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Research Paper

COMPARATIVE ANALYSIS OF TRACTOR'S TROLLEY AXLE BY USING FEA. (BY CONSIDERING CHANGE IN MATERIALS EXISTING SHAPE AND SIZE)

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In Central India, various small scale industries are adopting the crude methodologies for designing and manufacturing the machine components. One such industry producing tractor trolleys for agricultural use has been identified for this study. The existing trolley designed by the industry uses heavy axle without considering static and dynamic loading conditions which in turn leads to higher factor of safety increasing the overall cost of the axle. In this study, existing trolley axle is comparatively analysed by considering the static and dynamic load conditions. Tractor trolley or trailers are very popular and cheaper mode of goods transport in rural as well as urban area. But these trailers are manufactured in small scale to moderate scale industry. Especially in the small- and middle-scale agricultural machinery industry, insufficient use of new technology and new design features can cause problems such as breakdowns and failures during field operations. In present work finite element analysis approach is used to make a safer working condition of trolley axle as well as for stress concentration, weight and cost reduction of existing trolley axle.

Keywords: Trolley axle, Safety working condition, Cost reduction, PROE, ANSYS 12

INTRODUCTION

In the present market scenario, cost reduction technique is playing significant role to meet the competition in the market. Weight reduction and simplicity in design are application of industrial engineering. Various components or products, such as, farming machinery, thrashers, tractor's trolley, etc., mostly used in rural areas are manufactured in small scale industries. It has been observed that these products may not properly design. These products are manufactured as per need, by trial and error methods of manufacturing. So these products are required to design properly.

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Farm tractor is an off road vehicle, used as a portable machine to do various useful works such as farming, haulage, heavy earthmoving and transportation. An off-road vehicle is considered to be any type of vehicle which is capable of driving on and off paved or gravel surface. Off road condition includes uneven agricultural field surfaces and bumpy village roads on which the tractor has to operate. These ground irregularities leads to unexpected loads coming on the tractor components. Tractor trolley or Trailers are widely used for transporting agriculture product, building construction material, industrial equipments and many other types of goods. Many varieties are available in trailer and use of particular trailer depends upon the application. The main requirements of trailer manufacturing are high performance with longer working life and robust construction. Tractor trolleys used for transportation are manufactured in small to moderate scale industries. Though tractor trolleys are manufactured of various capacities by various industries, there is a variation in manufacturing methods. The axle of a tractor trolley is one of the major and very important component and needs to be designed carefully, science this part also experiences the worst load condition such as static and dynamic loads due to irregularities of road, mostly during its travel on off road. Therefore it must be resistant to tolerate additional stress and loads.

In our project work, finite element analysis approach will be used (by considering change in materials and change in existing shape and size). A CAD model of existing trolley axle is prepared using Pro-E wildfire 4.0 software then analysis is done with the help of Ansys workbench. The main purpose of project is to make a safer working condition of trolley axle as well as for stress concentration, weight and cost reduction.

Local Industries in MIDC, Akola, is presently the leading manufacturers of tractor trolleys producing about 2000 trolleys per annum. The analysis and discussion with owner of local Industries in MIDC, Akola, revealed that with proper design approach, the cost of trolley axle can be reduced. As there is lot of competition in the market, so reduction in cost is necessary.

MATERIALS AND METHODS

Methodology

The experimental analysis of trolley axle is done with the help of new technology of CAD/CAE.

For Designing: CAD software like Pro-E.

For FE Analysis: ANSYS WORKBENCH.

Tractor Trolley Axle

The axle of a tractor trolley is one of the major and very important components and needs to be designed carefully, since this part also experiences the worst load condition such as static and dynamic loads due to irregularities of road, mostly during its travel on off road. Therefore it must be resistant to tolerate additional stress and loads.

Trolley axle under consideration is a supporting shaft on which a wheel revolves. The axle is fixed to the wheels, fixed to its surroundings and a bearing sits inside the hub with which a wheel revolves around the axle. A trolley axle is also called as beam axle which is typically suspended by leaf springs as shown in Figure 2.

Figure 1: Axle Assembled with Leaf Spring

Figure 2: Step Turned Trolley Axle

Material Selection

Materials science and engineering plays a vital role in this modern age of science and technology. Various kinds of materials are used in industry, housing, agriculture, transportation, etc. to meet the plant and individual requirements. The rapid developments in the field of quantum theory of solids have opened vast opportunities for better understanding and utilization of various materials.

So for better design and reduce the cost of material we compare the three materials: (a) SAE-1020, (b) SAE 1040, (c) Ductile Cast Iron 80-55-06.

SAE-1020: The SAE-1020 grade steel material is existing material used for the axle which having carbon percentage up to 0.17-0.23 and percentage of silicon 0.15-0.35, also the density of material is 7870 (Kg/m^3) and its ultimate strength is 420 MPa. This material is generally used for making the farming equipments and industrial purpose.

SAE 1040: The SAE-1040 grade steel material is proposed material for the axle of tractor trolley, this material have the good properties than the SAE 1020 steel grade, its having the carbon percentage up to 0.37-0.44 and percentage of silicon 0.35,the percentage of carbon is higher than the SAE 1020 steel grade material. Also it's having density up to 7845 (Kg/m^3) and its ultimate strength is 595 MPa.

Ductile Cast Iron 80-55-06: Ductile iron is competitive with steel in strength for a given level of ductility and 8-10% lower in specific gravity than wrought steel. Ductile cast iron round bars were prepared using alloys with Carbon Equivalent percentage (CE) ranging between 4.50% and 4.76%. Different measurements were carried out on as—cast and heat-treated specimens. Ductile cast iron is essentially a family of materials with a wide verity of properties which are satisfactory for different engineering requirements. The soft ferrite grades are available to use when toughness and ductility are needed, while the harder pearlitic grades are used when higher strength is required. Grades with mixture of pearlite and ferrite in the matrix are also available.

Material Property

Table 1: Mechanical Material Properties

Material	Ultimate Strength (MPa)	Yield Strength (MPa)	Density (Kg/m^3)	Modolus of Elasticity (MPa)	Poissons Ratio
SAE 1020 (Existing Axel)	420	370	7870	205000	0.29
SAE 1040	595	515	7845	200000	0.29
Ductile Cast Iron 80-55-06	559	370	7150	168000	0.31

LOADING ON AXLE

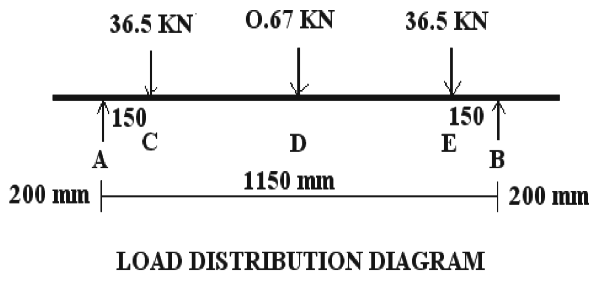
Static Load on Axle

The static load on axle is calculated by considering the fully loaded trolley model. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. Static analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects.

Static Load Analysis

The total capacity of the trolley is 60 KN but self weight of trolley and the axle assembly is 13 KN. So we consider the gross weight come over the axle is 73 KN. As the leaf spring is used as the isolator and whole weight of the trolley is mounted over there. Due to leaf spring the total weight of the trolley is transferred over the axle at two point C and E as shown in load distribution diagram.

Figure 3: Shear Force and Bending Moment on Axle



- Determination of reaction at support.
- Determination of value of shear force at change of load position.
- Determination of values of bending moment at change of load point.

Table 2: Shear Force and Bending Moment on Axle

Load Point	RA = 36.835 KN	RB = 36.835 KN
	Shear Force	Bending Moment
A	36.835 KN	0 KN mm
C	0.335 KN	5525.25 KN mm
D	–0.335 KN	5667.62 KN mm
E	–36.835 KN	5525.25 KN mm
B	0 KN	0 KN mm

Design of Existing Axle

An axle is a stationary machine element and is used for the transmission of bending moment only. It simply act as a support for some rotating body such as hoisting drum and in tractor trolley case the axle is supporting of rotating member known as hub for holding the tires.

So the axles are used to transmit bending moment only. Thus axles are designed on the basis of bending moment only.

When the axle is subjected to a bending moment only then we get the following data.

$M/I = (f_b)/Y$

M: Bending moment.

I: Moment of inertia.

f_b: Bending stress.

Y: Distance of outer fiber from neutral axis.

Moment of inertia of cross sectional area of the axle about the axis of rotation.

(I) is equal to 2636718.75 mm4

As we selected the material for axle is SAE 1020 (Cold rolled) having bending stress

(f_b) (Allowable) is 420 MPa.

Bending moment (M) is found to be 29531250 N-mm

The section modulus (z) of the existing axle (75 × 75 × 1550 mm) is found to be

$z = M/f_b = 70312.5$ mm^3.

We cross check this section modulus by using data book formulae. Section modulus.

(z) = $bh2/6$ = 70312.5 mm^3.

On the observations of the bending moment we found that:

When the axle length and the point load applied on it is considered then the maximum bending moment is found equal to 5667620 N-mm.

When the material is considered and the cross sectional area is considered then the maximum bending moment is found equal to 29531250 N-mm

The maximum moment (M) = 5667620 N-mm.

- The bending stress (allowable) (f_b) = 420 MPa (SAE 1020).
- Section modulas (z) = M/f_b = 13494.33 mm^3.
- The obtained value of z = 13494.33 mm^3 = $b3/6$ = 43.26 mm.
- b = 45 mm.

So on the basis of bending moment only we got the cross section of axle is 45 mm.

Dynamic Load

Trolleys are used in rural areas and on rough roads at moderate speed, i.e., up to 40 km per hour. On full load conditions the speed is 20 km per hour maximum. Due to moderate speed and wavy road conditions the axle is subjected to dynamic loads which are nonlinear in nature. The load coming on the axle due to this are much larger than static loads, which makes it necessary to analyses the axle for dynamic loads.

Dynamicic Load Analysis

As we know that the dynamic load is always more than static load but it is not possible to define the accurate dynamic load, so we consider as a maximum load due to dynamic loading is 50 KN on each leaf spring.

Figure 4: Shear Force and Bending Moment on Axle

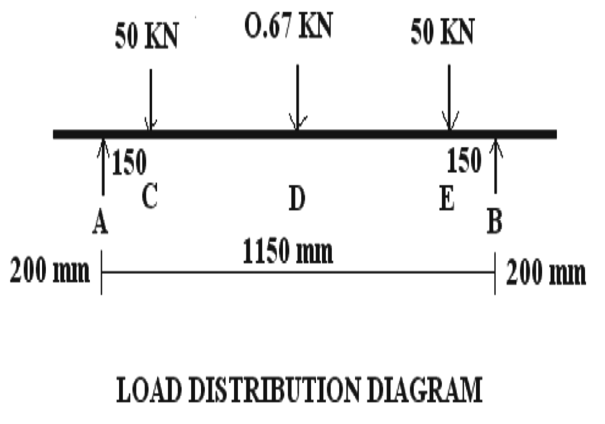


Table 3: Shear Force and Bending Moment on Axle

Load Point	RA = 50.33 KN	RB = 50.34 KN
	Shear Force	Bending Moment
A	50.33 KN	0 KN mm
C	0.33 KN	7555.25 KN mm
D	–0.34 KN	7695.50 KN mm
E	–50.34 KN	7551.00 KN mm
B	0 KN	0 KN mm

- The maximum moment (M) = 7695500.00 N-mm.
- The bending stress (allowable) (f_b) = 420 MPa (SAE 1020).
- Section modulas (z) = M/f_b = 18322.62 mm^3.
- The obtained value of z = 18322.62 mm^3.

(z) = b3/6

18322.62 = b3/6

b = 47.90 mm

b = 50 mm

So by considering the dynamic load condition we obtain the cross section of axle is 50 mm.

DESIGNS WITH DIFFERENT C/S

Design the axle while considering maximum bending MOMENT 7695.50 KN/mm for all c/s of axle.

Square Axle

Circular Axle

I-Section Axle

Figure 5: Square Cross Section Axle

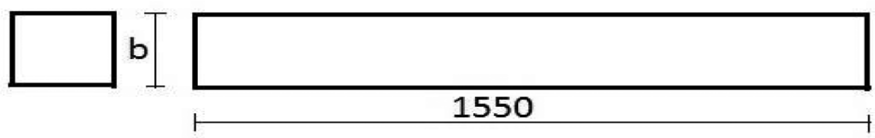


Table 4: Design of Square Axle for Different Material

SAE 1020 Material	SAE 1040 Material	Ductile Cast Iron Material
Section modulus (z) = M/f_b	(z) = M/f_b	(z) = M/f_b
= 7695.50 * 10^{03}/370	= 7695.50 * 10^{03}/515	= 7695.50 * 10^{03}/370
(z) = 20798.65 mm^3	(z) = 14942.72 mm^3	(z) = 21258.29 mm^3
(z) = b3/6	14942.72 = b3/6	21258.29 = b3/6
20798.65 = b3/6	b = 44.76 mm	b = 49.97 mm
b = 49.97 mm	b = 50 mm	b = 50 mm
b = 50 mm		

Figure 6: Circular Cross Section Axle

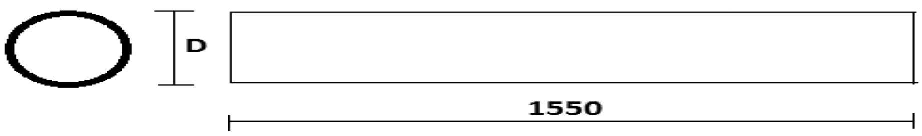


Table 5: Design of round axle for different material

SAE 1020 Material	SAE 1040 Material	Ductile Cast Iron Material
Section modulas (z) = M/f_b	= 7695.50 * 10^{03}/515	(z) = M/f_b
= 7695.50 * 10^{03}/370	(z) = 14942.72 mm	= 7695.50 * 10^{03}/370
(z) = 20798.65 mm^3	$14942.72 = \frac{\pi D^3}{32}$	(z) = 20798.65 mm^3
$Z = \frac{\pi D^3}{32}$	D = 53.39 mm	$Z = \frac{\pi D^3}{32}$
D = 59.61 mm	D = 60 mm	D = 59.61 mm
D = 60 mm		D = 60 mm

Figure 7: I Cross Section Axle

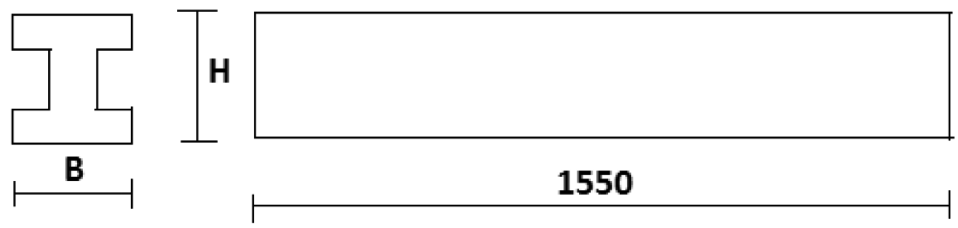


Table 6: Design of I Cross Section Axle for Different Material

SAE 1020 Material	SAE 1040 Material	Ductile Cast Iron Material
Section modulus (z) = M/f_b	Section modulus (z) = M/f_b	Section modulus (z) = M/f_b
(z) = 7695.50 * 10^{03}/370	(z) = 7695.50 * 10^{03}/370	(z) = 7695.50 * 10^{03}/370
= 20798.65 mm^3	=14942.72 mm^3	= 20798.65 mm^3
$z = \frac{BH^3 - bh^3}{6H}$	$z = \frac{BH^3 - bh^3}{6H}$	$z = \frac{BH^3 - bh^3}{6H}$
B = 44.94 mm, H = 53.93 mm	B = 40.50 mm, H = 48.59 mm	B = 44.94 mm, H = 53.93 mm
b = 22.47 mm, h = 26.96 mm	b = 20.25 mm, h = 24.30 mm	b = 22.47 mm, h = 26.96 mm

Assume: $H = 1.2\,B$, $h = H/2$, $b = B/2$.

Round Up the Values

B = 45.00 mm, H = 60.00 mm

b = 25.00 mm, h = 30.00 mm

ANALYSIS

ANSYS has developed product lines that allow you to make the most of your investment and choose which product works best in your environment. ANSYS is a Finite Element Analysis (FEA) code widely used in the Computer-Aided Engineering (CAE) field. A CAD model of existing trolley axle and new designed axle is prepared using Pro-E wildfire 4.0 software then analysis is done with the help of Ansys workbench.

Below figures shows the Equivalent (von-mises) stress on the axle when the load is applied. Red color shows the maximum stress and blue color shows minimum stress generated on the axle. For this analysis purpose following data are used.

Comparison of Stresses and Price

Cost Reduction

When we consider the different c/s of axle with different material then we got minimum weight of axle 23.273 Kg for I-section and material is ductile cast iron with price of Rs. 1457.821.

But the minimum cost for axle is obtain for I-section with material SAE 1040 the price is 1042.849 and weight of axle is 25.535 Kg.

Compare the existing axle price and new designed axle minimum price:

Existing axle price is Rs. 2802.10.

New designed axle minimum price is Rs. 1042.849.

So we got the price difference of Rs. 1759.25.

Means by adopting the new design of axle we can reduce the axle cost up to Rs. 1759.251.

Figure 8: Stress and Deflection in Existing Axle

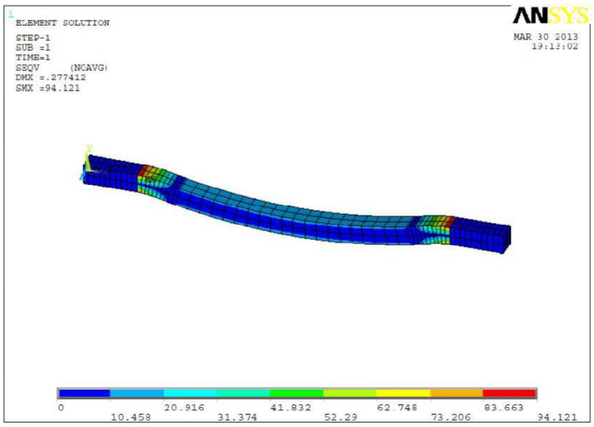


Figure 9: Stress and Deflection in New Designed Square Axle

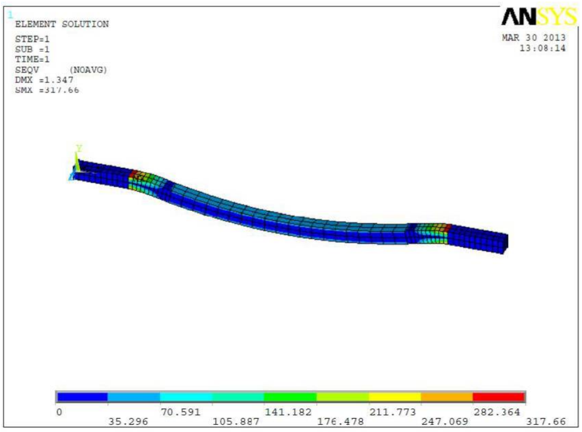


Figure 10: Stress and Deflection in New Designed Round Axle

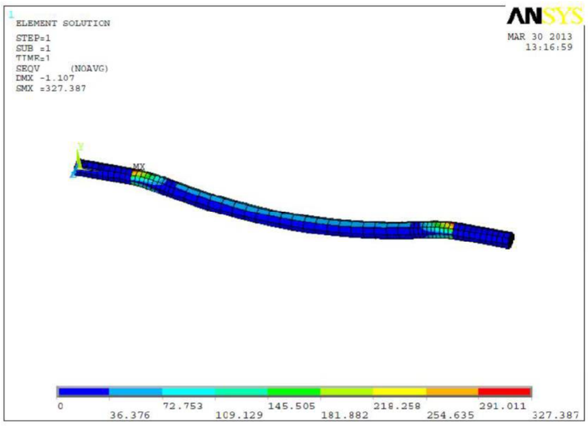


Figure 11: Stress and Deflection in New Designed I Cross Section Axle

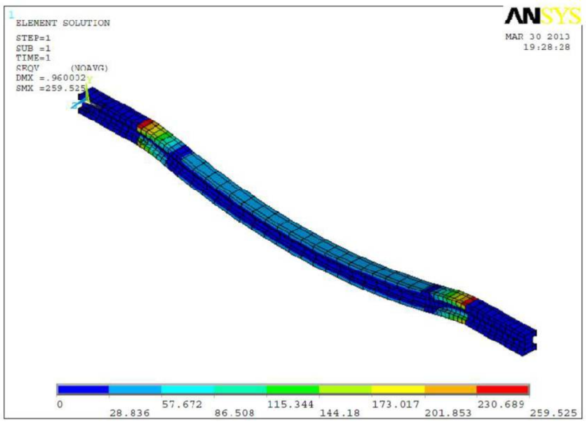


Figure 12: Stress and Deflection in New Designed Square Axle

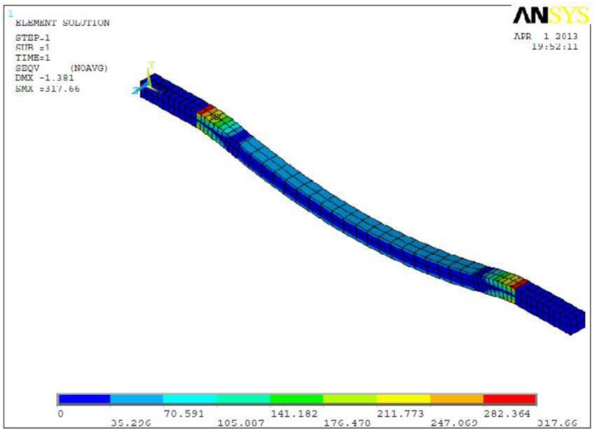


Figure 13: Stress and Deflection in New Designed Round Axle

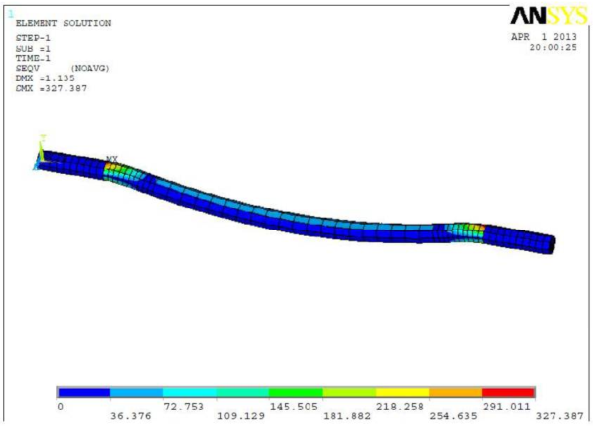


Figure 14: Stress and Deflection in New Designed I Cross Section Axle

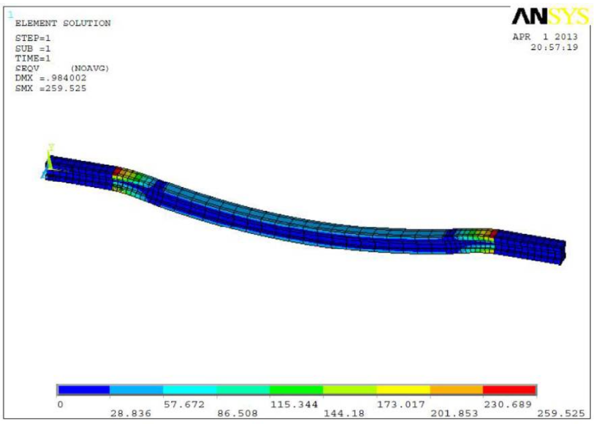


Figure 15: Stress and Deflection in New Designed Square Axle

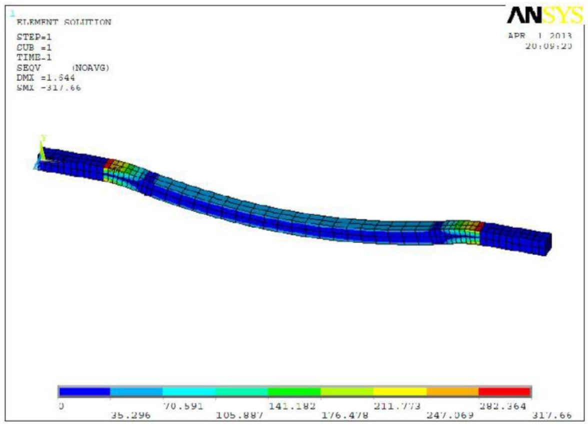


Figure 16: Stress and Deflection in New Designed Round Axle

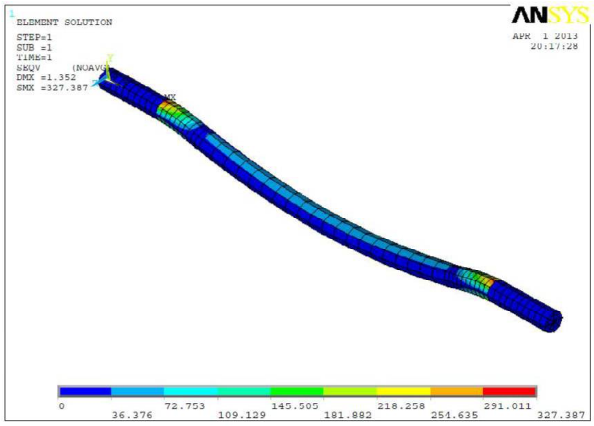


Figure 17: Stress and Deflection in New Designed I Cross Section Axle

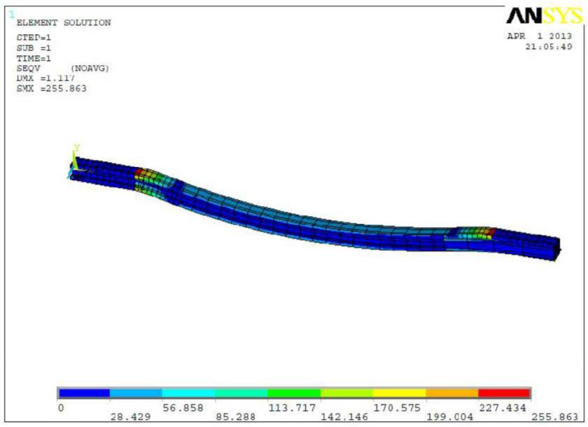


Table 7: Comparison of Stresses and Price for Different Cross Section Axle

Material	Shape of Axle	Maximum Stresses (N/mm^2)	Elongation (MM)	Mass of Axle (Kg)	Price/Piece (Rs.)
SAE 1020	Square (Existing Axle)	94.121	0.227	68.616	2802.100
SAE 1020	SQUARE	317.660	1.347	30.496	1245.466
	ROUND	327.387	1.107	34.490	1408.589
	I-SECTION	259.525	0.960	25.616	1046.157
SAE 1040	SQUARE	317.660	1.381	30.399	1241.510
	ROUND	327.387	1.135	34.552	1403.900
	I-SECTION	259.525	0.984	25.535	1042.849
Ductile Cast Iron	SQUARE	317.660	1.644	27.625	1730.422
	ROUND	327.387	1.352	31.294	1962.511
	I-SECTION	255.863	1.117	23.273	1457.821

CONCLUSION

This study was conducted on an existing rear axle shaft used in tractor trolley shows that the existing axle has greater factor of safety so un-wontedly heavy axle is used for trolley in existing condition which increase the weight of axle as well as cost of axle. But the newly designed axle with different cross section and different material show that we can maximally reduces the 33.92% weight as compare to the existing axle shown in comparison table. Also reduces the cost of trolley axle as the weight of the axle reduces. We reduce the cost of axle approximately up to Rs. 1759.251 per axle and the deformations as well as stresses developed in new designed axle are in within limits the minimum cost obtained for I cross section axle of SAE 1040 material, the deformation for that axle is 0.984 mm and stresses developed in that axle is 259.525 (N/mm^2) which are in within limit.

ACKNOWLEDGMENT

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