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DESIGN EVALUATION AND MATERIAL OPTIMIZIATION OF TRAIN BRAKE

[1] DR.PAVAN BALAPPA BAGALI, [2] HEMANT KUMAR SAHU, [3] K POORNACHANDHAR, [4] M SOWMYA, [5] N VEERESHU, [6] U UPENDAR

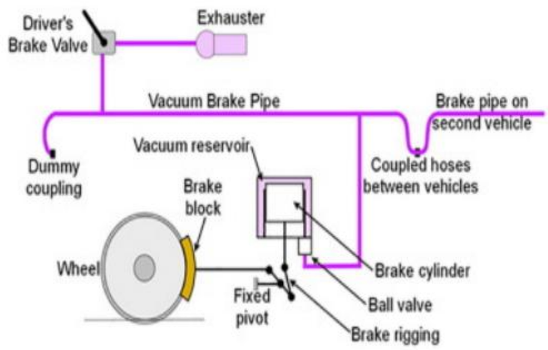
[1]Assistant Professor, Dept. Of MECH, DRK INSTITUTE OF SCIENCE & TECHNOLOGY, Hyderabad,

[2,3,4,5,6,]BTech Student, Dept. Of MECH, DRK INSTITUTE OF SCIENCE & TECHNOLOGY, Hyderabad

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. To validate the strength of train brake, Structural and Modal analysis are to be done on the train brake. In structural analysis, ultimate stress limit for the design is found and in modal analysis, mode shapes of the train brake for number of modes can be analyzed. The analysis is done by applying two different materials Cast Iron and High Carbon Steel for train brake*

I. INTRODUCTION

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 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.



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.

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.

a. Thermal Cracks on wheel tread.

b. Brake binding.

c. Reduce life of brake blocks.

A modification is made in this project work to overcome the above said troubles by reducing the minimum effective brake force on the brake blocks without affecting- the existing designed(braking function) requirements The suggested modification is to change the horizontal leverage ratio in the horizontal lever. The horizontal lever transfers braking force from brake cylinder to the brake rigging arrangement of Air brake system. By changing the horizontal leverage ratio, the mechanical advantage of the brake system can be reduced which in turn reduces the minimum effective brake force on the brake blocks. The procedure of implementation of modification and brake force calculation are discussed in this research

Air Brake System

In Air brake system compressed air is used for operating the brake system, the locomotive compressor charges continuously the feed pipe and brake pipe throughout the length of the train. The feed pipe is connected to the auxiliary reservoir and the brake pipe is connected to the brake cylinder through the distributor valve. Brake application takes place by dropping the air pressure in the brake pipe. Brake releasing by recharging brake pipe pressure to the required valve (5kg/cm2) through the driver valve. 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 a. Speed limitations due to longer braking distance. b. Brakes releasing time is more.

Limitations on train loads and lengths.

a. Vacuum in the last vehicle is not maintained as desired.

b. Lesser braking force generation by brake cylinder.

c. Higher maintenance cost. Air brake system has the following major advantages over vacuum brake system.

Rail or train transportation is one of the important and economical transportation systems available. Different types of braking systems are used in railway vehicles. 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 breaking 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 . The disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc (or rotor) usually made of cast iron or ceramic composites (including carbon, Kevlar and silica), is connected to the wheel and /or the axle. To stop the wheel, friction material in the form of brake pads is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop Axle mounted disc brakes require sufficient space to accommodate therefore used in trailer bogies. Wheel mounted disc brakes are used on motor bogies because it requires accommodating the traction motor only and having insufficient space for an axle mounted brake. In both systems, compressed air or oil is applied to a brake cylinder that pushes the brake lining against the disc.

Brake discs are dead weight that is useful only during braking; therefore, operators can install lighter discs. Carbon/carbon-composite multi-disc and aluminum composite discs offer lighter weights and are widely used. Tread of block braking is popular and frequently used mechanical braking system in trains. In tread braking, the braking action is obtained by pressing

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one, two or four brake block (brake shoes) against the tread of a wheel. There are different kinds of brake blocks materials; cast iron, organic composite materials and inter materials. During tread braking, kinetic energy of train gets dissipated in the form of heat at wheel – brake block interfaces. Heat generated during tread braking is shared by wheel and brake blocks. The main components of air braking system

II. LITERATURE SURVEY

Dr. D.S. Deshmukh & Jha Shankar Madanmohan , "Design Evaluation and Material Optimization of a Train Brake " stated that, 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 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". Vempada Vasudeva Rao & P. Jagan Mohan Rao "Design, Static Analysis and Comparison of Materials on Train Brake Pad" Stated that ,Train is one of the major transportation which makes the things easier at low cost. This train moves by fossil fuel and the consumption of the fuel is depends up on the engine performance and braking system, as the kinetic energy of the train is to be reduced by breaking and electric system. This kinetic energy is to be converted into heat by contact material to the rotating wheels or discs which are attached to the axles. Ramana Chary & MD Ezaz Kha "Design and analysis of train brake system" Stated that ,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.

III SOFTWARE OVERVIEW:

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Introduction to CATIA

CATIA-V5 is the industry's de factor standard 3D mechanical design suit. It is the world's leading **CAD/CAM /CAE** software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model. Because that CATIA-V5 is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains. Catia-v5 is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. Catia-v5 provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

Advantages of CATIA-V5:

- It is much faster and more accurate.
- Once a design is completed. 2D and 3D views are readily obtainable
- The ability to changes in late design process is possible.
- It is user friendly both solid and surface modeling can be done.
- It provides a greater flexibility for change. For example if we like to change the dimensions of our model, all the related dimensions in design assembly, manufacturing etc. will automatically change.
- It provides clear 3D models, which are easy to visualize and understand.
- CATIA provides easy assembly of the individual parts or models created it also decreases the time required for the assembly to a large extent.

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MODELING SOFTWARE:

CatiaV5 R15 is an interactive Computer- Aided Design and Computer Aided Manufacturing system. The CAD functions automate the normal engineering, design and drafting capabilities found in today's manufacturing companies. The CAM functions provide NC programming for modern machine tools using the CatiaV5 R15 design model to describe the finished part. CatiaV5 R15 functions are divided into "applications" of common capabilities. These applications are supported by a prerequisite application called "CatiaV5 R15 Gateway".

CatiaV5R15 is fully three dimensional, double precision system that allows to accurately describing almost any geometric shape. By combining these shapes, one can design, analyze, and create drawings of products.

BASIC PROCEDURE FOR CREATING A 3-D MODEL IN CATIAV5 R15:

Creation of a 3-D model in CatiaV5 R15 can be performed using three workbenches i.e., sketcher, modeling and assembly.

Sketcher:

Sketcher is used to create two-dimensional representations of profiles associated within the part. We can create a rough outline of curves, and then specify conditions called constraints to define the shapes more precisely and capture our design intent. Each curve is referred to as a sketch object.

Creating a new sketch:

To create a new sketch, chose Start→Mechanical Design→Sketcher then select the reference plane or sketch plane in which the sketch is to be created.

SKETCH PLANE

The sketch plane is the plane that the sketch is located on. The sketch plane menu has the following options:

Face/Plane: With this option, we can use the attachment face/plane icon to select a planar face or existing datum plane. If we select a datum plane, we can use the reverse direction button to reverse the direction of the normal to the plane.

XC-YC, YC-ZC, and ZC-XC: With these options, we can create a sketch on one of the WCS planes. If we use this method, a datum

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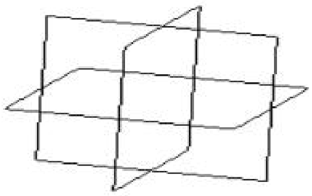
plane and two datum axes are created as below.



IV MODELING

FEATURE CREATION

"Feature" is an all-encompassing term that refers to all solids, bodies and primitives used in CatiaV5 R15Form Features are used to supply detail to the model in the form of standard feature types. These include hole, slot, groove, pocket, rib and pad. We can also create our own custom features using the User Defined option. All of these features are associative.

Reference Features allow creating reference planes, reference lines and reference points. These references can assist in creating features on cylinders, cones, spheres and revolved solid bodies. Reference planes can also aid in creating features at angles other than normal to the faces of a target solid. Dress up Feature options let's us modify existing solid bodies and features. These include a wide assortment of options such as edge fillet, variable fillet, chambers, draft, offset face, shell and tapers.

Wire frame and Surface design let's us create surface and solid bodies. A surface body with zero thickness, and consists of a collection of faces and edges that do not close up to enclose a volume. Most Free Form Feature options create surface bodies.

CREATION OF SOLID BODIES

We can create solid bodies by sweeping sketch and non-sketch geometry to create associative features or Creating primitives for the basic building blocks, then adding more specific features (for example, holes and slots).

Sweeping sketch and non-sketch geometry lets us to create a solid body with complex geometry. This method also gives us total control over the editing of the body. Editing is done by changing the swept creation parameters or by changing the sketch. Editing the sketch causes the swept feature to update to match the sketch.

Creating a solid body using primitives results in a simple geometry solid body. Making changes to primitives is more difficult, because primitives cannot always be parametric ally edited. We can use

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primitives when we do not need to be concerned with editing the model. Generally, however, it is to our advantage to create the model from a sketch.

CATIA User Interface:

Below is the layout of the elements of the standard CATIA application.

A. Menu Commands
B. Specification Tree
C. Window of Active document
D. Filename and extension of current document
E. Icons to maximize/minimize and close window
F. Icon of the active workbench
G. Toolbars specific to the active workbench
H. Standard toolbar
I. Compass
J. Geometry are

Different types of engineering drawings, construction of solid models, assemblies of solid parts can be done using inventor.

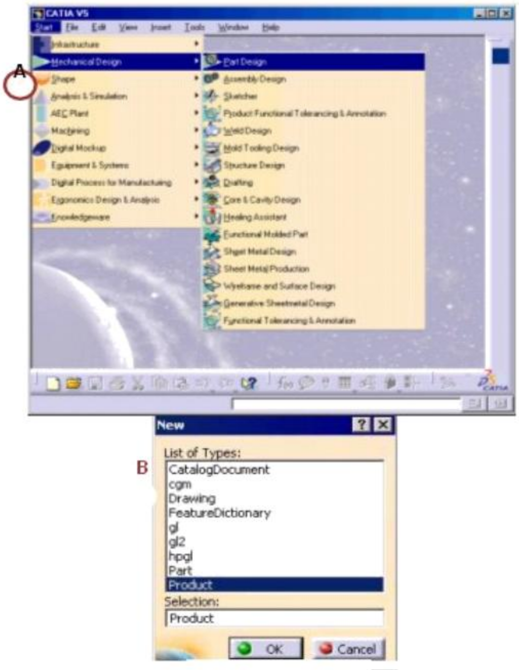
Different types of files used are:

Part files: .CAT Part

Assembly files: .CAT Product

Workbenches

Workbenches contain various tools that you may need to access during your part creation. You can switch between any primary workbenches using the following two ways:



Use the Start Menu.

Click File >New to create a new document with a particular file type.

The associated workbench automatically launches.

Generally all CAD models are generated in the same passion given bellow :

: Enter CAD environment by clicking, later into part designing mode to construct model.

: Select plane as basic reference.

: Enter sketcher mode.

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Environment

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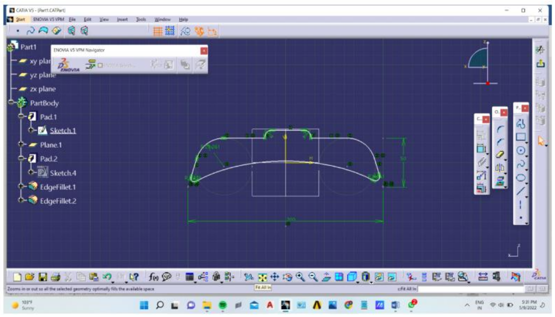

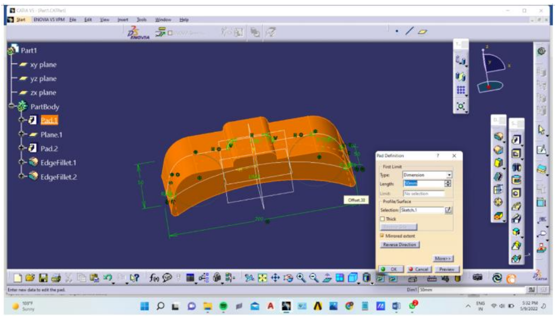

V MODAL ANALSYS

A Modal analsys determines the vibration characteristics (natural frequencies and corresponding mode shapes)of a structure or a machine component. It can serve as a starting point for other types of analsys by detecting unconstrained bodies in contact analysis or by indicating the necessary time step size for a transient analysis, for example. In addition the modal analyses results may be used in a downstream dynamic simulation employing mode. Super position methods, such as harmonic response analsys random vibration analysis or a spectrum analsys. The natural frequencies and mode shapes are important parameters in the design of a structure for a dynamic loading condition.

1. Add a modal analsys template by dragging the template from the tool box in to the project schematic or by double clicking the template in the tool box.

2. Load the geometry by right clicking on the geometry cell and choosing import geometry.

3. View the geometry by right clicking on the model cell. Alternatively, you can right click the set up cell and select edit. This step will launch mechanical application.

4. In the mechanical application window ,complete modal analsys using the mechanical applications tools and features. See modal analsys in the mechanical application help for more information on conducting a modal analsys in the mechanical application

STATIC STRUCTURAL ANALYS

A Static structural analysis determines the stress, displacements, strains, forces in structures or components caused by loads that do not induced significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

1. Add a static structural analysis template by dragging the template from the tool box into the project schematic or by double clicking the template in the tool bars.

2. Load on the geometry by right clicking on the geometry cell and choosing import geometry.

3. View the geometry by right clicking on the modeling cell and choosing edit or double clicking the model cell alternatively you can right click the set up cell and select edit. This step will touch the mechanical application.

4. The mechanical application window, complete static structural analysis using the mechanical applications tools and features.

Generic Steps to Solving any Problem in ANSYS:

Like solving any problem analytically, you need to define

(1) your solution domain,

(2) the physical model,

(3) boundary conditions and

(4) the physical properties.

You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

Build Geometry

Construct a two or three dimensional representation of the object to be modeled and tested using the work plane coordinate system within ANSYS.

Define Material Properties

Now that the part exists, define a library of the necessary materials that compose the object (or project) being modeled. This includes thermal and mechanical properties.

Generate Mesh

At this point ANSYS understands the makeup of the part. Now define how the modeled system should be broken down into finite pieces.

Apply Loads

Once the system is fully designed, the last task is to burden the system with

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constraints, such as physical loading or boundary conditions.

Obtain Solution

This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

Present the Results

After the solution has been obtained, there are many ways to present ANSYS' results, choose from many options such as tables, graphs, and contour plots.

Unequalled Depth

The ANSYS commitment is to provide unequalled technical depth in any simulation domain. Whether it's structural analysis, fluids, thermal, elector magnetic, meshing, or process & data management we have the level of functionality appropriate for your requirements. Through both significant R&D investment and key acquisitions, the richness of our technical offering has flourished. We offer consistent technology solutions, salable from the casual user to the experienced analyst, and seamless in their connectivity. In addition, we have world class expertise for all of these domains, available to help you implement your ANSYS technology successfully.

Unparalleled Breadth

Unlike other engineering simulation companies, who may possess competence in one, or maybe two, fields, ANSYS can provide this richness of functionality across a broad range of disciplines, whether it be explicit, structural, fluids, thermal, or electromagnetic. All of these domains are supported by a complete set of analysis types and wrapped by a unified set of meshing tools. Together, these domains form the cornerstones of the ANSYS portfolio for Simulation Driven Product Development, and constitute a complete portfolio of unparalleled breadth in the industry.

Comprehensive multi physics

A strong foundation for multi-physics sets ANSYS apart from other engineering simulation companies. Our technical depth and breadth, in conjunction with the scalability of our product portfolio, allows us to truly couple multiple physics in a single simulation. Technical depth in all fields is essential to understand the complex interactions of different physics.

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The portfolio breadth eliminates the need for clunky interfaces between disparate applications. The ANSYS capability in multi physics is unique in the industry; flexible, robust and architecture in ANSYS Workbench to enable you to solve the most complex coupled physics analyses in a unified environment.

Engineered Scalability

Scalability is a critical consideration when considering software for both current and long term objectives. At ANSYS engineered scalability means flexibility you need has been designed for your particular needs. ANSYS provides you with the ability to apply the technology at a level that is appropriate for the size of the problem, execute it on a full range of computing resources, based on what's appropriate and available, and finally the ability to deploy the technology within your company's user community. The result is efficient usage and optimum return on your investment, whether you have a single user or an enterprise-wide commitment to Simulation Driven Product Development. As your requirements grow and the level of sophistication and maturity evolves, the technology from ANSYS also will scale up accordingly.

Adaptive Architecture

Adaptive software architectures are mandatory for today's world of engineering design and development where a multiplicity of different CAD, PLM, in-house codes and other point solutions typically comprise the overall design and development process. A software environment is needed which anticipates these needs and gives you the tools and system services for customization as well as interoperability with other players. Such adaptability is a mandatory requirement and characteristic of the ANSYS simulation architecture, enabling your organization to apply the software in a manner which fits with your philosophy, environment and processes. ANSYS Workbench can be the backbone of your simulation strategy, or peer-to-peer with other software environments, or ANSYS technology can be a plug-in to your CAE supplier of choice. The ANSYS commitment to Simulation Driven Product Development is the same in any case.

Advantages of ANSYS

The ANSYS program is a flexible and cost effective tool which helps in the reduction of rework on prototype.

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ANSYS program is a graphical user interface that facilitates the users with easy and intuitive path to program commands, documentation and functions.

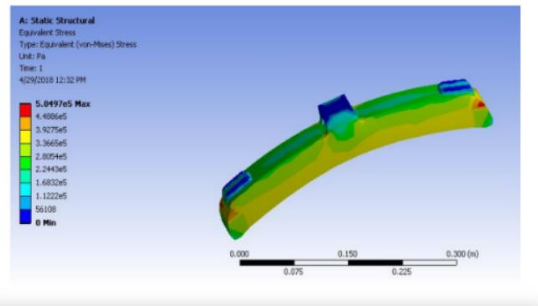
In order to reduce the production costs, ANSYS enables to optimize the design in the development process itself.

ANSYS program helps in designing the computer models and study the physical responses such as stress levels, temperature distribution.

DISADVANTAGES OF ANSYS

One of the major disadvantage of this particular software is that it consumes a lot of space on the RAM/ memory of the PC.

The software can not be used by anyone that doesn't have basic knowledge in Physics.



von-Mises Stress on Brake block using Grey Cast Iron

Material Properties of Brake Blocks

Material Properties of Brake Block

Materials Properties	C.I	Low C.S	High C.S	Unit
Density	7200	7870	7850	kg/m^3
Modulus of Elasticity	110000	205000	210000	MPa
Poisson Ratio	0.28	0.29	0.3	-
Yield Strength	320	370	490	MPa

VI CONCLUSION

According to the existing air brake system of Railway coach the brake force applied per one brake block is 2.187tons. 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 1.653tons.The analysis is done for two forces and by using two materials Cast Iron and High Carbon Steel. The maximum stress induced in the brake block by the application of modified brake force (1.653 N) is 2.765 N/mm2 which is less as compared with stress induced in the brake block by the existing brake force (2.187N) 3.67 N/mm2 . With the application of modified minimum brake force, the brake block is safe. Hence the modification carried out in this project work is justified. By comparing the results for both materials, stress obtained is less for High Carbon Steel is less when compared with Cast Iron. Therefore, from the present research it can be concluded that using High Carbon Steel is best for train brake.

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