ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Analysis of a Heavy Vehicle Front Axle

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ABSTRACT:

An axle is a central shaft for a rotating wheel. On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to its surroundings, with the wheels rotating around the axle. The axles serve to transmit driving torque to the wheel, as well as to maintain the position of the wheels relative to each other and to the vehicle body. The axles in a system must also bear the weight of the vehicle plus any cargo. The front axle beam is one of the major parts of vehicle suspension system. It houses the steering assembly as well. About 35 to 40percent of the total vehicle weight is taken up by the front axle.

Hence proper design of the front axle beam is extremely crucial. In present research work design of the front axle of heavy commercial vehicle were done. The approach in this project has been divided into two steps. In the first step, front axle was designed in CATIA V5 software later the model is imported into ANSYS for results. In the second step, the model is assigned with two different materials and the analysis results for both the materials are compared to conclude a suitable material for a Front axle manufacturing.

Keywords:

Modelling, Meshing, Analysis, Comparison of Results.

Introduction:

An auto industry is one of the important and key sectors of the Indian economy. The auto industry includes of automobile sector, auto components sectors and includes commercial vehicles, passenger cars, multi-utility vehicles, two wheelers, three wheelers and related auto parts.

The demands on the automobile designer increased and altered rapidly, first to meet system safety needs and later to reduce weight so as to satisfy fuel economy and vehicle performance requirements. Engine location important to provide greater stability and safety at high speeds by lowering the centre of gravity of the road vehicles; the complete centre portion of the axle is dropper. Front axles are subjected to both bending and shear stresses. In the static condition, the axle might be considered as beam supported vertically upward at the ends (at the centers of the spring pads Under the dynamic conditions, vertical bending moment is increased due to road roughness. Thus it is very difficult to find the crack propagation in short time. So it is necessary to incorporate finite element methodology. During the operation on vehicle, road surface irregularity causes cyclic fluctuation of stresses on the axle, which is the main load carrying member.

Therefore it is necessary to make sure whether or not the axle resists against the fatigue failure for a predicted service life. Axle experiences completely different loads in different direction, primarily bending load or vertical beaming due to curb weight and payload, torsion, due to drive torque, cornering load and braking load. Front axle will experience a 3G load condition when the vehicle goes on the bump. Performing physical test for vertical beaming fatigue load is expensive and time consuming. So there is a necessity for building FE models which may virtually simulate these loads and can predict the behavior. Even though the FEA produce fairly accurate results, solution accuracy heavily depends on accuracy of input conditions and overall modeling methodology used to represent the actual physics of problem.

Therefore validation of FEA model is of utmost importance. Typically FEA model is validated by correlating FEA results analytical design. Hence correct design of the front axle beam is very critical. The approach in this paper has been divided into two steps. In the first step analytical method used to design front axle. For this, the vehicle specifications, its gross weight and payload capacity in order to find out the stresses and deflection within the beam has been used. In the second step front axle were modelled in Pro-e. The cad model was solved in ANSYS software system. The FE results were compared with analytical design.

Construction and operation:

An axle is a central shaft used for rotating wheel. On wheeled vehicles, the axle could be mounted to the wheels, rotating with them, or located to its surroundings, with the wheels rotating around the axle. The axles achieve to transmit driving torque to the wheel. Also it can maintain the position of the wheels relative with each other and to the vehicle body. The axles must additionally bear the weight of the vehicle plus any cargo. The front axle beam is one of the main parts of vehicle suspension system shown in figure 1. It houses the steering assembly as well. About thirty 30-40 percentage of the total vehicle weight is taken up by front axle. Front axle is made of I-section in the middle portion and circular or elliptical section at the ends.

The special x-section of the axle makes it able to withstand bending loads due to weight of the vehicle and torque applied due to braking. It consists of main beam, stub axle, and swivel pin, etc. The wheels are mounted on stub axles.

The front axles are generally dead axles, but are live axles in small cars of compact designs and also in case of four-wheel drive.

Front Axle and Steering System:

Front axle carries the weight of the front part of the automobile as well as facilitates steering and absorbs shocks due to road surface variations. The front axles are generally dead axles, but are live axles in small cars of compact designs and also in case of four-wheel drive. The steering system converts the rotary motion of the driver's steering wheel into the angular turning of the front wheels as well as to multiply the driver's effort with leverage or mechanical advantage for turning the wheels. The steering system, in addition to directing the vehicle in a particular direction must be arranged geometrically in such a way so that the wheels undergo true rolling motion without slipping or scuffing. Moreover, the steering must be light and stable with a certain degree of self-adjusting ability. Steering systems may also be power assisted. The chapter discusses the front axle construction and its alignment, and steering geometry and steering systems.

Load Determined Design:

The first consideration when designing an automotive suspension is that the part assembly is subject to both static loads (applied by the car's stationary weight) and dynamic loads (those created while driving) corresponding to tension, compression and shear forces distributed in all three spatial axes: longitudinal, vertical and lateral. The dynamic forces imposed while driving can be up to five times greater than the car's static load; thus dynamic loads are the determining factors in the part's critical structural dimensions and overall design, Florentz says. Hutchinson's preliminary "macro" design solution to the problem of these multiaxial loads was to simulate the primary suspension structure with a beam-homogenized orthotropic model.

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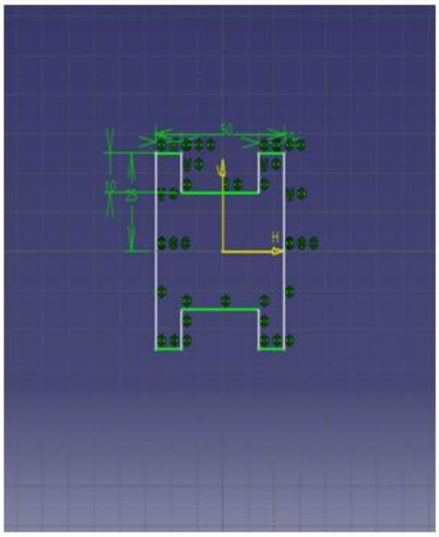
The beam orthotropic model served as a "baseline" that allowed engineers to target the localized stiffness properties necessary to meet the vehicle's basic static load. A material is orthotropic if its mechanical or thermal properties are unique and independent in three mutually perpendicular directions, as opposed to an isotropic material in which the properties are the same in all directions. Additionally, a material can have a homogeneous or non-homogeneous microstructure. A material such as rolled steel is naturally orthotropic and homogeneous. Designing a homogeneous orthotropic composite is a matter of constructing a laminate with the same "micro-structure" (i.e., materials, in this case, an epoxy resin) with a majority of unidirectional glass fibers, in a layup constituting varying thicknesses and directions. Such a structure would allow design engineers to account for various distortions and loads in each of the three independent axes by adding or subtracting reinforcement in specific areas after the part had been modeled in finite element analysis (FEA). Accordingly, the second step in the design process was the detailed finite element model (FEM) simulation of the suspension at the Hutchinson Research Centre.

Here, the simulation was used to model the stiffness of the composite blade and provide the detailed architecture of the layup, including orientation of fabric and local thicknesses. The result is a blade design that features three layups: layup one, on each end of the blade, where the ball joint attaches to the pillars (thicker and more particularly devoted to the wheel guidance with a high longitudinal stiffness); layup two, in the two side-center sections attached to the rubber-mounted, steel axle brackets; and layup three, in the center section between the brackets (thinner and more particularly dedicated to the vertical stiffness of the suspension). The load cases taken into account in the FEA simulation were vertical (symmetrical and asymmetrical), longitudinal, transverse, cornering, side-impact and fatigue. The simulation outputs were stiffness, displacements and kinematics of the blade in all directions, as well as local stress and strain for the resin and the fibers. Stresses and strains were then compared to the material allowables obtained by the lab department, including necessary "knockdown" factors.

CATIA:

CATIA is mechanical design software. It is a feature-based, parametric solid modeling design tool that takes advantage of the easy-to-learn Windows graphical user interface. You can create fully associative 3-D solid models with or without constraints while utilizing automatic or user-defined relations to capture design intent. To further clarify this definition, the italic terms above will be further defined:



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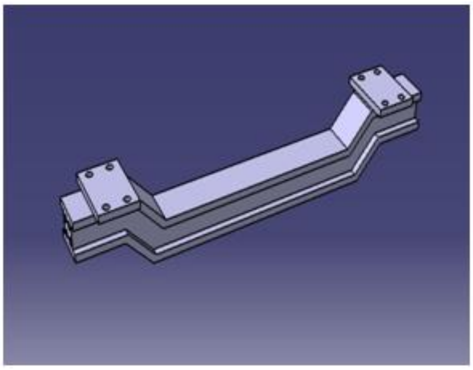
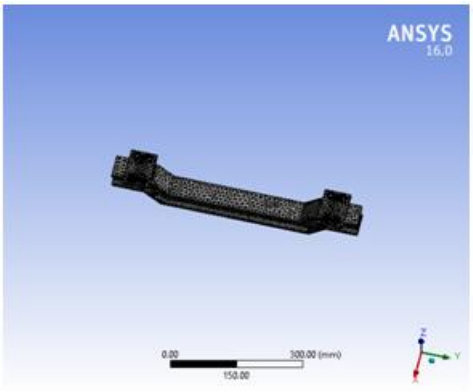
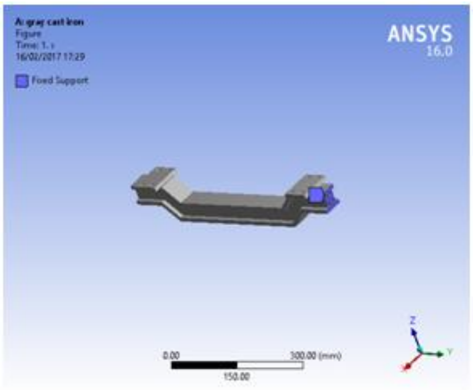


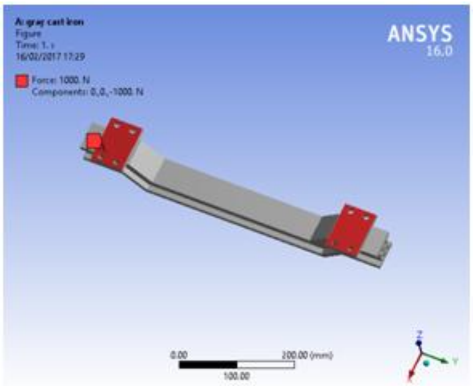
INTRODUCTION TO FEA:

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively.







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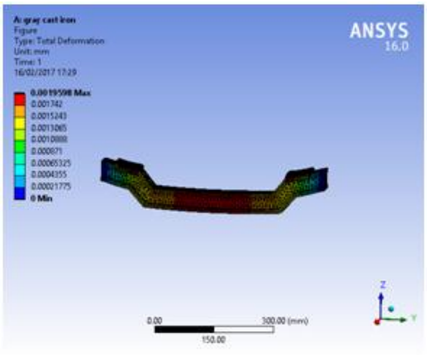

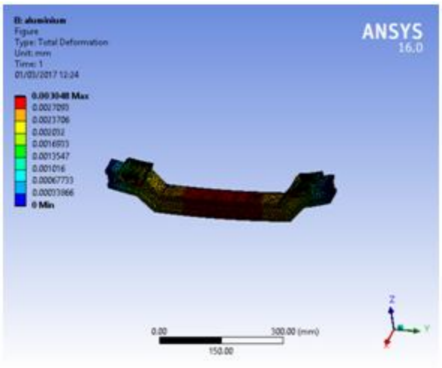

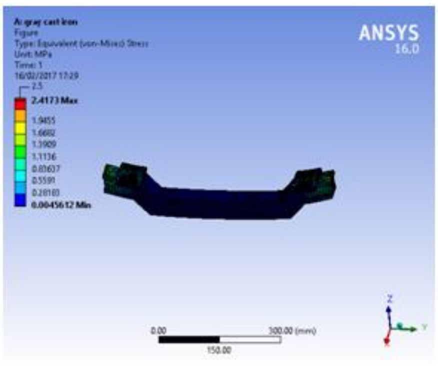

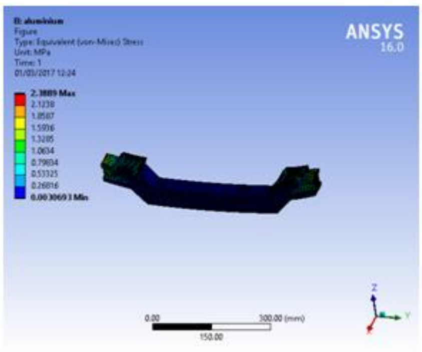

CONCLUSION:

From the above results, it is clear that the maximum deflection in axle is for Gray Cast Iron materials and at the same time the maximum stress distribution is also High for Iron than Aluminum Alloy. So, Aluminum Alloy is better material for manufacturing of axle than Gray Cast Iron. Correlation between stress results from analytical calculation and from FEA assures that the mesh size and modeling approach used for the component were well defined. Finally, we were able to deliver a safe and validate design to suit the requirements of the project.

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