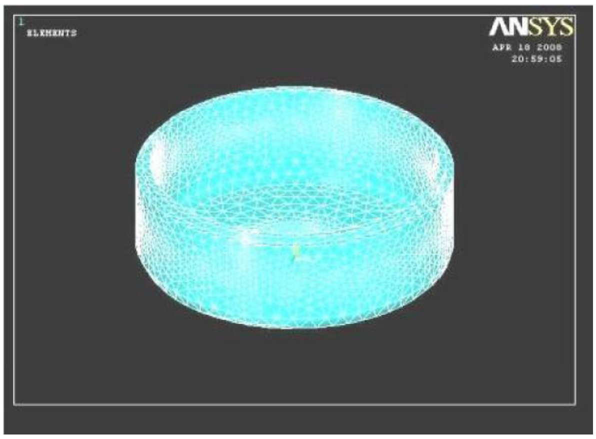


Figure 3: Mesh Generation in NANO Car Brake Drum



CONVENTIONAL ANALYSIS OF BRAKE DRUM DESIGN FOR INDICA CAR

- Mass of the car = 1490 kg (Data of the TATA INDICA car)
- Load (From luggage and passengers approx) = 500 kg
- Total weight = 1990 kg
- Maximum velocity of car = 152 kmph = 42.2 m/s
- Time = 3 sec
- Speed of the car = 4030 rpm

Force on the braking system = m(rw)/t = 1990 × 42.2/3 = 27992.6 N

- Force on each brake drum = F/4 = 6943.3 N
- Area of the shoe brake in contact with brake drum = 2 × 104.71 × 30 × 10^{-6} = 6.282 × 10^{-3}
- Pressure on the brake drum = F/A = 6943.3/ 6.28 × 10^{-3} = 1.105 Mpa

To calculate the stress in the Brake Drum by the application of pressure:

If the thickness to diameter ratio (t/D ratio) is 1/10 to 1/20 then the cylinder can be considered as thin cylinder. Since, our Brake Drum ratio is 1/20. We can consider our Brake Drum as thin cylinder (Table 2).

To Calculate Stresses

"Stress is resistance offered by the body to deformation." Generally, maximum pressure acts on trailing side of Brake Drum.

We know that,

Table 2: Brake Drum Parameters for INDICA Car

S. No.	Parameter	Magnitude
1.	Pressure	1.105 MPa
2.	Diameter of Brake Drum	0.2 m
3.	Thickness of Brake Drum	0.010 m

Hoop Stress σ_h = (PD/2t) = (1.105 × 0.2)/(2 × 0.01) = 11.05 MPa

Longitudinal Stress σ_h = (PD/4t) = (1.105 × 0.2)/(4 × 0.01) = 5.525 MPa

Von Miss Stress: (σ von miss) 2 = $\sigma_h^2 + \sigma_1^2 - 2(\sigma_h \times \sigma_1)$

To calculate the deformation or change in diameter:

$= (11.05 \times 10^6)2 + (5.525 \times 10^6)2 - (2 \times 11.05 \times 5.525 \times 10^{12}) = 6.2 \times 10^6$ MPa

In thin cylinders, the stresses in radial direction are zero, i.e. $\sigma_r = 0$

$\Delta D = [D \times (\sigma_h - \mu_\sigma 1)]/E$

Change in deformation or displacement of INDICA car brake drum:

$\Delta D = [0.2 \times (11.05 \times 10^6) - (0.25 \times 5.525 \times 10^6)]/125 \times 10^9 = 1.547 \times 10^{-5}$

CONVENTIONAL ANALYSIS OF BRAKE DRUM DESIGN FOR NANO CAR

- Mass of the car = 1000 kg (Data of the TATA NANO car)
- Load (From luggage and passengers appro) = 500 kg
- Total weight = 1500 kg
- Maximum velocity of car = 105 kmph = 29.16 m/s
- Time = 3 sec
- Speed of the car = 3093 rpm
- Force on the braking system = m (rw)/t = $1500 \times 29.16/3 = 14579.66$ N
- Force on each brake drum = F/4 = 3644.9 N
- Area of the shoe brake in contact with brake drum = $2 \times 94.23 \times 30 \times 10^{-6} = 5.65 \times 10^{-3}$
- Pressure on the brake drum = F/A = 3645/ 5.65×10^{-3} = 0.645 MPa

To calculate the stress in the Brake Drum by the application of pressure:

If the thickness to diameter ratio (t/D ratio) is 1/10 to 1/20 then the cylinder can be considered as thin cylinder. Since, our Brake Drum ratio is 1/18. We can consider our Brake Drum as thin cylinder (Table 3).

To Calculate Stresses

"Stress is resistance offered by the body to deformation." Generally, maximum pressure acts on trailing side of Brake Drum.

We know that,

Table 3: Brake Drum Parameters for NANO Car

S. No.	Parameter	Magnitude
1.	Pressure	0.645 MPa
2.	Diameter of Brake Drum	0.18 m
3.	Thickness of Brake Drum	0.010 m

Figure 4: Cross Section of Drum Brake

RESULTS AND DISCUSSION

The results and discussions presented in the outputs of both FEM and conventional method. These results are discussed below:

- The braking force obtained by considering specifications for the INDICA car is 6943.3 N under 4030 rpm and temperatures produced is 87'C. The diameter of the brake drum is 200 mm, and its thickness is 10 mm.

- The braking force obtained by considering specifications for the NANO car is 3641.9 N under 3093 rpm and temperatures produced is 65 °C. The diameter of the brake drum is 180 mm, and its thickness is 10 mm.

From the thermal and structural analysis of Brake Drum by using Finite Element Method, and after finding the suitable size of the NANO car brake drum, the following salient points are observed.

The results shown that the size of the brake drum required for NANO car is smaller than the size that is being used in INDICA car with lesser brake load than the later one.

CONCLUSION

The main conclusions based on the results are given below.

The obtained stresses in the brake drum are lower the allowable stresses of the brake drum material. Our design will be acceptable.

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