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Design And Analysis of Drum Brakes

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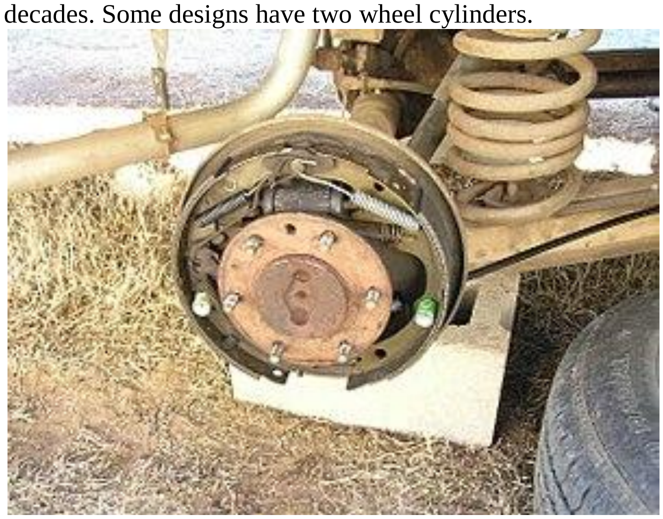
Abstract: A brake is a mechanical device which inhibits motion. A drum brake is a brake that uses friction caused by a set of shoes or pads that press against a rotating drum-shaped part called a brake drum. The brake drum is a critical component that experiences high temperatures and develop thermal stresses during application of brakes. In addition, the application of shoe pressure gives rise to mechanical loads. So the analysis takes into account both the displacement loads and mechanical stresses together. Brakes in cars and trucks are safety parts. Requirements not only in performance but also in comfort, serviceability and working lifetime are high and rising; i.e. the brake pad with the friction material, the counter body and caliper, can be modeled. When the brake is applied repeatedly the brake pad undergoes critical stresses to determine the critical stresses the structural analysis is carried out. In my thesis, I focus on the analysis of the brake shoes and its components. I perform solid-mechanical calculations, and a finite-element analysis, and experimentally investigate the structural integrity of the components. The solid model is generated and designed in Catia-V5. Then the model is imported to Ansys through IGES / Catia-V5 format. The quality mesh is prepared in Ansys for converged solution for analysis package with high optimizing results.

Keywords: Drum Brakes, CATIA V5, Mechanical Design, CAE Training.

I. INTRODUCTION

A drum brake is a brake that uses friction caused by a set of shoes or pads that press outward against a rotating cylinder-shaped part called a brake drum. The term drum brake usually means a brake in which shoes press on the inner surface of the drum. When shoes press on the outside of the drum, it is usually called a clasp brake. Where the drum is pinched between two shoes, similar to a conventional disc brake, it is sometimes called a pinch drum brake, though such brakes are relatively rare. A related type called a band brake uses a flexible belt or "band" wrapping around the outside of a drum. The modern automobile drum brake was first used in a car made by Maybach in 1900, although the principle was only later patented in 1902 by Louis Renault. He used woven asbestos lining for the drum brake lining, as no alternative dissipated heat like the asbestos lining, though Maybach had used a less sophisticated drum brake. In the first drum brakes, levers and rods or cables operated the shoes mechanically. From the mid-1930s,oil pressure in small wheel cylinder and pistons (as in the picture) operated the brakes, though some vehicles continued with purely mechanical systems for decades. Some designs have two wheel cylinders.

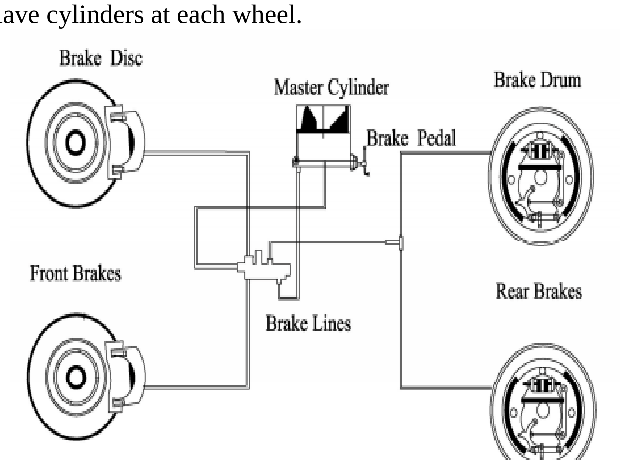


As the shoes in drum brakes wear, brakes required regular manual adjustment until the introduction of self-adjusting drum brakes in the 1950s. Drums are prone to brake fading with repeated use. In 1953, Jaguar fielded three cars equipped with disc brakes at Le Mans, where they won, in large part due to their superior braking over drum-equipped rivals.[3] This spelled the beginning of the crossover of drum brakes to disc brakes in passenger cars. From the 1960s to the 1980s, disc brakes gradually replaced drum brakes on the front wheels of cars. Now practically all cars use disc brakes on the front wheels, and many use disc brakes on all four wheels. Early brake shoes contained asbestos. When working on brake systems of older cars, care must be taken not to inhale any dust present in the brake assembly. The United States Federal Government began to regulate asbestos production, and brake manufacturers had to switch to non-asbestos linings. Owners initially complained of poor braking with the replacements; however, technology eventually advanced to compensate. A majority of daily-driven older vehicles have been fitted with asbestos-free linings. Many other countries also limit the use of asbestos in brakes.

II. LITERATURE REVIEW

The brake system is the most important system in vehicles. It converts the kinetic energy of the moving vehicle into thermal energy while stopping. The basic functions of a brake system are to slow the speed of the vehicle, to maintain its speed during downhill operation, and to hold the vehicle stationary after it has come to a complete stop. The brake system is composed of master cylinder, brake lines, wheel cylinders or slave cylinders, shoes or pads, drum or disc and brake fluid the master cylinder is located under the hood and it is directly connected to the pedal. It converts the foot's mechanical pressure into hydraulic pressure. A mater cylinder has two complete separate cylinders in one housing, each handling two wheels. Even if one cylinder fails, the other cylinder will stop the vehicle. The brake fluid travels from the master cylinder to the wheels through a series of steel tubes. It uses non-corrosive seamless steel tubing with special fittings at all attachment points. Wheel cylinders are cylinders in which the movable pistons convert the hydraulic pressure of the brake fluid into mechanical force. It consists of a cylinder that has two pistons, one on each side. Each piston has a rubber seal and a shaft that connect the piston with a brake shoe. The wheel cylinders of the brake drum are made up of a cylindrical casting, an internal compression spring, two pistons, two rubber cups or seals, and two rubber boots to prevent the entry of dirt and water. The wheel cylinders are fitted with push rods that extent from the outer side of each piston through a rubber boots, where they bear against the brake shoes.

Hydraulic pressure forces the pistons in the wheel cylinder which forces the brake shoes or pads against the machined surface of the brake drums or rotors. When the brake pedal is depressed, it moves the pistons within the master cylinder, pressurizing the brake fluid in the brake lines and slave cylinders at each wheel.



The fluid pressure causes the wheel cylinders pistons to move, which forces the shoes against the brake drums. Brake drums use return springs to pull the pistons back away from the drum when the pressure is released. The lining materials are either asbestos (organic), semi-metallic, or asbestos free materials. The lining material consists of fibers, fillers, binders and friction modifiers. The brake drums are made up of cast iron and have a machined surface inside the drum where the shoes make contact. The brake drums will show the signs of wear as the lining seats themselves against the machined surface of the brake drum. When new drums are installed, the brake drum should be machined smooth. The brake fluid is special oil that has specific properties. It is designed to withstand cold temperatures without thickening as well as very high temperatures without boiling. Literatures are available on the general optimization procedures (Arora 1989, Rao 1995). Rajendran et al (2001) formulated a solution technique using genetic algorithm for design optimization of composite leaf spring. On applying the GA, they have obtained optimum dimensions for the composite leaf spring, which contributes towards achieving the minimum weight with adequate strength and stiffness. Rangaswamy et al (2005) have established a model to optimize the parameters of the composite drive shaft to reduce the weight of the composite drive shaft using genetic algorithm. They have achieved a considerable weight saving and the variation of the stress is also found to be within the permissible limit. Xuelin wang et al (1999) have developed a method for shape optimization process to enable the description of the shape.

III. DESCRIPTION OF PROJECT

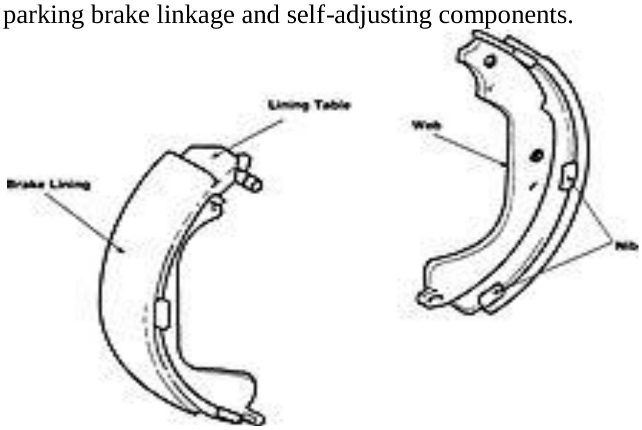
Drum brake components include the backing plate, brake drum, shoe, wheel cylinder, and various springs and pins.

Backing plate: The backing plate provides a base for the other components. The back plate also increases the rigidity of whole set-up, supports the housing, and protects it from foreign materials like dust and other road debris. It absorbs the torque from the braking action, and that is why back plate is also called the "Torque Plate".

Brake drum the brake drum is generally made of a special type of cast iron that is heat-conductive and wear-resistant. It rotates with the wheel and axle. When a driver applies the brakes, the lining pushes radically against the inner surface of the drum, and the ensuing friction slows or stops rotation of the wheel and axle, and thus the vehicle. This friction generates substantial heat.

Wheel cylinder One wheel cylinder operates the brake on each wheel. Two pistons operate the shoes, one at each end of the wheel cylinder. The leading shoe (closest to the front of the vehicle) is known as the primary shoe. The trailing shoe is known as the secondary shoe.

Brake shoe Brake shoes are typically made of two pieces of steel welded together. The friction material is either riveted to the lining table or attached with adhesive. The crescent-shaped piece is called the Web and contains holes and slots in different shapes for return springs, hold-down hardware, parking brake linkage and self-adjusting components.



Linings must be resistant to heat and wear and have a high friction coefficient unaffected by fluctuations in temperature and humidity.

Advantages:

Advantages of drum brakes:

- less expensive to produce
- Slightly lower frequency of maintenance due to better corrosion resistance compared to disks.
- Built-in self energizing effect requires less input force (such as hydraulic pressure).
- Wheel cylinders are somewhat simpler to recondition compared to calipers.
- Minor weight savings, primarily from much smaller and lighter hydraulic cylinders vs. calipers.

Disadvantages:

- Consequence of overheating is fade. this is due to one of several processes or more usually an accumulation of all of them.
- When the drums are heated by hard braking, the diameter of the drum increases slightly due to thermal expansion, so the shoes must move farther and the driver must press the brake pedal farther.
- The properties of the friction material can change if heated, resulting in less friction. This can be a much larger problem with drum brakes than disc brakes, since the shoes are inside the drum and not exposed to cooling ambient air.
- Excessive brake drum heating can cause the brake fluid to vaporize, which reduces the hydraulic pressure applied to the brake shoes. Therefore, the brakes provide less deceleration for a given amount of pressure on the pedal.

IV. WORKING MECHANISM AND CALCULATION

Normal braking: When the brakes are applied, brake fluid is forced under pressure from the master cylinder into the wheel cylinder, which in turn pushes the brake shoes into contact with the machined surface on the inside of the drum. This rubbing action reduces the rotation of the brake drum, which is coupled to the wheel. Hence the speed of the vehicle is reduced. When the pressure is released, return springs pull the shoes back to their rest position.

Drum brake designs: Drum brakes are typically described as either leading/trailing or twin leading. Rear drum brakes are typically of a leading/trailing design (for non-servo systems), or primary/secondary (for duo servo systems) the shoes being moved by a single double-acting hydraulic cylinder and hinged at the same point.[5] In this design, one of the brake shoes always experiences the self-applying effect, irrespective of whether the vehicle is moving forwards or backwards. This is particularly useful on the rear brakes, where the parking brake (handbrake or footbrake) must exert enough force to stop the vehicle from traveling backwards and hold it on a slope. Provided the contact area of the brake shoes is large enough, which isn't always the case, the self-applying effect can securely hold a vehicle when the weight is transferred to the rear brakes due to the incline of a slope or the reverse direction of motion. A further advantage of using a single hydraulic cylinder on the rear is that the opposite pivot may be made in the form of a double-lobed cam that is rotated by the action of the parking brake system.

Calculation: The steps needed to perform an analysis depend on the study type. You complete a study by performing the following steps:

- Create a study defining its analysis type and options. If needed, define parameters of your study.
- A parameter can be a model dimension, material property, force value, or any other input.
- Define material properties.
- Specify restraints and loads.

- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements.
- Fatigue and optimization studies use the meshes in referenced studies.
- Run the study and View results.

Table1. Analysis Properties

S.No	Properties	Values
1	Young's Modulus (MPa)	2 x 10^5
2	Poison's ratio	0.3
3	Elements	Solid – 10 node 187

Table2. Materials properties for Aluminum

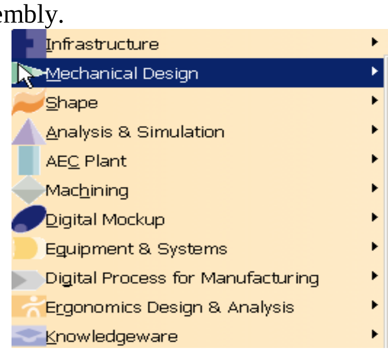
S.No	Material	Aluminum
1	Young's Modulus (MPa)	7.1 x 10^5
2	Poison's ratio	0.33
3	Yield strength (N/mm^2)	240
4	Mass of Component (Kgs)	10.66
5	Density (kg/m^3)	2710

Table3. Materials properties for Carbon Steel:

S.No	Material	Carbon Steel
1	Young's Modulus (MPa)	2.1 x 10^5
2	Poison's ratio	0.30
3	Yield strength (N/mm^2)	250
4	Mass of Component (Kgs)	30.91
5	Density (kg/m^3)	7860

V. DESIGN METHODLOGY OF DRUM BRAKE

The concept of CATIA V5 is to digitally include the complete process of product development, comprising the first draft, the Design, the layout and at last the production and the assembly.



The workbench Mechanical Design is to be addressed in the Context of this CAE training course. CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. CATIA V4,CATIAV5, Pro/ Engineer, NX (formerly Unigraphics), and Solid Works are the dominant systems.

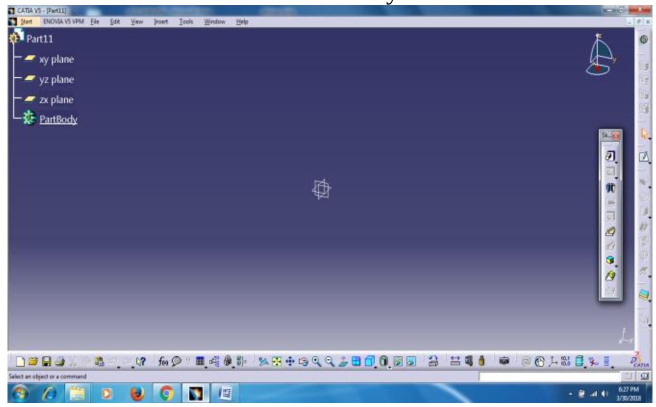


Fig5.1. Home Page of CatiaV5.

A. Modeling of Drum Brake in CATIA V5

This Drum Brake is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

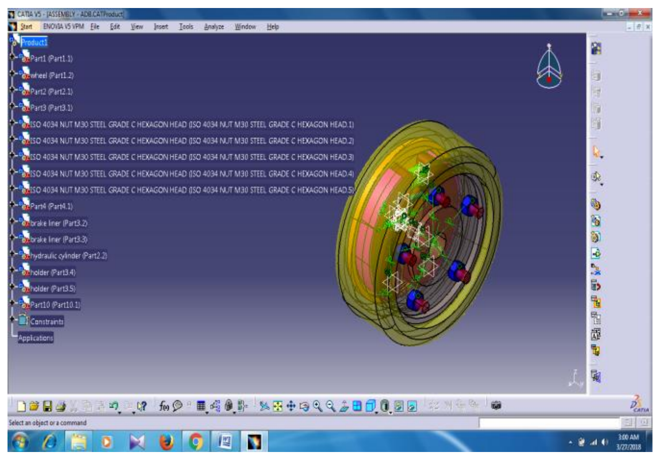


Fig5.2. Model design in CATIA-V5.

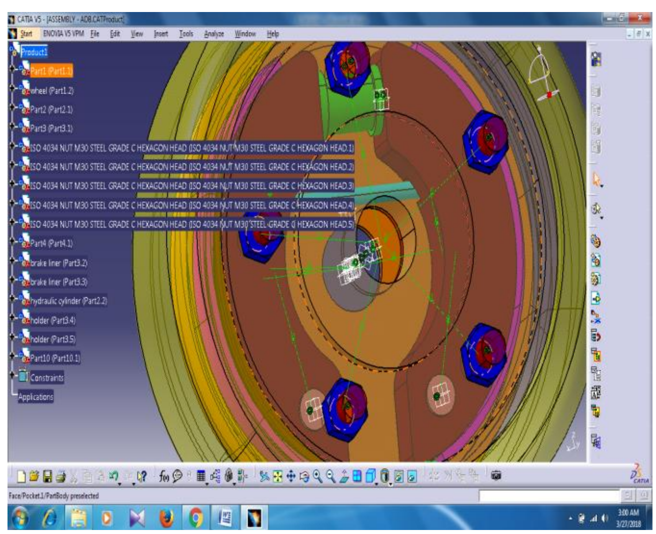


Fig5.3. Model arrangement mechanism in CATIA-V5

VI. ANALYSIS OF AUTOMOBILE DRUM BRAKE

A. Procedure for FE Analysis Using ANSYS

The analysis is done using ANSYS. For compete assembly is not required, motor and attached system is to carried out by applying moments at the rotation location along which axis we need to mention. Fixing location is bottom legs of assembly of the craft.

B. Preprocessor

In this stage the following steps were executed:

Import file in ANSYS window:

File Menu > Import> STEP > Click ok for the popped up dialog box > Click

Browse" and choose the file saved from CATIAV5R19 > Click ok to import the file

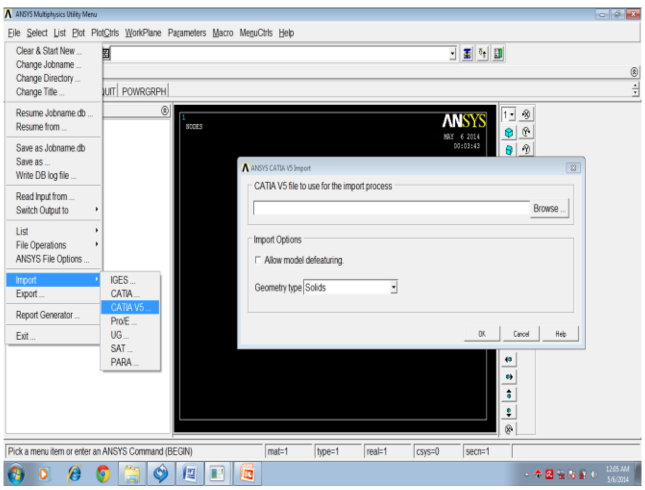


Fig6.1. Importing file in Ansys.

VII. DISCUSSION ON ANALYSYS RESULT

A. Meshed View of components:

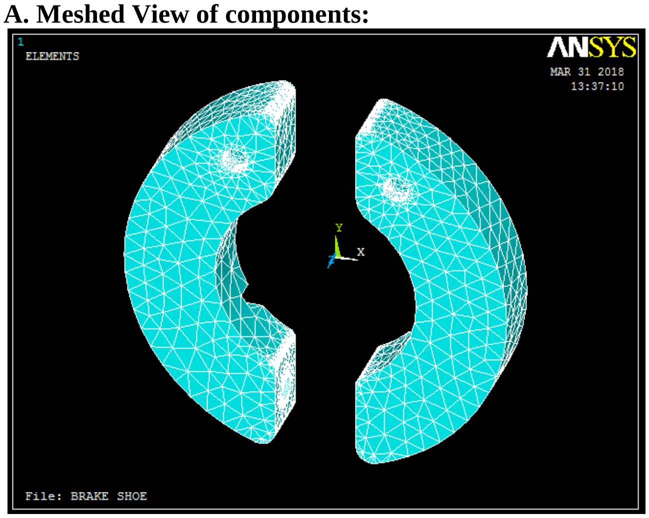


Fig.7.1 Meshing Brake Shoe

After completing the meshing of each assembly components next is to do analysis based on the application. So all the models which are analyzed, we need to mention in the Ansys software to get accurate results as per the original component. Some of the components are needed to be solved using static analysis.

Load is applied and fixing at the bottom key location, was validated in the analysis. The material and geometric properties are listed.

Results for BRAKE SHOE – Aluminum (Al) Material:

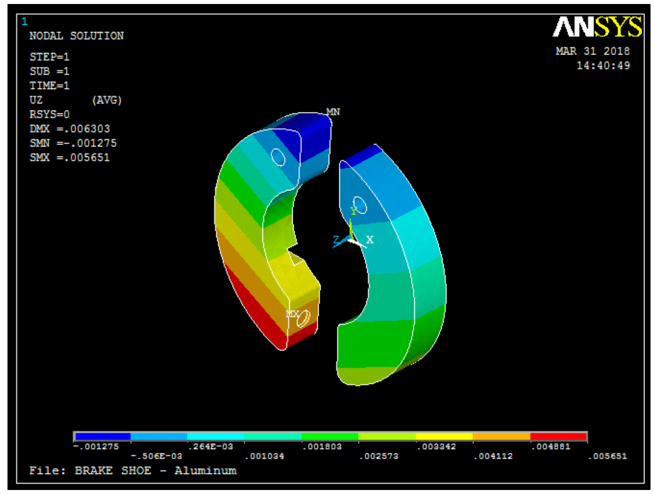


Fig7.2. Displacement

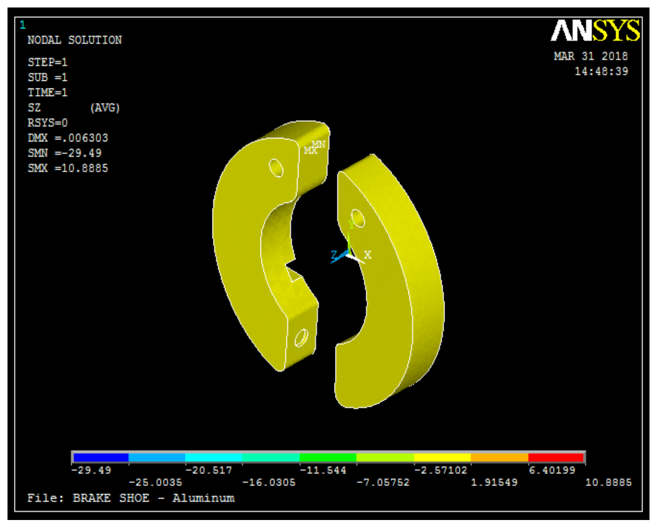


Fig7.3. Stress Analysis.

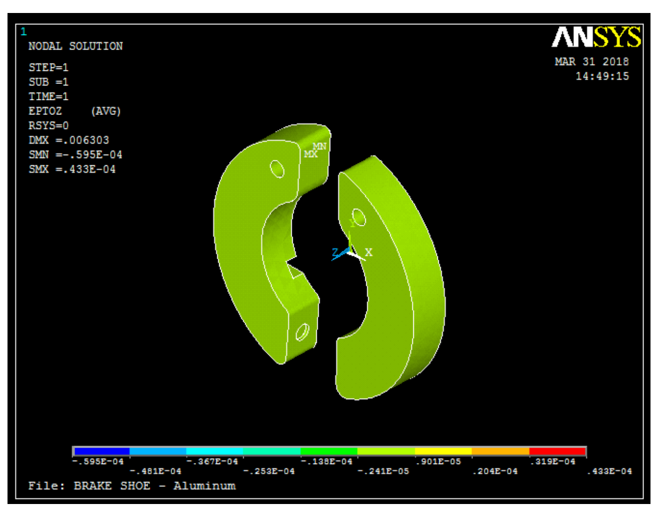


Fig7.4. Strain Analysis

Results for BRAKE SHOE - Carbon Steel(CS) Material:

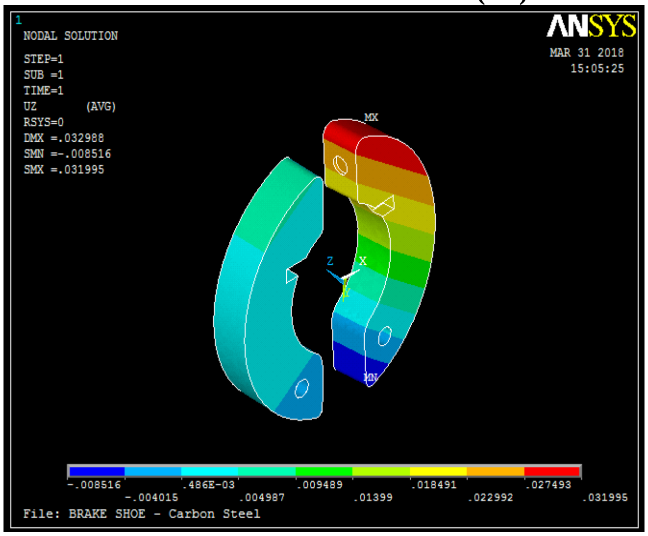


Fig7.5. Displacement.

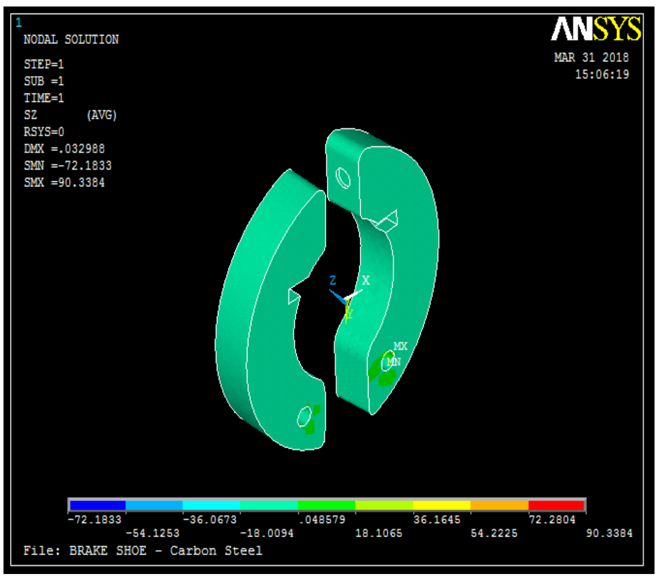


Fig7.6. Stress Analysis

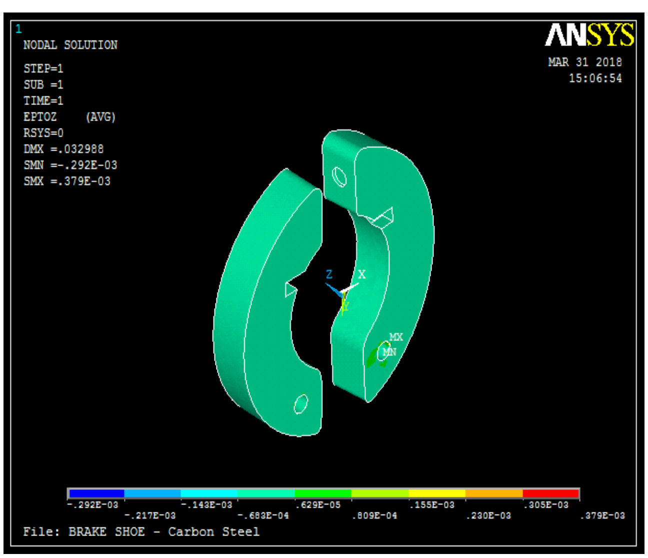


Fig7.7. Strain Analysis.

VIII. CONCLUSION

It can be seen from the above result that, our objective to decrease the velocity of a car has been successful. As shown above figures the displacement of the complete design assembly is meshed and solved using Ansys and displacement is very less. This is showing us that clearly each component in assembly is having minor displacement. Stress is at the fixing location (Minimum Stress which is acceptable). The value is very less compared to both the brake shoe models; this is below the yield point.

S.No	Results	Brake Shoe (Aluminum Material)	Brake Shoe (Carbon Steel Material)
1	Displacement	0.0056 mm	0.0319 mm
2	Stress (Max)	10.88 MPa	90.33 MPa
3	Strain (Max)	0.433 E-04 MPa	0.379 E-03 MPa

The maximum stress is coming, this solution solving with the help of Ansys software so that the maximum stress is less .so we can conclude our design parameters are approximately correct. The design of the car drum brake worked flawlessly in analysis as well. All these facts point to the completion of our objective in high esteem.

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