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# DESIGN AND ANALYSIS OF TRAIN BREAK SYSTEM

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***Abstract:*** A moving train contains energy, known as kinetic energy, which needs to be removed from the train in order to cause it to stop. The simplest way of doing this is to convert the energy into heat. The conversion is usually done by applying a contact material to the rotating wheels or to discs attached to the axles. The material creates friction and converts the kinetic energy into heat. The wheels slow down and eventually the train stops. The material used for braking is normally in the form of a block or pad. The vast majority of the world's trains are equipped with braking systems which use compressed air as the force to push blocks on to wheels or pads on to discs. These systems are known as "air brakes" or "pneumatic brakes". The existing air brake system of Railway coach has the following drawbacks due to excessive brake force on the brake blocks - thermal cracks on wheel tread, brake binding and reduced life of brake block. The aim of the project is to overcome the above said drawbacks by reducing the effective brake force on the brake blocks without affecting the existing designed (Braking Function) requirements .The modeling is done using CATIA and analysis is done using ANSYS. CATIA is a 3d modeling software widely used in the design process. CATIA is used by the automotive and aerospace industries for automobile and aircraft product and tooling design. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements

## I.INTRODUCTION

Imagine a vehicle that is a mile in length. It is so long that the front of the vehicle might be climbing a grade while the back is descending, or perhaps the front and back are turning left while the middle is turning right. This same vehicle is more than 300 times as long as it is wide. Next, imagine that it weighs more than 8 million pounds (3,700,000kg) or 4000 tons. Onboard the vehicle are televisions, foodstuffs and hazardous material. Now visualize the vehicle is traveling at 70 MPH and the operator wants to stop.

This is a complex and challenging problem, but a situation that occurs thousands of times every day. The vehicle of course is a typical freight train. This short paper will introduce the reader to the principles of how train brakes accomplish this remarkable task.

Each power unit (locomotive) has an air compressor that supplies air for the entire train’s braking system. The brake pipe carries the compressed air from the control unit to the rest of the train. Unlike truck brakes (and passenger train brakes for that matter ) this single source of air carries both the air that powers the brakes as well as the signal control them.

### INTRODUCTION TO BRAKES

A brake is a device that decelerates a moving object such as a machine or vehicle by converting its kinetic energy into another form of energy, or a device which prevents an object from accelerating.

Most commonly brakes use friction convert kinetic energy into heat, but in regenerative braking much of the energy is converted instead into useful electrical energy or potential energy in a form such as pressurized air, oil, or a rotation flywheel.

### Air Brake System

The vast majority of the world's trains are equipped with braking systems which use compressed air as the force to push blocks onto wheels or pads on to discs. These systems are known as "air brakes" or "pneumatic brakes". The compressed air is transmitted along the train through a "brake pipe". Changing the level of air pressure in the pipe causes a change in the state of the brake on each vehicle. It can apply the brake, release it or hold it "on" after a partial application. The system is in widespread use throughout the world.

In the air brake's simplest form, called the straight air system, compressed air pushes on a piston in a cylinder. The piston is connected through mechanical linkage to brake shoes that can rub on the train wheels, using the resulting friction to slow the train. The mechanical linkage can become quite elaborate, as it evenly distributes force from one pressurized air cylinder to 8 or 12 wheels.

The pressurized air comes from an air compressor in the locomotive and is sent from car to car by a train line made up of pipes beneath each car and hoses between cars. The principal problem with the straight air braking system is that any separation between hoses and pipes causes loss of air pressure and hence the loss of the force applying the brakes. This deficiency could easily cause a runaway train. Straight air brakes are still used on locomotives, although as a dual circuit system, usually with each bogie (truck) having its own circuit.

In order to design a system without the shortcomings of the straight air system, Westinghouse invented a system wherein each piece of railroad rolling stock was equipped with an air reservoir and a triple valve, also known as a control valve.

When the train brakes are applied during normal operations, the engineer makes a “service application” or a “service rate reduction”, which means that the train line pressure reduces at a controlled rate. It takes several seconds for the train line pressure to reduce and consequently takes several seconds for the brakes to apply throughout the train. In the event the train needs to make an emergency stop, the engineer can make an “emergency application,” which immediately and rapidly vents all of the train line pressure to atmosphere, resulting in a rapid application of the train's brakes. An emergency application also results when the train line comes apart or otherwise fails, as all air will also be immediately vented to atmosphere.

**Comparison of air brakes and vacuum brakes**

| Parameter | Air Brakes | Vacuum Brakes |
|---|---|---|
| Principle of working | The compressed air is used for obtaining brake application. The brake pipe and feed pipe run throughout the length of the coach. Brake pipe and feed pipe on consecutive coaches in the train are coupled to one another by means of respective hose couplings to form a continuous air passage from the locomotive to the rear end of the train. The compressed air is supplied to the brake pipe and feed pipe from the locomotive. The magnitude of braking force increases in steps with the corresponding reduction in brake pipe pressure and vice-versa. | The vacuum brake system derives its brake force from the atmospheric pressure acting on the lower side of the piston in the vacuum brake cylinder while a vacuum is maintained above the piston. The train pipe runs throughout the length of the coach and connected with consecutive coaches by hose coupling. The vacuum is created in the train pipe and the vacuum cylinder by the ejector or exhauster mounted on the locomotive. |

Fig 1.1: Air break

The triple valve is often described as being so named because it performs three functions, but this is a widespread myth, as the triple valve simply performs two functions: it applies the brakes and releases them. In so doing, it supports certain other actions (i.e. it 'holds' or maintains the application and it permits the exhaust of brake cylinder pressure and the recharging of the reservoir during the release). In his patent application, Westinghouse refers to his 'triple-valve device' because of the three componentvalvular parts comprising it: the diaphragm-operated poppet valve feeding reservoir air to the brake cylinder, the reservoir charging valve, and the brake cylinder release valve. When he soon improved the device by removing the poppet valve action, these three components became the piston valve, the slide valve, and the graduating valve.

- If the pressure in the train line is lower than that of the reservoir, the brake cylinder exhaust portal is closed and air from the car's reservoir is fed into the brake cylinder to apply the brakes. This action continues until equilibrium between the brake pipe pressure and reservoir pressure is achieved. At that point, the airflow from the reservoir to the brake cylinder is lapped off and the cylinder is maintained at a constant pressure.

If the pressure in the train line is higher than that of the reservoir, the triple valve connects the train line to the reservoir feed, causing the air pressure in the reservoir to increase. The triple valve also causes the brake cylinder to be exhausted to atmosphere, releasing the brakes.

- As the pressure in the train line and that of the reservoir equalize, the triple valve closes, causing the air pressure in the reservoir and brake cylinder to be maintained at the current level.

Unlike the straight air system, the Westinghouse system uses a reduction in air pressure in the train line to apply the brakes. When the engineer (driver) applies the brake by operating the locomotive brake valve, the train line vents to atmosphere at a controlled rate, reducing the train line pressure and in turn triggering the triple valve on each car to feed air into its brake cylinder. When the engineer releases the brake, the locomotive brake valve portal to atmosphere is closed, allowing the train line to be recharged by the compressor of the locomotive. The subsequent increase of train line pressure causes the triple valves on each car to discharge the contents of the brake cylinder to atmosphere, releasing the brakes and recharging the reservoirs.

Under the Westinghouse system, therefore, brakes are applied by reducing train line pressure and released by increasing train line pressure. The Westinghouse system is thus fail safe—any failure in the train line, including a separation ("break-in-two") of the train, will cause a loss of train line pressure, causing the brakes to be applied and bringing the train to a stop.

## II. COMPONENTS OF AIR BRAKE SYSTEM

The diagram below shows the principal parts of the air brake system and these are described below

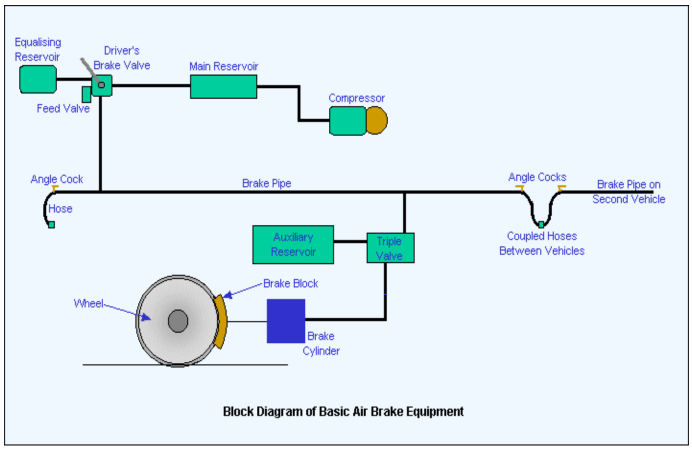


**Fig 2.1: Block diagram of basic air brake equipment**

### 2.1 Compressor

It is the pump which draws air from atmosphere and compresses it for use on the train. Its principal use is for the air brake system, although compressed air has a number of other uses on trains.

### 2.2 Main Reservoir

It is a storage tank for compressed air for braking and other pneumatic systems.

### 2.3Driver's Brake Valve

It is the means by which the driver controls the brake. The brake valve will have (at least) the following positions: "Release", "Running", "Lap" and "Application" and "Emergency". There may also be a "Shut Down" position, which locks the valve out of use.

The "Release" position connects the main reservoir to the brake pipe. This raises the air pressure in the brake pipe as quickly as possible to get a rapid release after the driver gets the signal to start the train.

In the "Running" position, the feed valve is selected. This allows a slow feed to be maintained into the brake pipe to counteract any small leaks or losses in the brake pipe, connections and hoses.

"Lap" is used to shut off the connection between the main reservoir and the brake pipe and to close off the connection to atmosphere after a brake application has been made. It can only be used to provide a partial application. A partial release is not possible with the common forms of air brake, particularly those used on US freight trains.

"Application" closes off the connection from the main reservoir and opens the brake pipe to atmosphere. The brake pipe pressure is reduced as air escapes. The driver (and any observer in the know) can often hear the air escaping.

Most driver's brake valves are fitted with an "Emergency" position. Its operation is the same as the "Application" position, except that the opening to atmosphere is larger to give a quicker application.

### 2.4 Feed Valve

To ensure that brake pipe pressure remains at the required level, a feed valve is connected between the main reservoir and the brake pipe when the "Running" position is selected. This valve is set to a specific operating pressure. Different railways use different pressures but they generally range between 65 and 90 psi (4.5 to 6.2 bar).

### 2.5 Equalizing Reservoir

This is a small pilot reservoir used to help the driver select the right pressure in the brake pipe when making an application. When an application is made, moving the brake valve handle to the application position does not discharge the brake pipe directly, it lets air out of the equalizing reservoir. The equalizing reservoir is connected to a relay valve (called the "equalizing discharge valve" and not shown in my diagram) which detects the drop in pressure and automatically lets air escape from the brake pipe until the pressure in the pipe is the same as that in the equalizing reservoir.

The equalizing reservoir overcomes the difficulties which can result from a long brake pipe. A long pipe will mean that small changes in pressure selected by the driver to get a low rate of braking will not be seen on his gauge until the change in pressure has stabilized along the whole train. The equalizing reservoir and associated relay valve allows the driver to select a brake pipe pressure without having to wait for the actual pressure to settle down along a long brake pipe before he gets an accurate reading.

### 2.6 Brake Pipe

The pipe running the length of the train, which transmits the variations in pressure required to control the brake on each vehicle. It is connected between vehicles by flexible hoses, which can be uncoupled to allow vehicles to be separated. The use of the air system makes the brake "fail safe", i.e. loss of air in the brake pipe will cause the brake to apply. Brake pipe pressure loss can be through a number of causes as follows:

- A controlled reduction of pressure by the driver
- A rapid reduction by the driver using the emergency position on his brake valve
- A rapid reduction by the conductor (guard) who has an emergency valve at his position
- A rapid reduction by passengers (on some railways) using an emergency system to open a valve
- A rapid reduction through a burst pipe or hose
- A rapid reduction when the hoses part as a result of the train becoming parted or derailed.

### 2.7 Angle Cocks

At the ends of each vehicle, "angle cocks" are provided to allow the ends of the brake pipe hoses to be sealed when the vehicle is uncoupled. The cocks prevent the air being lost from the brake pipe.

### 2.8 Coupled Hoses

The brake pipe is carried between adjacent vehicles through flexible hoses. The hoses can be sealed at the outer ends of the train by closing the angle cocks.

### 2.9 Brake Cylinder

Each vehicle has at least one brake cylinder. Sometimes two or more are provided. The movement of the piston contained inside the cylinder operates the brakes through links called "rigging". The rigging applies the blocks to the wheels. Some modern systems use disc brakes. The piston inside the brake cylinder moves in accordance with the change in air pressure in the cylinder.

### 2.10 Auxiliary reservoir

The operation of the air brake on each vehicle relies on the difference in pressure between one side of the triple valve piston and the other. In order to ensure there is always a source of air available to operate the brake, an "auxiliary reservoir" is connected to one side of the piston by way of the triple valve. The flow of air into and out of the auxiliary reservoir is controlled by the triple valve.

### 2.11 Brake Block

This is the friction material which is pressed against the surface of the wheel tread by the upward movement of the brake cylinder piston. Often made of cast iron or some composition material, brake blocks are the main source of wear in the brake system and require regular inspection to see that they are changed when required.

**2.12 Brake Rigging**

This is the system by which the movement of the brake cylinder piston transmits pressure to the brake blocks on each wheel. Rigging can often be complex, especially under a passenger car with two blocks to each wheel, making a total of sixteen. Rigging requires careful adjustment to ensure all the blocks operated from one cylinder provide an even rate of application to each wheel. If you change one block, you have to check and adjust at axle.

**2.13 Triple Valve**

The operation of the brake on each vehicle is controlled by the "triple valve", so called because it originally comprised three valves - a "slide valve", incorporating a "graduating valve" and a "regulating valve". It also has functions - to release the brake, to apply it and to hold it at the current level of application. The triple valve contains a slide valve which detects changes in the brake pipe pressure and rearranges the connections inside the valve accordingly. It either:

- recharges the auxiliary reservoir and opens the brake cylinder exhaust,
- closes the brake cylinder exhaust and allows the auxiliary reservoir air to feed into the brake cylinder or
- holds the air pressures in the auxiliary reservoir and brake cylinder at the current level

**2.14 Brake Application**

- The driver has placed the brake valve in the "Application" position. This causes air pressure in the brake pipe to escape. The loss of pressure is detected by the slide valve in the triple valve. Because the pressure on one side (the brake pipe side) of the valve has fallen, the auxiliary reservoir pressure on the other side has pushed the valve (towards the right) so that the feed groove over the valve is closed. The connection between the brake cylinder and the exhaust underneath the slide valve has also been closed. At the same time a connection between the auxiliary reservoir and the brake cylinder has been opened. Auxiliary reservoir air now feeds through into the brake cylinder. The air pressure forces the piston to move against the spring pressure and causes the brake blocks to be applied to the wheels. Air will continue to pass from the auxiliary reservoir to the brake cylinder until the pressure in both is equal. This is the maximum pressure the brake cylinder will obtain and is equivalent to a full application. To get a full application with a reasonable volume of air, the volume of the brake cylinder is usually about 40% of that of the auxiliary reservoir.
- **Lap**
- The purpose of the "Lap" position is to allow the brake rate to be held constant after a partial application has been made.
- When the driver places the brake valve in the "Lap" position while air is escaping from the brake pipe, the escape is suspended. The brake pipe pressure stops falling. In each triple valve, the suspension of this loss of brake pipe pressure is detected by the slide valve because the auxiliary pressure on the opposite side continues to fall while the brake pipe pressure stops falling. The slide valve therefore moves towards the auxiliary reservoir until the connection to the brake cylinder is closed off. The slide valve is now half-way between its application and release positions and the air pressures are now is a state of balance between the auxiliary reservoir and the brake pipe. The brake cylinder is held constant while the port connection in the triple valve remains closed. The brake is "lapped".
- Lap does not work after a release has been initiated. Once the brake valve has been placed in the "Release" position, the slide valves will all be moved to enable the recharge of the auxiliary reservoirs. Another application should not be made until sufficient time has been allowed for this recharge. The length of time will depend on the amount of air used for the previous application and the length of the train.

## III. DESIGN OF TRAIN BRAKE

Fast expanding industrialization of country needs fast movement of higher freight and passenger. Railway traffic coupled with safety of men and material. Air brake system plays an important role in running of trains.

The existing air brake system of Railway coach has the following draw backs due to excessive brake force on the brake blocks.

- Thermal Cracks on wheel tread.
- Brake binding.
- Reduce life of brake blocks.

**3.1 MODIFICATION TO THE EXISTING SYSTEM**

In the existing horizontal lever and bottom fulcrum bracket plate, the modifications are to be carried out.

- The bottom fulcrum bracket plate and horizontal lever assembly is to be removed from brake rigging mounted under the coach.
- The horizontal lever is to be rotated by 180 degrees so that the existing SAB

(Slack adjusting barrel) and hole will become brake cylinder end hole and the brake cylinder end hole become sab end hole for modification lever.

- The existing bottom fulcrum bracket pivot hole on the lever is to be closed suitably.
- A new hole of 55 mm diameter is tobe drilled in horizontal lever at the distance of 328 mm from the centre of the sab end hole. Before drilling 55mm diameter hole, a12mm diameter pilot hole is to be drilled.
- From the centre line of the newly provided hole (i.e. 55 mm diameter hole) a hole of 10 mm diameter is to be drilled in the horizontal lever at a distance of 150 mm to avoid the relative movement of horizontal levers so that both will act as one unit

- Nylon bushes of suitable size are to be provided in the newly drilled holes to avoid metal contact, thereby reducing wear and tear, friction and for noise control
- The modification lever assembly is to be assembled on the under frame.

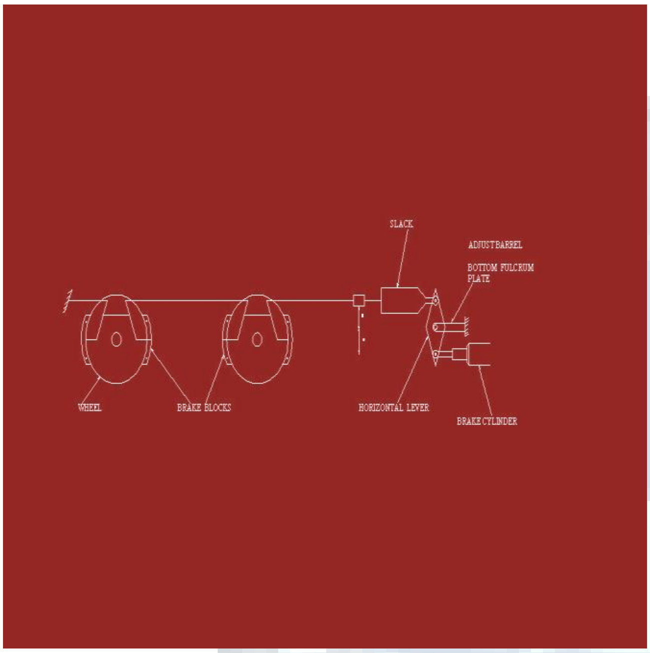


Fig 3.1.1: line diagram of railway linkages

**3.1.1.BRAKE RIGGING ARRANGEMENT**

Before modification, X = 420 mm, Y = 280 mm

Total 700 mm

After modification, X = 372 mm, Y = 328 mm

Total 700 mm

**AIR BRAKE SYSTEM**

The Railway administration introduced highly efficient and reliable air brake system over heavy freight wagons and coaches. Thus conventional vacuum brake on the rolling stock has been replaced which has several limitations.

**Limitations of vacuum Brake system:**

- Speed limitations due to longer braking distance.
- Brakes releasing time is more.
- Limitations on train loads and lengths.
- Vacuum in the last vehicle is not maintained as desired.
- Lesser braking force generation by brake cylinder.
- Higher maintenance cost.

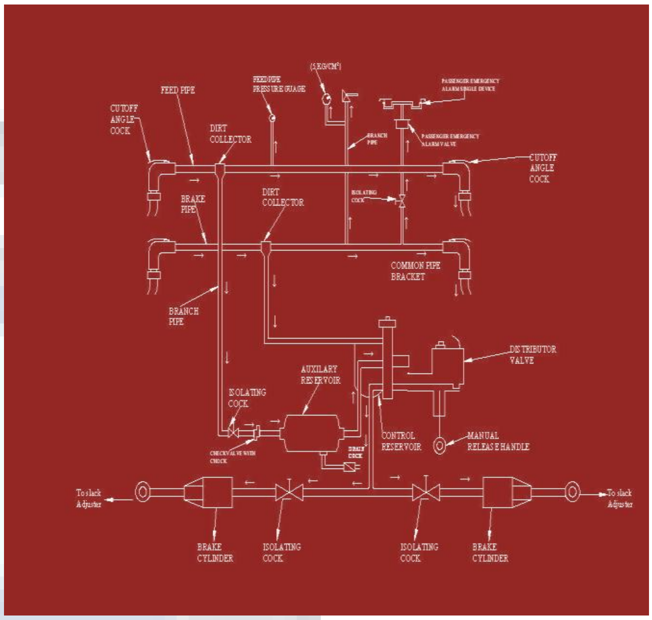


Fig 3.1.2: line diagram of railway braking system

**TROUBLE WITH EXISTING SYSTEM**

Trouble with existing system is that the excessive brake force development at the brake blocks with the existing air brake system which results in

- Thermal cracks on wheel tread.
- Brake binding.
- Reduced life of the brake blocks.

**Suggestions Modification:**

The suggested modification is to reduce the excessive brake force on brake by changing the existing horizontal leverage ratio 420: 280 to a modified value 372: 328 which in turn reduces the excessive brake force.

**3.2 Standard Designed values:**

According to RDSO (Research and Development Standards Organization), Lucknow, the following are standard designed values for Railway air brake system.

- Brake cylinder diameter : 355.6 mm (14 inches)
- Effective piston force of brake cylinder :3.6 tons.
- Number of brake cylinders per coach : 2
- Number of brake bogie levers per coach : 4.
- Mechanical efficiency of brake rigging : 0.9.
- Brake rigging ratio : 0.9.
- Number of brake blocks per one coach : 16

**3.3 Air brake Details:**

- Mechanical advantage of bogie

Bogie leverage ratio X no. of bogie levers

- Mechanical advantage of complete brake system

Mechanical advantage of bogie X Horizontal leverage ratio

- Theoretical brake force.

Mechanical advantage of complete brake system X Effective piston force

X No. of Brake cylinders per coach

- Minimum effective brake force

Theoretical brake force X Brake rigging ratio X Mechanical efficiency of brake rigging

**3.4 BRAKE FORCE CALCULATIONS:**

| **S.No** | **Description** | **Existing** | **Modified** |
|---|---|---|---|
| **1** | Bogie leverage ratio | 1 : 1 | 1: 1 |
| **2** | Mechanical advantage of bogie = Bogie leverage ratio x No. of bogie levers | 1 x 4 = 4 | 1 x 4 = 4 |
| **3** | Mechanical advantage of complete brake system=Mechanical advantage of bogie x horizontal leverage ratio | 420 x 4 = 6<br>280 | 372 x4 = 4.536<br>328 |
| **4** | Theoretical brake force = Mechanical advantage of complete brake system x Effective piston force x No. Of brake cylinders | 6 x 3.6 x 2 = 43.2 tons | 4.536 x 3.6x 2 =32.66 tons |
| **5** | Minimum effective brake force = Theoretical brake force x mechanical efficiency of brake rigging x brake rigging ratio | 43.2 x 0.9 x 0.9= 34.99tons | 32.66 x 0.9 x 09 = 22.45 |

## IV. OUTPUT RESULTS

**Nodal Displacement Vector Sum**

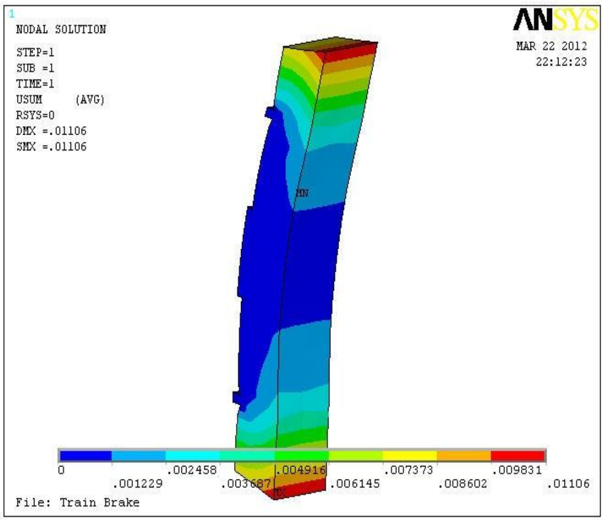


Fig 4.1: elemental vector diagram of brake shoe

The Maximum Displacement in the Brake Block for a Brake force of 2.187 ton per block is 11.06 mm.

**Von Mises Stress**

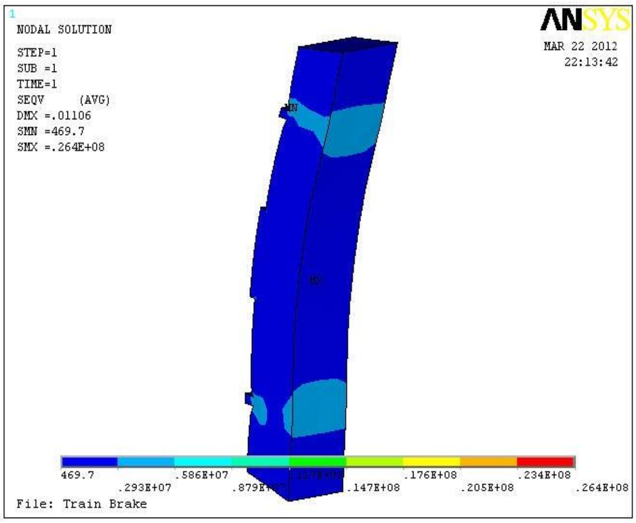


Fig 4.2: von mises stress diagram of brake shoe

The Maximum Stress induced in the Brake Block for a Brake force of 2.187 ton per block is 26.4 Mpa.

- The minimum effective brake force before modification = 34.99 ton
- The minimum effective brake force after modification = 26.45 ton
- Reduction in minimum effective brake force due to modification
  = 34.99 – 26.45
  = 8.54 ton
- Percentage of reduction in minimum effective brake force
  = 8.54 X 100
  34.99
  = 24.4%
- The minimum effective brake force on each brake block before modification
  = 34.99
  16

= 2.187 ton

- The minimum effective brake force on each brake block after modification
  = 26.45 / 16
  = 1.653 ton

- The reduction in minimum effective brake force on each brake block due to modification
  = 2.187 – 1.653
  = 0.534 ton

- The compressive stress induced in the brake block due to modified minimum effective brake force = 19.9Mpa

- The ultimate compressive stress of the brake block material before modification= 26.4Mpa.

## V.CONCLUSION

According to the existing air brake system of Railway coach the brake force applied per one brake block is 2.187 ton. The following drawbacks due to existing brake force on the brake blocks - thermal cracks on wheel tread, brake binding and reduced life of brake block. A modification is done in the project to overcome the above said troubles by reducing the minimum effective brake force without affecting the existing designed requirements. After modification, the brake force applied per one brake block is 1.653 ton. The maximum compressive stress induced in the brake block by the application of modified brake force (1s.653 ton) is 19.9Mpa which is less as compared with stress induced in the brake block by the existing brake force (2.187 ton) is 26.4Mpa. With the application of modified minimum brake force, the brake block is safe. Hence the modification carried out in this project work is justified.

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