iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** IX **Month of publication:** September 2016

DOI:

Volume 4 Issue IX, September 2016
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Designing and Analysis of Brake Drum

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Abstract: The brake drum is a specialized brake that uses the concept of friction to decelerate .The deceleration is achieved by the assistance of the friction generated by a set of brake shoes or pads. During the brake operation heat is ejected out this causes damage to the brake. To satisfy this condition the drum material should possess a high thermal conductivity, thermal capacity and high strength .The common material used for construction of brake drum is cast iron. . A thermal analysis of different materials such as aluminium alloy, cast iron and stainless steel 304 for a brake drum will be done. The maximum temperature that is generated is calculated with the help of the ambient temperature for all the three materials. The area of cross section is calculated and thus their weight is calculated for three different densities of the three materials. . A model is created with the help of computer aided drafting software, namely AUTO CAD. This is then imported to an analysis software, namely ANSYS. The cross section design is initially studied and then meshing is done for it in analysis software. Steady state condition is studied for all the three materials. Thermal flux is also studied for all the three materials. Then thermal deformation is calculated assuming a pressure of one Newton is applied as a braking energy or force. Then, going forward for transient state analysis, for regular 30 seconds, 90, 120 and 210, temperature distribution and thermal flux is studied. . A comparison of all the three results is done and aluminium alloy material is proved better than the other materials

Keywords:-brake drum, thermal analysis, weight, auto cad, and ansys.

I. INTRODUCTION

A brake drum is a metal cylinder to which pressure is applied by a braking mechanism in order 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.

II. LITERATURE SURVEY

Allan Michael Lang [1] in his research concluded that no simple relationship exists between the natural frequencies of the brake components and the squeal frequency and during squeal both the drum and shoes hold complex modes, which can be best visualized as the superposition of pairs of similar normal modes phase shifted both spatially and in time relative to each other.

Mohd Zald Bin Akop [2] in his project concluded that safety aspect in automotive engineering has been considered as a number one priority in development of new vehicle and it is a must for all vehicles to have proper brake system.

Ramesha.D.K et al [3] in his thesis concluded that the maximum temperature obtained for aluminum alloy brake drum is less as compared to the cast iron brake drum for a truck. Also, concluded that thermal deformation is less for aluminum alloy brake drum than the cast iron brake drum. As his study states that the weight of Aluminum is lesser than the Cast iron, it is better to use the Aluminum material in the construction of brake drum.

Nurulhuda Binti Khalid [4] in his project concluded that the temperature changes on the brake drum during the deceleration providing the heat distribution and the distribution of temperature depends on the various factors such as friction, surface roughness, speed, and others.

Ray W.Murphy et al [5] in their report concluded that the braking efficiency of trucks and can be improved by careful distribution of braking effort among the axles of the vehicle.
Mr Songwut Mongkonlerdmanee [7] in his thesis concluded that to achieve maximum brake efficiency, vehicle geometry and real friction coefficient should be considered to design the brake proportion on each axle and the deceleration and braking distance on the front axle was better than those on the other axles because of the additional vertical load from the dynamic transfer.

III. SCOPE OF PRESENT WORK

Braking systems and brake drums have been reviewed. Thermal analyses on the brake drum on different materials such as aluminium alloy and cast iron have been done. A thermal analysis of different materials such as aluminium composite, cast iron and stainless steel 304 for a brake drum will be done as this type of analysis has not been done before.
The objectives of this study are:
To calculate the maximum temperature that is developed on a truck brake drum for cast iron, aluminium alloy and stainless steel 304 material brake drums.
To study the transient state conditions for intervals of time such as 30, 90, 120 and 210 seconds respectively.
To calculate the weight of cross section for the above stated materials for a particular geometry.
To calculate the thermal deformation that is produced due to the application of brake as it exerts an amount of force for the above stated materials.
To compare all the three results and conclude a best material for the selection of a brake drum.

IV. EXPERIMENTAL PROCEDURE

The material properties of the materials which are used for this analysis are studied carefully. The materials that are being used here are cast iron, aluminium composite, and stainless steel 304.

A. Cast Iron

Cast iron is iron or a ferrous alloy which has been heated until it liquefies, and is then poured into a mould to solidify. Carbon (C) and silicon (Si) are the main alloying elements, with the amount ranging from 2.1 to 4 wt% and 1 to 3 wt%, respectively. Cast iron tends to be brittle, except for malleable cast irons. With its relatively low melting point, good fluidity, cast ability, excellent machinability, resistance to deformation and wear resistance, cast irons have become an engineering material with a wide range of applications and are used in pipes, machines and automotive industry parts. The chemical composition of the cast iron which is being taken into consideration for this particular study is stated as below.

Iron - 95%, Carbon - 4%, Silicon - 1%

B. Aluminum Alloy

Aluminum alloy is a lightweight panel material which is designed for interior and exterior applications. The chemical composition of the aluminum alloy which is being taken into consideration for this particular study is stated as below.
Alumina – 30 %, Magnesium – 1 %, Balance is Aluminum.
Aluminum oxide is an amphoteric oxide with the chemical formula Al2O3. It is commonly referred to as alumina, Aluminum oxide is a chemical compound of aluminum and oxygen with the chemical formula Al_2O_3. Al_2O_3 is an electrical insulator but has a relatively high thermal conductivity (30 $Wm^{-1}K^{-1}$) for a ceramic material. The aluminum oxide generated by anodizing is typically amorphous, but discharge assisted oxidation processes such as plasma electrolytic oxidation result in a significant proportion of crystalline aluminum oxide in the coating, enhancing its hardness. Aluminum oxide is completely insoluble in water. However it is an amphoteric substance, meaning it can react with both acids and bases, such as hydrochloric acid and sodium hydroxide.

$$Al_2O_3 + 6\ HCl \rightarrow 2\ AlCl_3 + 3\ H_2O$$

$$Al_2O_3 + 6\ NaOH + 3\ H_2O \rightarrow 2\ Na_3Al\ (OH)_6$$

C. Stainless Steel 304

Type 304 stainless steel is a T 300 Series Stainless Steel austenitic. It has a minimum of 18% chromium and 8% nickel, combined

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ISSN: 2321-9653

with a maximum of 0.08% carbon. It is defined as a Chromium-Nickel austenitic alloy. Grade 304 is the standard "18/8" stainless that you will probably see in your pans and cookery tools. Stainless steel has excellent corrosion resistance and good resistance to intergranular corrosion. Excellent hot and cold forming process and performance. Better low temperature performance. At -180 ℃ condition, strength, elongation, area reduction rate is very good. In the absence of brittle transition temperature, often used at low temperatures. It has good weld ability. Welding method can be used often, both before welding without heat treatment after welding. The chemical composition of Stainless Steel 304 is stated as below.

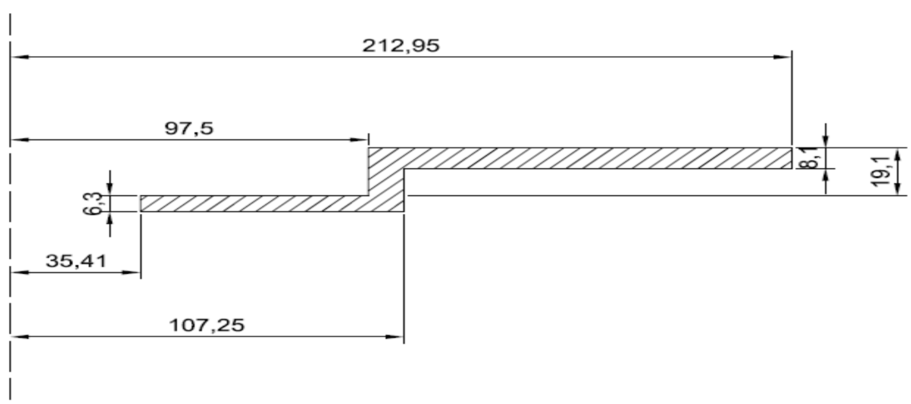
Carbon - 0.08% max.
Manganese - 2.00% max.
Phosphorus - 0.045% max.
Sulphur - 0.030% max.
Silicon - 0.75% max.
Chromium - 18.00-20.00 %
Nickel - 8.00-12.00%
Nitrogen - 0.10% max.
Iron - Balance

A truck brake drum is chosen and its dimensions are noted. A model is created with the help of computer aided drafting software, namely AUTO CAD. This is then imported to an analysis software, namely ANSYS. The cross section of this design is considered for the analysis. The maximum temperature that is generated is calculated with the help of the ambient temperature for all the three materials. The area of cross section is calculated and thus their weight is calculated for three different densities of the three materials. Steady state condition is studied for all the three materials. Then, going forward for transient state analysis, for regular 30 seconds, 90, 120 and 210, temperature distribution and thermal flux is studied.

Material properties

Properties	Cast-Iron (4%C)	Aluminium alloy material Al-1% Mg/Alumina (30%)	Stainless Steel 304
Thermal conductivity K, W/mm°C	51.9e-3	97.8e-3	21.5e-3
Specific heat Cp , J/kg°C	0.417e3	0.828e3	0.5e3
Density ρ , kg/mm^3	7.304e-6	3.03e-6	8e-6
Young's modulus E, N/mm^2	1.177e5	1.32e5	1.93e5
Poisson's ratio ν	0.29	0.28	0.29
Max. Operating temperature MOT,°C	400	538	870

V. BOUNDARY CONDITIONS



The ambient temperature considered for this problem is 22.22°C.
The general room temperature T_R = 30°C
Heat transfer Q = 22.22 Watts
q = Q / A
A = 19 x 9 mm^2

Boundary conditions are applied on the brake drum for steady state analysis.

Heat flux q = 0.1308 W/mm^2

Heat transfer coefficient h = 0.018166 W/mm^2 °C
Boundary conditions are applied on the brake drum for transient analysis.
Heat flux q = 0.1308 W/mm^2 is applied on surface of the brake drum at 30 and 120 seconds.
Heat transfer coefficient h = 0.018166 W/mm^2 °C is applied on surface of the brake drum at 90 and 210 seconds.

VI. THE ORITICAL CALCULATION OF MAXIMUM TEMPERATURE & WEIGHT

FOR CAST IRON

k = 51.9e-3 for Cast Iron

Hence, T_2 = 42.63°C

FOR ALUMINIUM ALLOY

k = 97.8e-3 for Aluminium Alloy

Hence, T_2 = 32.83°C

FOR STAINLESS STEEL 304

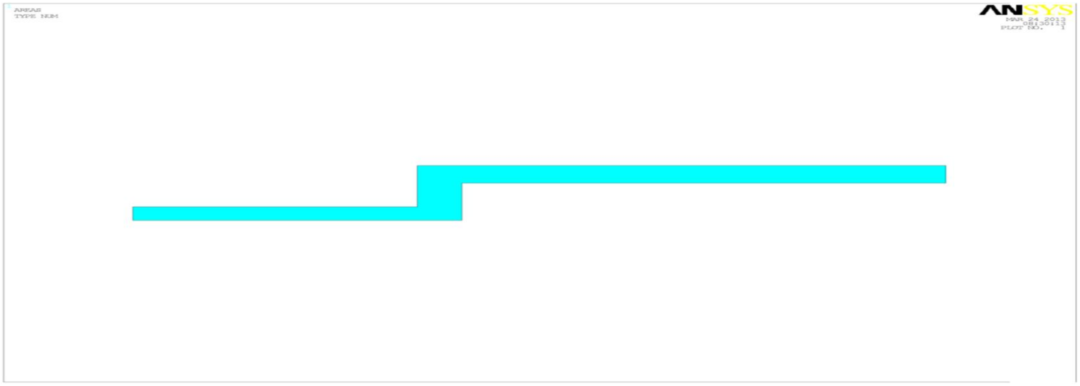
k = 21.5e-3 for Stainless Steel 304

Hence, T_2 = 71.27°C

Weight of Cast Iron = 7.304e-6 x 1.54779e6 = 11.305 kgf

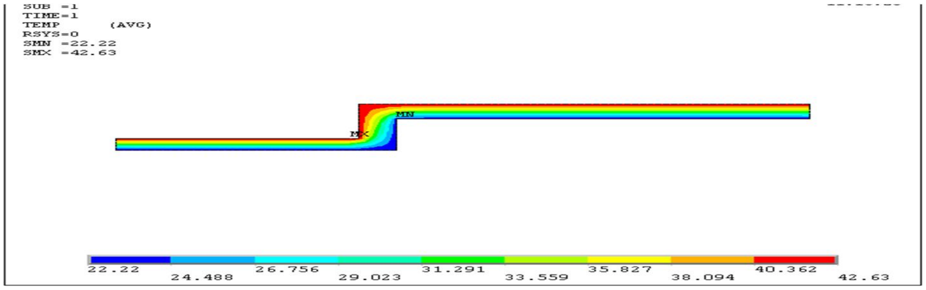
Weight of Aluminium Alloy = 3.03e-6 x 1.54779e6 = 4.6898 kgf

Weight of Stainless Steel 304 = 8e-6 x 1.54779e6 = 12.38232 kgf



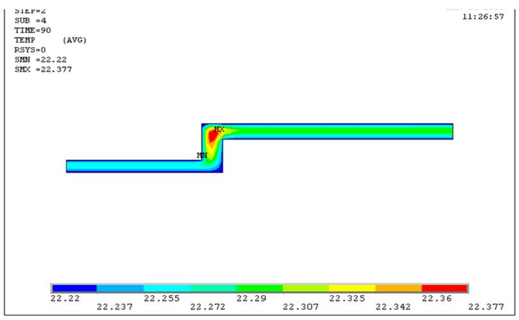
Geometry of cross section of brake drum

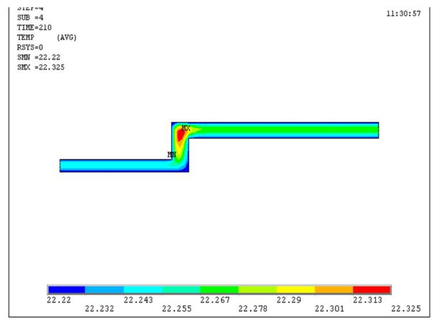
A. Steady State Thermal Analysis of Cast Iron Material



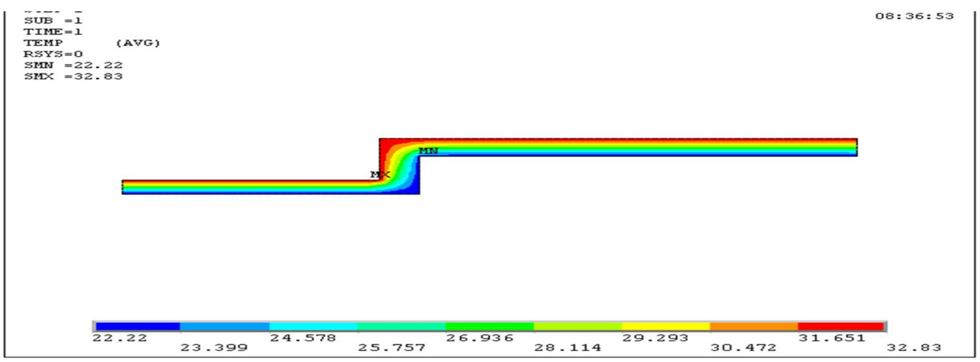
The maximum temperature that is obtained for this cast iron brake drum from calculations is 42.63°C.

B. Transient Thermal Analysis of Cast Iron Material

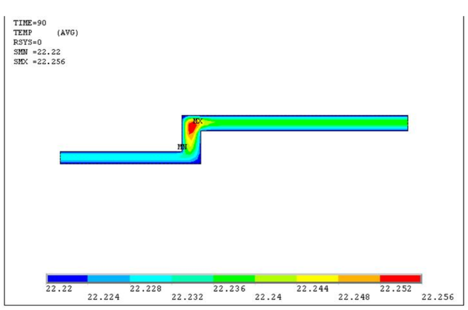


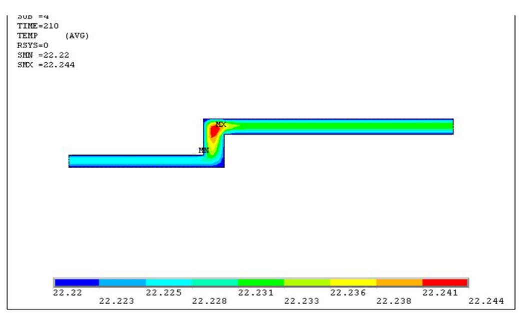


C. Steady State Thermal Analysis of Aluminum Alloy Material



D. Transient Thermal Analysis Of Aluminum Alloy Material





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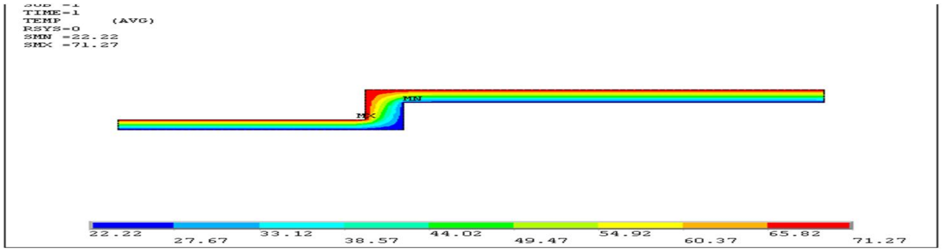
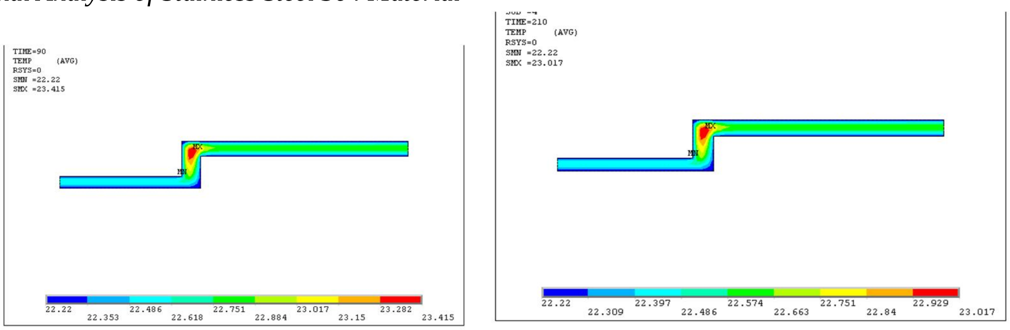
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

E. Steady State Thermal Analysis of Stainless Steel 304 Material



F. Transient Thermal Analysis of Stainless Steel 304 Material



VII. RESULTS & DISCUSSIONS

THEORITICAL VALUES FOR MAXIMUM TEMPERATURES AND WEIGHT

	CAST IRON	ALUMINUM ALLOY	STAINLESS STEEL 304
MAXIMUM TEMPERATURE, °C	42.63 °C	32.83 °C	71.27 °C
THERMAL DEFORMATION, mm	0.007096	0.006329	0.004328
WEIGHT OF CROSS SECTION, kg	11.305	4.6898	12.38232

The stainless steel 304 material has maximum operating temperature compared to cast iron material and aluminium alloy material. Since the thermal conductivity of the aluminium alloy material is high in comparison with cast iron material and stainless steel material, heat generated within the brake drum is easily dissipated to atmosphere. As most of the heat is carried away from the drum surface, the chances for generation of cracks are less in aluminium alloy brake drum compared to cast iron brake drum and stainless steel 304 brake drum. Both cast iron brake drum and stainless steel brake drum are heavy for the given geometry, compared to aluminium alloy brake drum.

VIII. BRAKING PERIOD VERSUS MAXIMUM TEMPERATURE DEVELOPED

A heavy deviation is not recognized among the values for maximum temperatures. If both the theoretical and FEA values are same, they are not considered. The deviations obtained are very small and can be neglected

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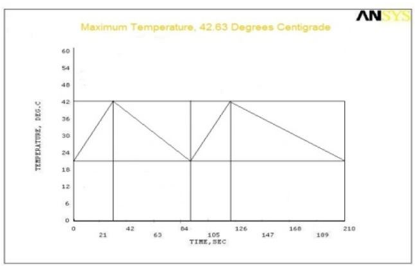
Braking Period	Ambient Temperature °C	Maximum Temperature FEA °C	Deviation °C
Cast Iron at 90 seconds	22.22	22.377	0.157
Cast Iron at 210 seconds	22.22	22.325	0.105
Aluminium alloy at 90 seconds	22.22	22.256	0.036
Aluminium alloy at 210 seconds	22.22	22.244	0.024
Stainless Steel 304 at 90 seconds	22.22	23.415	1.195
Stainless Steel 304 at 210 seconds	22.22	23.017	0.797

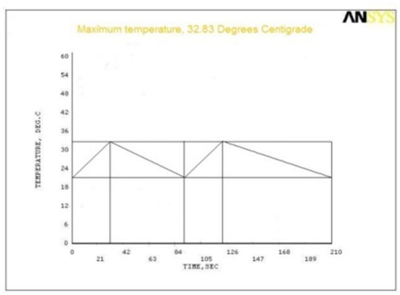
Percentage of deviation in weight for aluminium alloy compared to cast iron = (W_{CI} - W_{AC}) x 100 / (W_{CI})
= (11.305 – 4.6898) x 100 / (11.305)
= 58.52 %
Percentage of deviation in weight for stainless steel 304 compared to cast iron = (W_{CI} - W_{SS}) x 100 / (W_{CI})
= (11.305 – 12.38232) x 100 / (11.305)

= -9.53%
Percentage of deviation in thermal deformation for aluminium alloy compared to cast iron = (T_{CI} – T_{AC}) x 100 / (T_{CI})
= (0.007096 – 0.006329) x 100 / (0.007096)
= 10.81%
Percentage of deviation in thermal deformation for stainless steel 304 compared to cast iron = (T_{CI} – T_{SS}) x 100 / (T_{CI})
= (0.007096 – 0.004328) x 100 / (0.007096)
= 39.01%

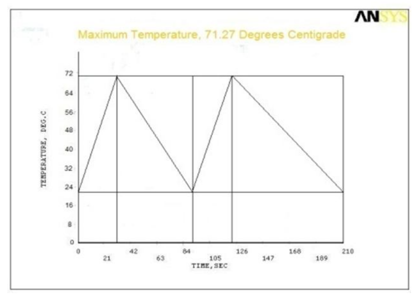
Temperature variation graphs during braking period



Cast iron



Aluminum alloy



Stainless steel 304

IX. CONCLUSIONS

The maximum temperature obtained for aluminium alloy 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. The weight of the existing cast iron brake drum cross section is 11.305 kilograms. The percentage reduction in weight when using aluminium alloy material is 58.52%, and the percentage increment in weight when using stainless steel 304 material is 9.53%. Thermal deformation for aluminium alloy brake drum is 0.006329 millimetres 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 millimetres. Among the three materials that have been taken into consideration for this study, aluminium alloy material is proved better than the other materials considered in this investigation.

X. SCOPE FOR FUTURE WORK

Similar type of investigation can be replicated on some other materials.
Similar analysis can be carried out on a disc brake.
Steady and transient thermal analysis can be carried out at various heat flux and different braking cycles.

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