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Optimization of Design of Brake Drum of Two Wheeler through Approach of Reverse Engineering by Using Ansys Software

Meenakshi Kushal[1] Suman Sharma[2]
[1] *ME Persuing, Department of Mechanical Engineering*
TRUBA College of Engineering & Technology, Indore, India.
[2]*Professor, Department of Mechanical Engineering*
TRUBA College of Engineering & Technology, Indore, India.

Abstract: *The aim of this article is to optimize the design of Hero Honda Passion brake drum (i.e. through reverse engineering approach). Optimization is done by changing the material of the brake drum, under different braking time and operational conditions. Brake drum is optimized to obtained different stresses, deformation values, rise in temperature on different braking time and heat transfer rate. Optimized results obtained are compared for Aluminium and CE (Controlled Expansion) material alloys. It concludes that the CE (Controlled Expansion) alloys can be a better candidate material for the brake drum applications of light commercial vehicles and it also increases the braking performance.*
Keywords: *Brake drum, Al alloy brake drum, CE alloy brake drum, Computer Aided Modeling, Finite Element Analysis, Inventor professional, Ansys workbench.*

I. Introduction

Drum brakes were the first types of brakes used on motor vehicles. Nowadays, over 100 years after the first usage, drum brakes are still used on the rear wheels of most vehicles. The drum brake is used widely as the rear brake particularly for small car and motorcycle. The leading-trailing shoe design is used extensively as rear brake on passenger cars and light weight pickup trucks. Most of the front-wheel-drive vehicles use rear leading-trailing shoe brakes. Such design provided low sensitivity to lining friction changes and has stable torque production (Limpert, 1999).[1] A brake is a mechanical device which is used to absorb the energy possessed by a moving system or mechanism by means of friction. The primary purpose of the brake is to slow down or completely stop the motion of a moving system, such as a rotating disc/drum, machine or vehicle. Many aspects of slowing and stopping a vehicle are controlled by simple physics dealing with the deceleration of a body in motion. The simplest way to stop a vehicle is to convert the kinetic energy into heat energy. The energy absorbed by brakes is dissipated in the form of heat. The heat is dissipated in surrounding, air, water etc. [2]

The braking equipment of a vehicle includes all of its brake system that is all of reducing velocity of a moving vehicle, reducing its rate of acceleration, increasing its rate of deceleration, halting the acceleration, increasing its rate of deceleration, halting the vehicle and preventing the vehicle from returning movement once it is stationary. [3]

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 brake drum is generally made of cast iron that rotates with the wheel. When a driver applies the brakes, the lining pushes radially against the inner surface of the drum, and the ensuing friction slows or stops rotation of the wheel and axle, and thus the vehicle.

Internal expanding shoe brakes are most commonly used in automobiles. In an automobile, the wheel is fitted on a wheel drum. The brake shoes come in contact with inner surface of this drum to apply brakes. The whole assembly consists of a pair of brake shoes along with brake linings, a retractor spring two anchor pins a cam and a brake drum. Brake linings are fitted on outer surface of each brake shoe. The brake shoes are hinged at one end by anchor pins. Other end of brake shoe is operated by a cam to expand it out against brake drum. A retracting spring brings back shoes in their original position when brakes are not applied. The brake drum Braking System closes inside it the whole mechanism to protect it from dust and first. A plate holds whole assembly and fits to car axle. It acts as a base to fasten the brake shoes and other operating mechanism

Braking power is obtained when the brake shoes are pushed against the inner surface of the drum which rotates together with the axle. Drum brakes are mainly used for the rear wheels of passenger cars and trucks while disc brakes are used exclusively for front brakes because of their greater direction stability. The backing plate is a pressed steel plate, bolted to the rear axle housing. Since the brake shoes are fitted to the backing plate, all of the braking force acts on the backing plate.

A drum brake has a hollow drum that turns with the wheel. Its open back is covered by a stationary back plate on which there are two curved shoes carrying friction linings. The shoes are forced outwards by hydraulic pressure moving pistons in the brake's wheel cylinders, so pressing the linings against the inside of the drum to slow or stop it.[4]

Optimal design of today's brake systems is found using additional calculations based on Finite element methods. For both types of brake systems, drum brakes and disk brakes. Results include deformation, stress distribution, contact pressure and showing which regions of the contact area are in sticking or sliding condition. [5] A parametric modeling of a drum brake based on 3-D Finite Element Methods for non-contact analysis is presented. Many parameters are examined during this study such as the effect of drum-lining interface stiffness, coefficient of friction, and line pressure on the interface contact. It is shown that the Unsymmetrical modal analysis is efficient enough to solve this linear problem after transforming the non-linear behavior of the contact between the drum and the lining to a linear behavior. [6] A multi objective optimization design model of drum brake with the goals of maximizing the efficiency factor of braking, minimizing the volume of drum brake, and minimizing the temperature rise of brake, in order to better meet the requirements of engineering practice. And the results of optimizing the new brake model indicate that DECell obviously outperforms the compared popular algorithm NSGA-II concerning the number of obtained brake design parameter sets, the speed, and stability for finding them. It is an effective algorithm that can be applied to solve the drum brake parameters optimization and other complicated engineering problems. [7] To establish a brake test rig capable of measuring the performance of a drum brake at different operational and environmental conditions, the effects of dry and humid environment are considered under different applied forces and vehicle sliding speed. The experimental results showed a slight increase in the friction coefficients between drum and brake lining with increasing pressure or speed at dry and wet conditions. [8] Brake torque is reduced in the absence of cooling so the result shows to eliminate brake fade if the cooling is very effective. Brake fading is due to temperature rise of brake shoe and brake drum. The heat generated due to braking rises the temperature reducing the coefficient of friction at the interface of brake shoe and brake drum. The reduced coefficient of friction reduces the brake torque, thus reduces the brake effectiveness. It was observed that brake torque was reduced by 25% in the absence of cooling as the brake cooling improved the brake fade reduced(Brake torque improved).[9]

II. Methods And Material

To create the cad model of the brake drum we find the existing brake drum of Hero Honda Passion from market for reverse engineering. We can measure all the visible dimensions manually with specified measuring instruments to create accurate and scaled model. To find out accurate feature location like holes plane angles etc.CMM is done. Using CAD software we can create CAD model of brake drum as per measurement data we Import the CAD Model (IGES) in the Ansys Workbench 14.5 for pre-processing and then the stress and thermal analysis is done on the brake drum. The Analysis involves the discritization called meshing, boundary conditions and loading. For analysis we take Aluminium with aluminium alloys and controlled expansion alloys as the material .The Aluminium has been selected based on the properties required for the existing brake drum. The aluminium alloys has been selected as matrix for manufacturing the MMC based on the ease of manufacturing.

Specifications of brake drum

Inner diameter (mm) = 110.
Outer diameter (mm) = 164
Outer Width (mm) = 10
Inner Width (mm) = 38
Contact an angle per shoe = 120
Width of Shoe (mm) = 25
No. of shoes = 2

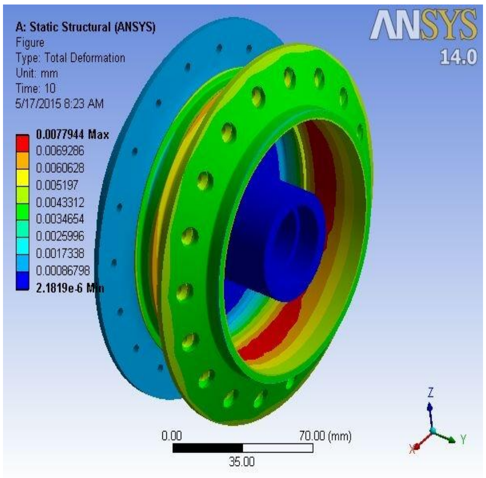
Material properties of brake drum

Material	Density (g/cm3)	Tensile Strength (Mpa)	Young's modulus (x10^3N/ mm2)	Thermal conductivity (cal/cm2/c m/25 oC)	MASS (kg)	Cofficient of thermal expansion (ppm/0c)	Poisson's ratio
Aluminium	2.7	241	70	0.42-0.46	1.246	24	0.3
LM28	2.68	165	82	0.26-0.29	1.232	19	0.3
LM29	2.65	160	88	0.24-0.27	1.218	20	0.3
A356	2.67	234	112	0.32-0.37	1.228	21	0.3
CE13	2.55	176	107	0.34-0.38	1.172	13.6	0.27
CE17	2.6	236	92	0.44-0.48	1.195	17	0.28

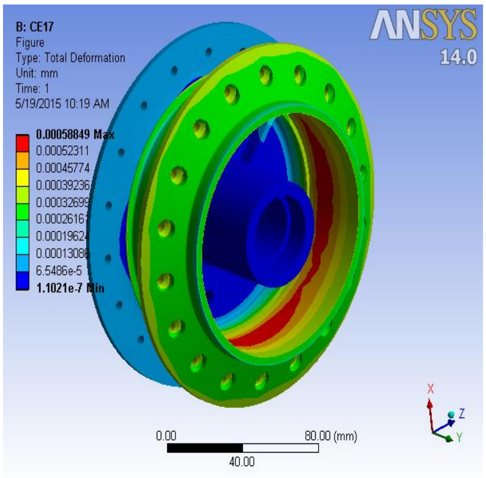
Solid Modeling: The first step was to prepare a solid model of the brake drum. This was carried out by using Inventor professional 2012 Software.

Analysis: Brake drum finite element analysis is done through Ansys workbench 14.0 software. Both stress analysis and thermal analysis is done under different braking time and operational conditions.

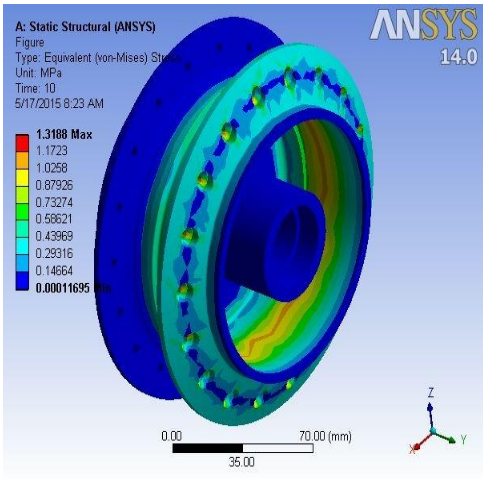
Boundary Conditions: For Stress analysis, pressure is applied on the internal surface of the cylindrical face of the brake drum, and the hub of the brake drum where the wheel of the vehicle rests is supported with the fixed support.



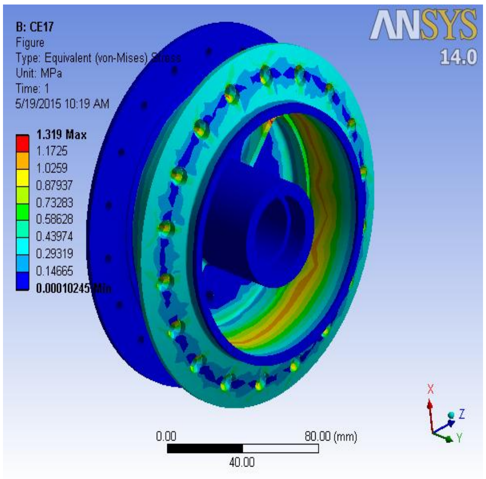
Deformation for Aluminium



Deformation for CE17



Stresses for Aluminum

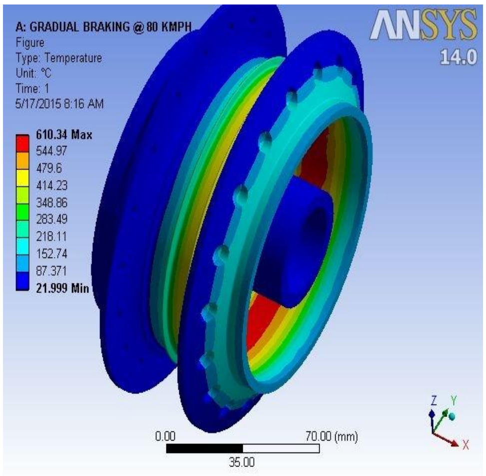


Stresses for C17

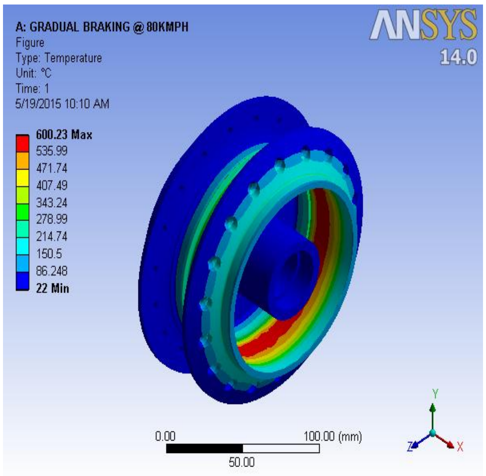
Thermal Analysis: For thermal analysis we assign the calculated heat flux on the inner face of brake drum. We calculate the heat flux on two conditions:

1. Gradual braking (time=15sec) at 80kmph
2. Sudden braking (time=5 sec)at 80kmph

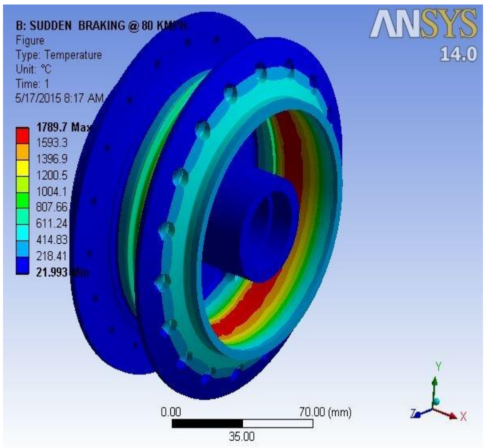
Boundary Conditions: For heat transfer analysis heat flux is applied on the internal surface of the cylindrical face of the brake drum, and the hub of the brake drum where the wheel of the vehicle rests is supported with the fixed support.



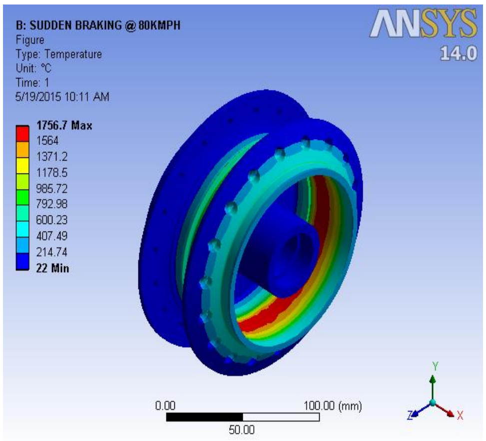
Gradual braking for Aluminium



Gradual braking for CE17



Sudden braking for aluminium



Sudden braking for CE17

III. Results

Table 1 for deformation of materials

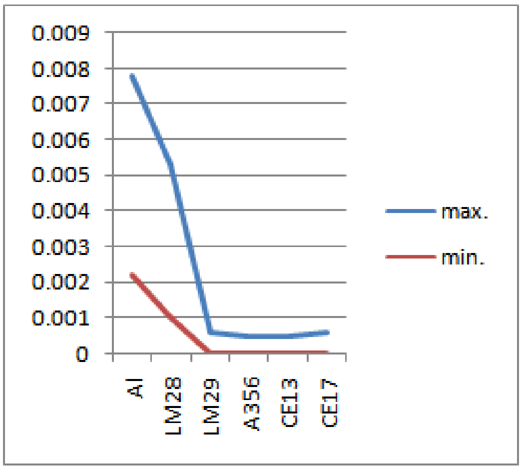
S.no.	Material	Deformation(mm)	
		Max	Min.
1	Aluminium	0.007794	0.0021819
2	LM28	0.005308	0.0010044
3	LM29	0.000615	0.000011714
4	A356	0.000486	1.6286E-07
5	CE13	0.000505	9.738E-08
6	CE17	0.000588	1.1021E-07

Table 2 for gradual braking temp.variation

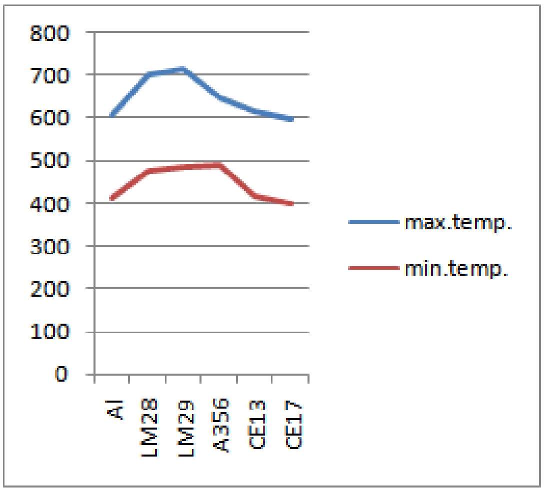
S.no.	Material	Max.temp	Outer face temp.	Heat transferred at outer surface
1	Aluminium	610	414	196
2	LM28	700.42	474.28	226.14
3	LM29	714.52	483.68	230.84
4	A356	650.01	488	162.01
5	CE13	617.62	419	198.62
6	CE17	600.23	400	200.23

Table 3 for sudden braking temp.variation

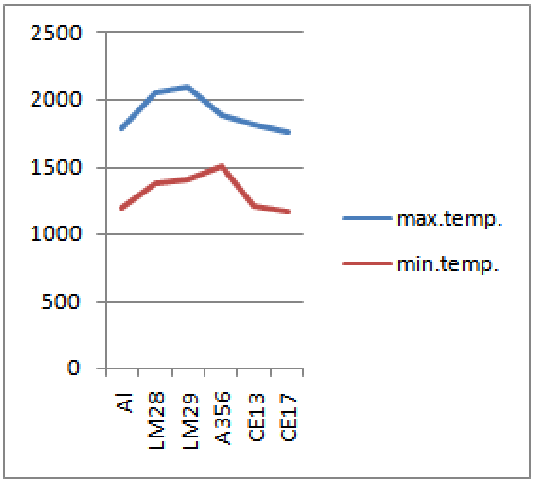
S.no	Material	Max temp	Outer face temp.	Heat transferred at outer surface
1.	Aluminium	1789.7	1200	589.7
2.	LM28	2057.6	1379.1	678.5
3.	LM29	2099.8	1407.2	692.6
4.	A356	1880.2	1500	380.2
5.	CE13	1808.9	1213.2	595.7
6.	CE17	1756.7	1165.5	591.2



Variation in deformation



Variation in Heat transfer for gradual braking at 80Kmph



Variation in Heat transfer for sudden braking at 80Kmph

IV. Conclusion

The deformation and the stress induced in the aluminium alloy and CE (Controlled Expansion) alloy brake drums during the application of brake force have been determined using finite element analysis. It is observed from the analysis that the deformation in CE (Controlled Expansion) alloy brake drum is considerably less than the Aluminium alloy brake drum.

The stresses in the CE (Controlled Expansion) alloy and Al alloy brake drums are found to be almost same. There is negligible variation in them. Hence, the required factor of safety is maintained in both the CE (Controlled Expansion) alloy and Al alloy brake drums. While braking from a speed of 80km/h at a constant deceleration of4.44 m/sec2 at sudden braking and 1.481m/sec2 at gradual braking, it is observed that the temperature rise in CE (Controlled Expansion) alloy brake drums surface is less than the Al alloy brake drums and the heat transferred at the outer surface of the brake drum increases. It increases the life of lining material and the temperature rise in brake components is reduced which will increase the braking performance. During sudden braking, the temperature rise in brake drum is found to be 65 to 66 % more than the gradual braking. It concludes that temperature rise in the surface of brake drum also depends upon the time of braking. A comparative study has been conducted between CE (Controlled Expansion) alloy and Al alloy brake drums based on weight, temperature rise and deformation. The CE (Controlled Expansion) alloys brake drum has comparatively less weight than Pure Aluminium and Aluminium alloys brake drum. CE (Controlled Expansion) alloys have low expansion, stiffer, excellent machinibility as compared to Pure Aluminium and Aluminium alloys.

From the above observations, it is concluded that the CE (Controlled Expansion) alloy brake drum has less weight, less deformation, minimum temperature at the surface. Hence, the CE (Controlled Expansion) alloys can be a better candidate material for the brake drum applications of light commercial vehicles.

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