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Comparison of stress displacement and factor of safety of mild steel and high strength steel in a heavy duty axle

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Abstract: Almost all trucks share a common construction: they are made of a chassis, a cab, an area for placing cargo or equipment, axles, suspension and road wheels. The structure of chassis is generally made robust enough to withstand high loads. And also there cannot easily be a change in its design or capacity. The suspension system is quite flexible in terms of increasing the load capacity of the vehicle. The above can be done by increasing the number of leafs. The increase in number of leafs is up to a limit. The axle of the vehicle which has a specified load limit mentioned by the manufacturer. The load capacity of the axle can in some conditions be effectively augmented by increasing the speed of the vehicle. By increasing the speed of the vehicle the stress concentration is reduced. There is always a flexibility in the design of axle as it is smaller (but important) part of vehicle as compared to the structure of chassis. The objective of the study is to analyze a heavy duty axle whose thickness has been optimized in order to reduce the mass of the axle and also to reduce the material used.

INTRODUCTION

The load carrying capacity of a heavy duty vehicle depends basically upon four factors:

1. Structure of chassis.
2. Suspension system.
3. Axle.
4. Tyres.

Structure of chassis: The chassis is the part of a heavy duty vehicle on which whole of the goods or the load is placed. The structure of chassis is generally made robust enough to withstand high loads. And also there cannot easily be a change in its design or capacity, as the design is quite complex in terms of withstanding load.

Suspension system: The suspension system is quite flexible in terms of increasing the load capacity of the vehicle. The above can be done by increasing the number of leafs. Generally the increase in leafs augments the capacity of the vehicle to 2 to 3 times the general capacity. The increase in number of leafs is up to a limit. The maximum number of leafs can be 15-17.the failure of the suspension system will lead to high loss to vehicle as well as loss of goods if the vehicle is loaded.

Axle: The axle of the vehicle which has a specified load limit mentioned by the manufacturer. The load capacity of the axle can in some conditions be effectively augmented by increasing the speed of the vehicle. By increasing the speed of the vehicle the stress concentration is reduced. There is always a flexibility in the design of axle as it is smaller (but important) part of vehicle as compared to the structure of chassis. The design of axle is a critical issue. Also the capacity of the axle is dependent on the properties of the material, it is made of.

Tyres: In case of the tyres, there is but a lesser scope of change that can effectively induce a change in capacity of the vehicle. Though the tyres do effect the vehicle performance under variable loads depending upon the conditions of road and the design and material of the tyres. So the main focus should be on effectively analyzing the axle and optimizing its design and changing the material to reduce the mass of the axle and the capacity of the axle.

Objective of the work

The objective of the study is to analyze a heavy duty axle whose thickness has been optimized in order to reduce the mass of the axle and also to reduce the material used. The thickness of the axle for a heavy duty purpose is generally between 14.5mm and 16mm, in this analysis the thickness has been optimized to 13mm.The axle will be analyzed with five different materials. The stress plot displacement plot and the factor of safety plot will be drawn with the help of Ansys. Though the cost of material in some cases may be high but the weight reduction and the services provided by material like durability, strength over a long period Justifies the cost.

Introduction to Finite Element Method

Finite Element Method originally introduced by Turner et.al [1956] is a powerful computational technique for approximation of these types of engineering problem. The Finite Element Method (FEM) is a numerical approach by which this partial equation can be solved approximately. FEM is a numerical approach for solving engineering problem like stress analysis, heat transfer etc. by using of computer simulation. In FEM we divide a complex problem into smaller and simpler problem that can be solved by existing knowledge of mechanics of materials and by mathematical tool, so the basic idea of FEM is whole domain will be divided into finite elements or called simple elements the shape of elements may be triangular or quadrilateral. The process of dividing the domain (Model) into small elements is called meshing. The elements shares common points called nodes. The behaviour of each elements is well known under all possible support and load applied.

The FEM provide a systematic methodology by which the solution can be given by the computer program. The finite element program determine the value of field variable e.g. displacement in case of stress analysis and temperature in case of heat analysis at each nodes of each elements. The results are usually presented as computer visualization such as contour plots. These results are used in the engineering design process. After that FEM was used in aero industry in1950. In the late 1960s, the field stimulated the interest of many mathematicians, who showed that for linear problems, finite element solutions converge to the correct solution of the partial differential equation. In other words, it has been shown that as the number of elements increases, the solutions improve and tend in the limit to the exact solution of the partial differential equations.

Introduction to Axle

An axle is a central shaft for a rotating wheel or gear. On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to the vehicle, with the wheels rotating around the axle. In the former case, bearings or bushings are provided at the mounting points where the axle is supported. In the latter case, a bearing or bushing sits inside a central hole in the wheel to allow the wheel or gear to rotate around the axle. Sometimes, especially on bicycles, the latter type axle is referred to as a spindle. Drive axle: An axle that is driven by the engine or prime mover is called a drive axle. Modern front wheel drive cars typically combine the transmission (i.e. gearbox and differential) and front axle into a single unit called a transaxle. The drive axle is a split axle with a differential and universal joints between the two half axles. Each half axle connects to the wheel by use of a constant velocity (CV) joint which allows the wheel assembly to move freely vertically as well as to pivot when making turns. Lazy axle: A dead axle, also called lazy axle, is not part of the drive train but is instead free-rotating. The rear axle of a front-wheel drive car is usually a dead axle. Many trucks and trailers use dead axles for strictly load-bearing purposes. A dead axle located immediately in front of a drive axle is called a pusher axle. A tag axle is a dead axle situated behind a drive axle. Dead axles are also found on semi trailers, farm equipment, and certain heavy construction machinery serving the same function. On some vehicles (such as motor coaches), the tag axle may be steerable. In some designs the wheels on a lazy axle only come into contact with ground when the load is significant, thus saving unnecessary tire wear.
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EXPERIMENT AND DATA ANALYSIS

Introduction to ANSYS software

The usage of the Finite Element Method as a tool to solve engineering problems commercially in industrial applications is quite new. It was used in the late 1950’s and early 60’s, but not in the same way as it is today. The calculations were at that time carried out by hand and the method was force based, not displacement based as we use it today. In the mid 60’s, very specialized computer programs were used to perform the analysis. The 1970’s was the time when commercial programs started to emerge. At first, FEM was limited to expensive mainframe computers owned by the aeronautics, automotive, defence and nuclear industries. Today commercial programs are very powerful and large, complex problems can be solved by one person on a PC. Many of them have the possibility to handle different kinds of physical phenomena such as e.g. thermo mechanics, electro mechanics and structural mechanics. One often talks about metaphysics, were different kinds of physical phenomena are coupled in the same analysis. There are many available commercial programs, ABAQUS, FLUENT, and ANSYS are just a few examples. ANSYS is a widely used commercial general-purpose finite element analysis program. ANSYS is a complete FEA software package used by engineers worldwide in virtually all field of engineering:

- Structural
- Thermal
- Fluid, CFD(Computational Fluid Dynamics)
- Electrical

Result and Discussion

Problem Definition

A cad model of heavy duty axle with the length of 1980mm and dia of 150mm at the circular ends and dimensions of 150mmat the square portion.
The results have been obtained using ANSYS 14.0 as it is known for giving accurate results.

CASE-I: In the first case our material is mild steel the properties of which are as follows:

TABLE: mild steel properties

Young's Modulus (Mpa)	Poisson's Ratio	Yield Strength (MPa)
2.10E+05	0.29	200

The equivalent von mises stress plot is obtained by ANSYS which shows a maximum stress of 78.76 MPa.The stress is mainly concentrated at ends where the axle is fixed.

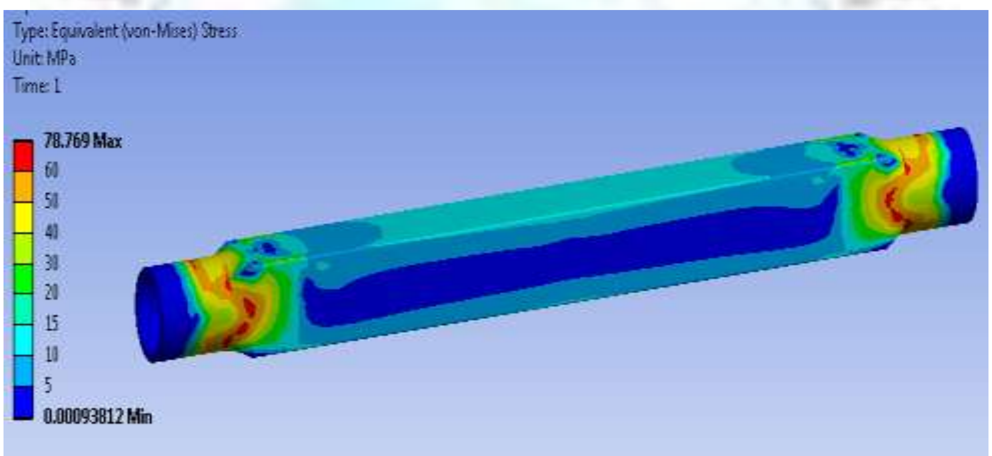

Figure: Equivalent von mises stress for mild steel

The following figure shows the sectional view of the mild steel axle.

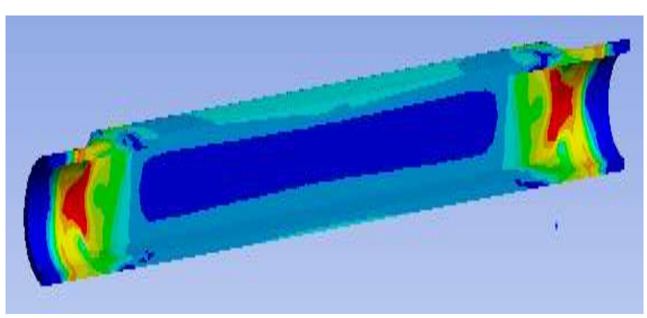

Figure: sectional view of von mises stress

The displacement under the given load is depicted by the following figure which is maximum at middle portion of the axle.this is shown by the red area where the displacement is .30323mm.

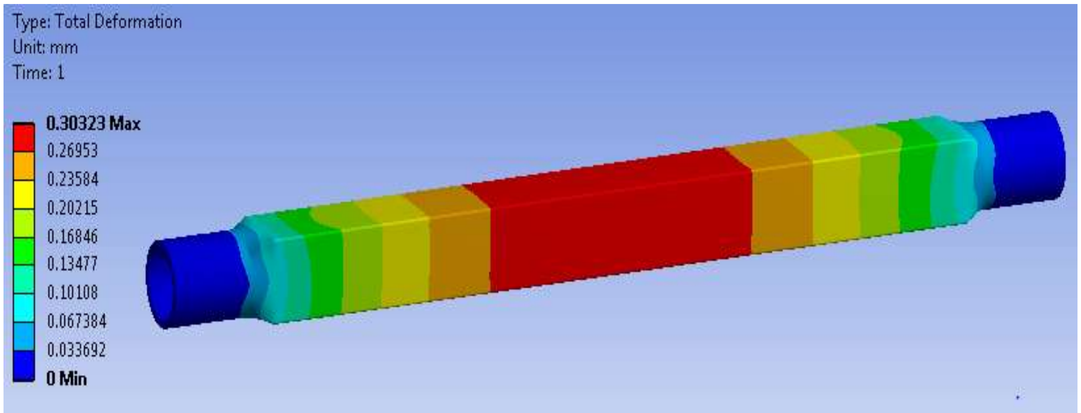

Figure: displacement in the material

The factor of safety for the given material i.e. can be found out manually by dividing the yield strength With respect to the equivalent maximum stress in the material. i.e. yield strength of mild steel is 200MPa and the maximum stress in the material is 78.76MPa. Hence factor of safety is obtained which is equal to 2.5391 which is shown by the figure.

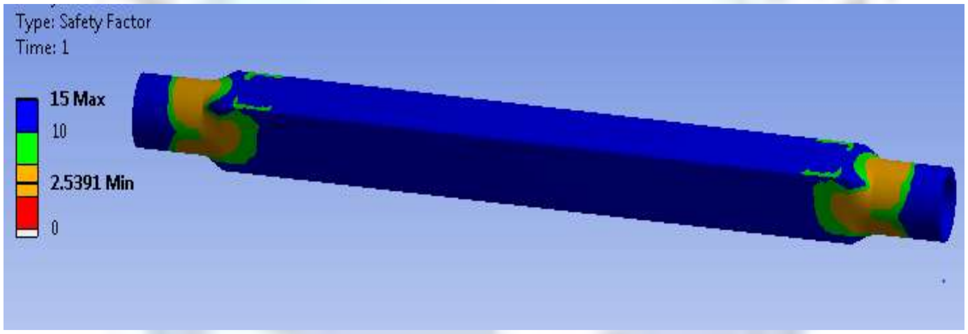

Figure: factor of safety plo

CASE-II

In the second case our material is high strength steel the properties of which are as follows:

Young's Modulus (Mpa)	Poisson's Ratio	Yield Strength (MPa)
2.10E+05	0.29	1240

The equivalent von mises stress plot is obtained by ANSYS which shows a maximum stress of 78.76 MPa.The stress is mainly concentrated at ends where the axle is fixed.

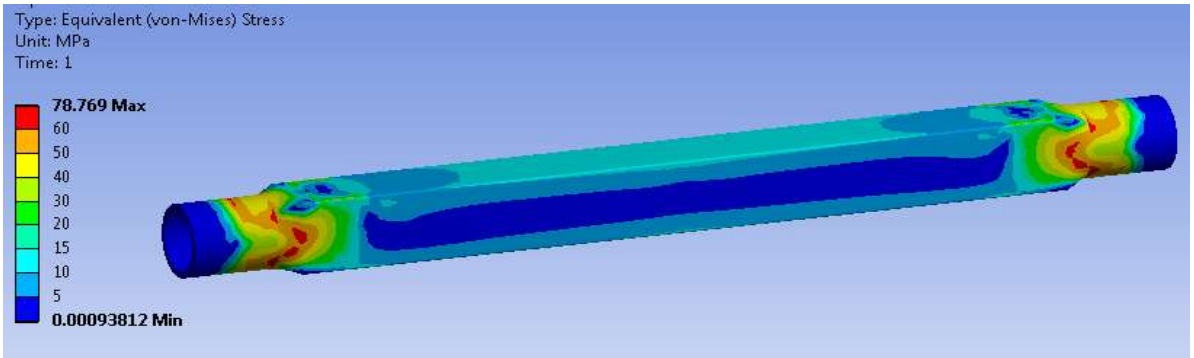

Figure: vonmises stress plot for high strength steel

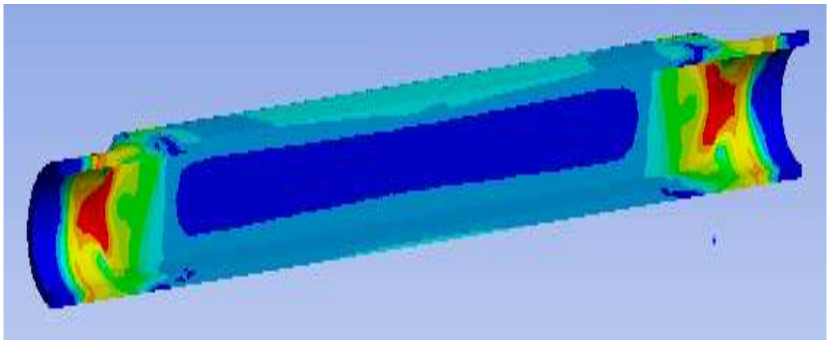

Figure: sectional view of von-mises stress plot

The displacement under the given load is depicted by the following figure which is maximum at middle portion of the axle. This is shown by the red area where the displacement is .30323mm.

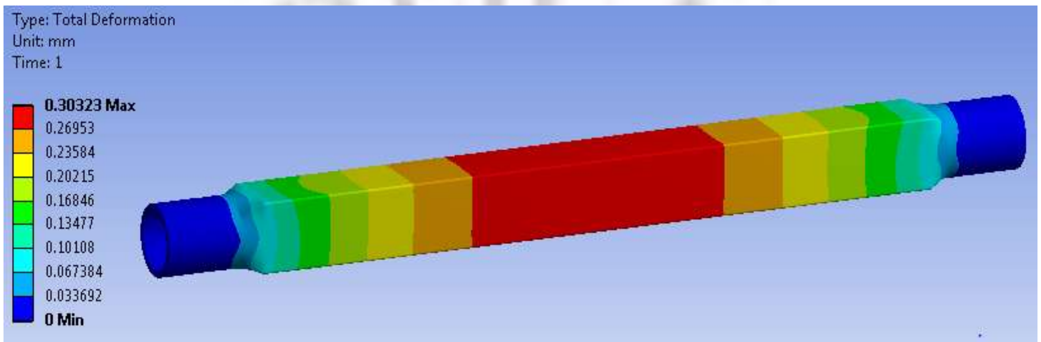

Figure: total deformation in the material

The factor of safety for the given material i.e. can be found out manually by dividing the yield strength with respect to the equivalent maximum stress in the material.
i.e. yield strength of mild steel is 1240MPa and the maximum stress in the material is 78.76MPa.
Hence factor of safety is obtained which is equal to 15.7440 which is shown by the figure.

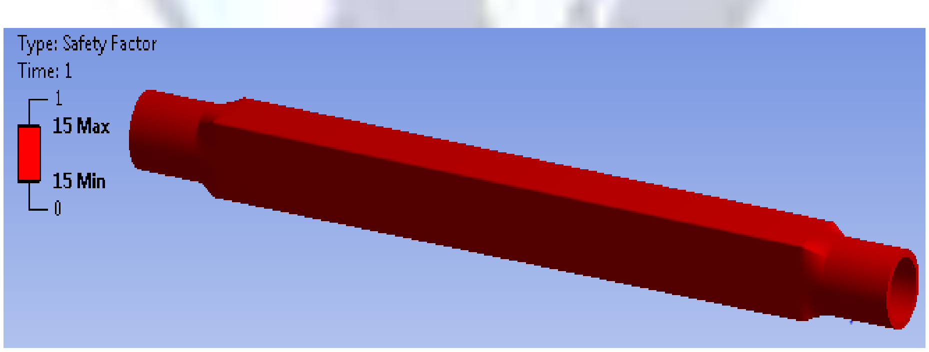

Figure: factor of safety plot for high strength steel

Conclusions

The following table shows stress, displacement and factor of safety for different materials:

Material	Stress	Displacement	Factor of safety
Mild Steel	78.769	.30323	2.5391
High Strength Steel	78.769	.30323	15.744

Future Scope of the Work

As it is best known to us that bulk carriers/trailers form a major part of the transportation industry, a step towards enhancing their performance by engineering analysis would be much fruitful.
Further scope of the work may be termed in the following ways:

- Mass reduction of the axle by using lighter materials.
- Composite materials might prove to be a good choice for mass reduction with high strength of the axle.
- Finite element analysis is good technique to analyze any change in the design of axle accurately and economically with software like ANSYS.

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