Thermal Analysis of Brake Drums at Various Temperatures

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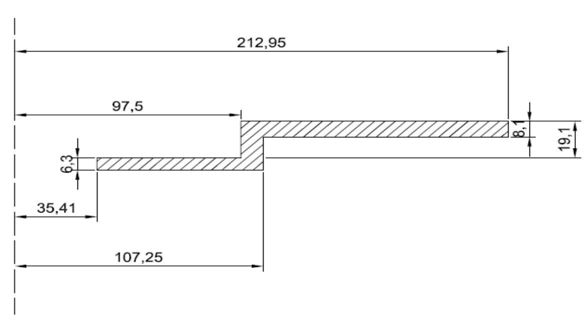
Abstract -- The function of a brake is to control the motion of a machine member or a vehicle. A brake may be used to slow down, stop or hold a load or release a load and control its speed. In the process of performing its function, an effective breaking is required to convert large amount of kinetic energy of the brake components and dissipate it in the form of heat transferred from the brake system. The capacity of any brake depends upon the unit pressure between the braking surfaces, the coefficient of friction and the heat dissipating capacity of the brakes. The brakes must be strong enough to stop the vehicle within a minimum distance in an emergency. Cast iron, steel are the commonly used materials for the brake drum. In the present work an attempt is made to replace the existing cast iron brake drum of a truck with two other materials namely aluminum composite and stainless steel 304. The dimension of the proposed brake drum is considered the same as that of the existing cast iron brake drum. Modeling of the brake drum was done in Auto-CAD software. Steady state and transient analyses was carried out using ANSYS 10.0 software package. For the analysis, four cyclic braking conditions i.e, 30 seconds, 90 seconds, 120 seconds, and 210 seconds are considered to determine the peak temperature developed and thermal deformation. The design constraints considered in this investigation were heat flux and convective heat transfer coefficient.

I. INTRODUCTION

A brake drum is a metal cylinder to which pressure is applied by a braking mechanism to arrest rotation of the wheel or shaft to which the cylinder is attached. A drum brake is a brake that uses friction caused by a set of shoes or pads that press against a rotating drum-shaped part called a brake drum. The working principle of the drum brakes involves a set of shoes or pads that create friction against a drum connected to the rotating wheel. Brake drum components include the back plate, brake drum, shoe, wheel cylinder, and various springs and pins. Brake drum was invented by Louis Renault in 1902. He used woven asbestos lining for the brake drum lining as no alternative dissipated heat like the asbestos lining, though Maybach has used a less sophisticated brake drum. In the first brake drums, levers and rods or cables operated the shoes mechanically. From the mid-1930's, oil pressure in a small wheel cylinder and pistons operated the brakes, though small vehicles continued with purely mechanical systems for decades. Some designs have two-wheel cylinders. The shoes in brake drums wear thinner, and brakes required regular adjustment until the introduction of self-adjusting brake drums in 1950's. The brake drum is used widely on road vehicles and consists of a drum attached to the rotating wheel. The drum has an internal machined cylindrical surface. Inside the drum and protected from the environment are two shoes lined with friction material which can be pivoted to make a forced contact with the internal cylindrical surface. A drum brake unit consists of two brake shoes mounted on a stationary backing plate. When the brake pedal is pressed, a hydraulically activated wheel cylinder pushes the shoes out to contact a rotating drum which creates friction and slows the vehicle. As the pedal is released, return springs retract the shoes to their original position.

BRAKE DRUM



Brake drums must have sufficient strength to resist the mechanical and thermal stresses developed during braking. To satisfy these requirements the drum material should possess a high thermal conductivity, thermal capacity, and low coefficient of thermal expansion, modulus of elasticity, high strength, sufficient hardness and a suitable metallurgical structure. The steady state thermal analysis calculates the effects of steady thermal loads on the brake drum. Transient thermal analysis determines temperatures that vary over time. A transient thermal analysis follows basically the same procedures as a steady-state thermal analysis. The main difference is that most applied loads in a transient analysis are functions of time. To specify time-dependent loads, it can use either a function tool to define an equation or a function describing the curve and then apply the function as a boundary condition, or it can divide the load versus time curve into load steps. Temperatures that a transient thermal analysis calculates can be used as input to structural analysis for thermal stress evaluations.

II. MATHEMATICAL MODEL FOR TEMPERATURE DISTRIBUTION

For Steady state analysis, since the temperature does not vary with time, the problem is considered as one-dimensional heat transfer through a slab.

From the Fourier's law of conduction, heat transfer

$Q = k\,A\,dt/dx$ Watts $\rightarrow$ 3.1

$q = Q/A$ = Heat flux, W/mm^2 $\rightarrow$ 3.2

k= Thermal conductivity, W/mm °C

dt/dx = Temperature gradient $\rightarrow$ 3.3

For surfaces which are heated during the braking,

$Q = Es / A$ Watts $\rightarrow$ 3.4

Where Es is the power transmitted through the surface, and A is the area of the surface.

$A = \pi (R_1^2 - R_0^2)$ mm^2 $\rightarrow$ 3.5

If the friction torque between the drum and the brake liner is constant Es can be written as

$Es = Esmax / t_b (t_b - t)$ Wmm^2/second $\rightarrow$ 3.6

Where Esmax is the maximum braking power and t_b is the total braking time. For Transient analysis, a finite difference procedure has been adopted to obtain the temperature distribution across the drum. Thus heat flow in a drum reduces to heat conduction through infinite slab.

III. MODELING AND ANALYSIS

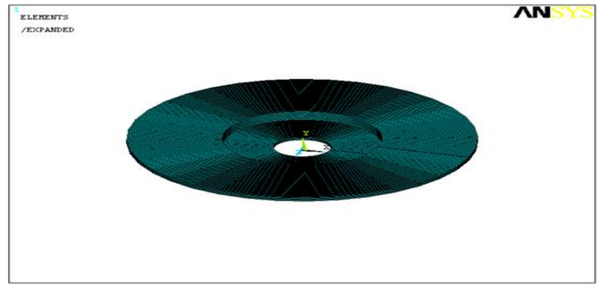


Figure: Full geometry of brake drum with elements

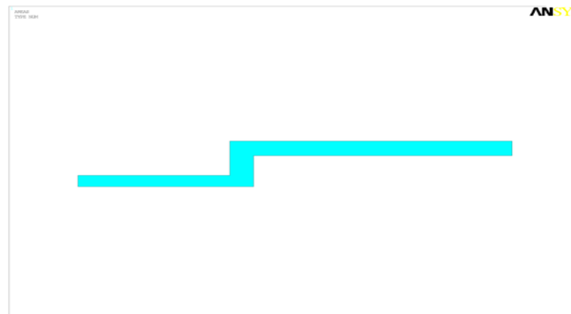


Figure: Geometry of cross section of brake drum

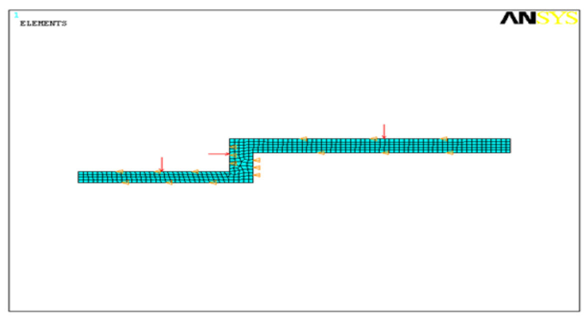


Figure: Boundary conditions for steady state and transient analysis

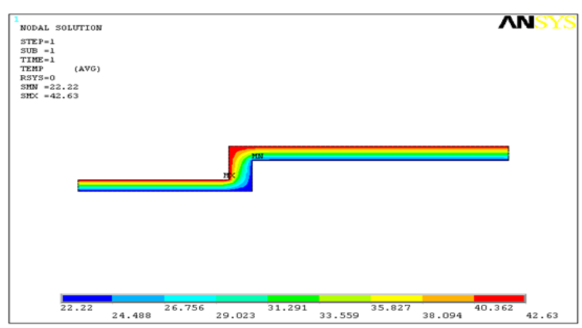


Figure: Temperature distribution for cast iron material in steady state condition

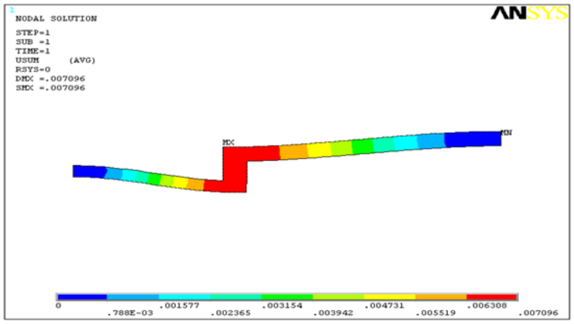


Figure: Thermal deformation for cast iron material

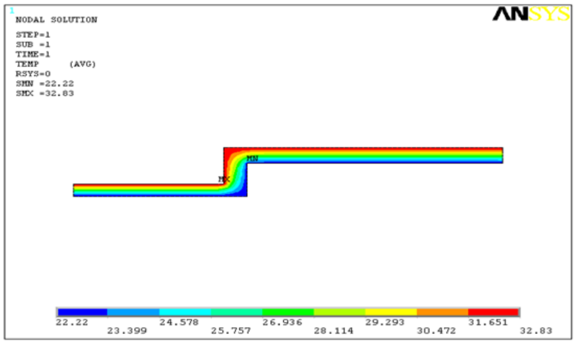


Figure: Temperature distribution for aluminum composite material in steady state condition

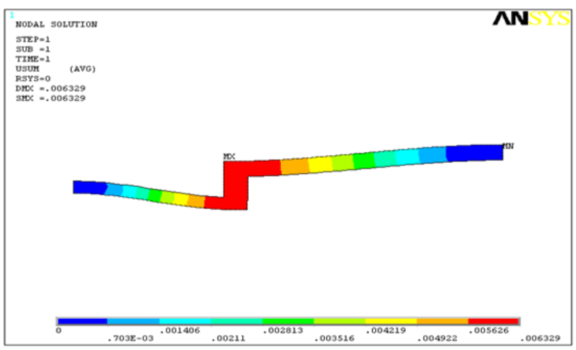


Figure: Thermal deformation for aluminum composite m

	Cast iron	Aluminium composite
Ambient temperature	22.220c	22.220c
Maximum temperature	42.630c	32.830c

IV. CONCLUSION

A finite element model has been developed for estimating the time depending temperature distribution in brake drum. Steady state and transient thermal analyses of brake drum are carried out for different materials such as aluminum composite, cast iron and stainless steel 304 used in the construction of brake drum. Based on the experimental observations the following conclusions are drawn.

1. The maximum temperature obtained for aluminum composite brake drum is 32.83°C which is less compared to the maximum temperature prevailing in cast iron brake drum and stainless steel 304 brake drum.

2. Thermal deformation for aluminum composite brake drum is 0.006329 millimeters which is lesser than the thermal deformation of cast iron brake drum but slightly more than the thermal deformation of stainless steel brake drum which has 0.004328 millimeters.

3. The thermal deformation of aluminum composite brake drum is 10.81% lesser than the cast iron brake drum.

4. The thermal deformation of stainless steel 304 brake drum is 39.01% lesser than the cast iron brake drum.

5. The weight of the existing cast iron brake drum cross section is 11.305 kilograms. The percentage reduction in weight when using aluminum composite material is 58.52%, and the percentage increment in weight when using stainless steel 304 material is 9.53%.

Thus, based on the experimental investigation, it is better to use the Aluminum composite material as an alternative material in the place of existing cast iron material brake drum by just neglecting the minute difference in the thermal deformation of the aluminum material which is just a little bit more than that of the stainless steel 304 material. In an overall aspect, among the three materials that have been taken into consideration for this study, aluminum composite material is proved better than the other materials considered in this investigation.

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