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Comparative Analysis Of Tractor's Trolley Axle By Analytical Method (By Considering Change In Material And Change In Existing Shape And Size)

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Abstract:

In the present market scenario, cost reduction technique is playing signified role to meet the competition in the market. Weight reduction and simplicity in design are application of industrial engineering etc., the sources of the technique which are used. Various components or products used in rural areas are mostly manufactured in small scale industries such as farming machinery, thrashers, tractor trolleys etc. It has been observed that these rural products are not properly designed. These products are manufactured as per need, by trial and error methods of manufacturing. Big industrial sectors have not yet entered in manufacturing of these products; hence no significant development in design of rural product has been done so far. In Present work theoretical 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.

1.Introduction

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 modify existing rear axle of tractor trolley. Fatigue failure of the rear axle finite element model was predicted after the dynamic load was imposed on it.

Trolley axle under consideration is a supporting shaft on which a wheel revolves. The axle is fixed to the wheels, fixed to its surroundings & 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.

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, analytical analysis approach is used, (By considering Change in materials & change in existing shape & size). A existing trolley axle is redesigned for the given load condition, then check the actual deflection occurred in existing axle, also different material and different shape axle get design, Select the best axle according to condition. 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.

2.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.

2.1.Material Property

MATERIAL	ULTIMATE STRENGTH(MPa)	YIELD STRENGTH (MPa)	DENSITY (Kg/m3)	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

Table 1: Mechanical Material Properties

3.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.

$M/I = (f_b)/Y$

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 X 75 X 1550 mm) is found to be

$z = M / f_b$ = 70312.5 mm3.

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 mm3
  - The obtained value of z = 13494.33 mm3 = b3 / 6 = 43.26mm.
  - b = 45 mm.

4.Dynamicic Load Analysis

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,

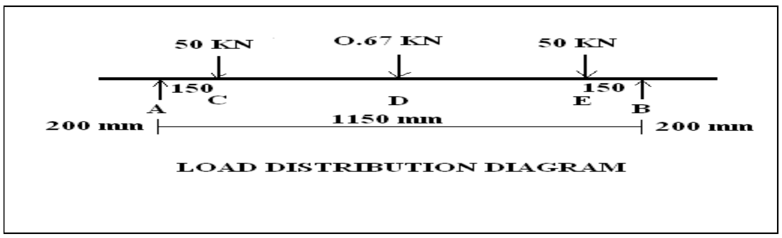

Figure 1: Shear force and bending moment on axle

RA = 50.33 KN RB = 50.34 KN

Load Point	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

Table 2: Shear force and bending moment on axle

- The maximum moment (M) = 7695500.00 N-mm.
- The bending stress (allowable) (fb)= 420 MPa(SAE 1020)
- Section modulas (z) = M / fb = 18322.62 mm3
- The obtained value of z = 18322.62 mm3

(z) = b3 / 6

18322.62 = b3 / 6

b = 47.90mm. b=50mm.

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

5.Designs With Different C/S

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

5.1.Square Axle

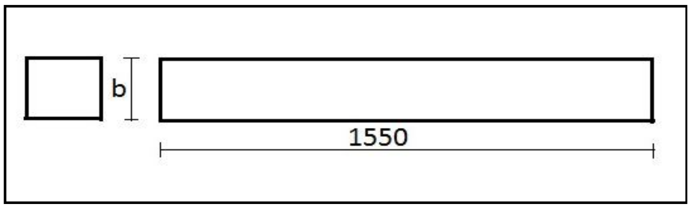

Figure 2: Square cross section axle.

SAE 1020 material	**SAE 1040 material**	**Ductile Cast Iron material**
Section modulus (z) = M / fb = 7695.50 * 10^{03} / 370 (z) = 20798.65 mm3 (z) = b3 / 6 20798.65 = b3 / 6 b = 49.97mm b=50mm.	(z) = M / fb = 7695.50 * 10^{03} / 515 (z) = 14942.72 mm3 14942.72 = b3 / 6 b = 44.76mm. b=50mm.	(z) = M / fb = 7695.50 * 10^{03} / 370 (z) = 21258.29 mm3 21258.29 = b3 / 6 b = 49.97mm. b=50mm.

Table 3: Design of square axle for different material

5.2.Circular Axle

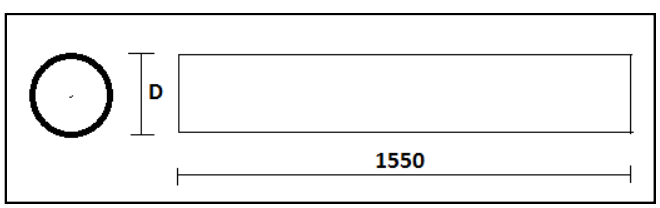

Figure 3: Circular cross section axle

SAE 1020 material	**SAE 1040 material**	**Ductile Cast Iron material**

Section modulas (z) = M / fb = 7695.50 * 10^{03} / 370 (z) = 20798.65 mm3 Z = πD^3 / 32 D = 59.61 mm D = 60 mm	= 7695.50 * 10^{03} / 515 (z) = 14942.72 mm 14942.72 = πD^3 / 32 D = 53.39mm. D = 60mm.	(z) = M / fb = 7695.50 * 10^{03} / 370 (z) = 20798.65 mm3 Z = πD^3 / 32 D = 59.61 mm D = 60 mm

Table 4: Design of round axle for different material

5.3.I-Section Axle

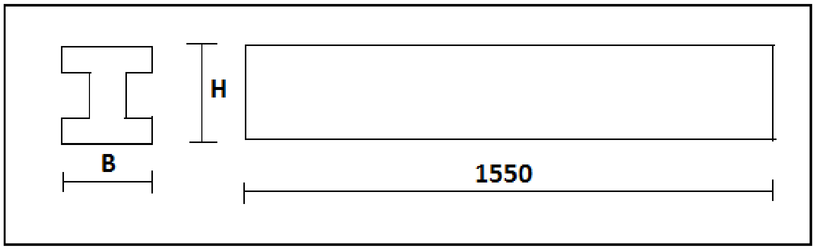

Figure 4: I cross section axle

Assume H = 1.2 B, h = H/2, b = B/2

SAE 1020 material	SAE 1040 material	Ductile Cast Iron material
Section modulus (z) = M / fb (z) = 7695.50 * 10^{03} / 370 =20798.65 mm3 z = $BH^3 – bh^3$ / 6H B = 44.94 mm , H = 53.93 mm b = 22.47 mm, h = 26.96 mm	Section modulus (z) = M / fb (z) = 7695.50 * 10^{03} / 370 =14942.72 mm3 z = $BH^3 – bh^3$ / 6H B = 40.50 mm , H = 48.59 mm b = 20.25 mm , h = 24.30 mm	Section modulus (z) = M / fb (z) = 7695.50 * 10^{03} / 370 =20798.65 mm3 z = $BH^3 – bh^3$ / 6H B = 44.94 mm , H = 53.93 mm b = 22.47 mm, h = 26.96 mm

Table 5: Design of I cross section axle for different material

5.4.Round Up The Values

B = 45.00 mm	H = 60.00 mm
b = 25.00 mm	h = 30.00 mm

6.Analysis

6.1.Theoritical Deflection And Stress Calculation For Existing Axle

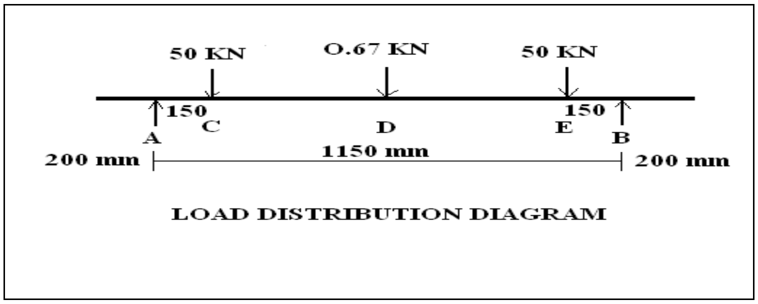

Figure 5: Loading on existing axle

$$\delta = \frac{W a^3 b^3}{3EIl^3}$$

δ = Change in length, W = Load.

a = Distance from support to applied load.

b = Distance from applied load to next support.

E = modulus of elasticity.

I = Moment of inertia, l = length of beam.

- Find out the deflection (δ_1) due to load at C point.

a = 150 mm, b = 1000 mm

$$\delta_1 = \frac{50*10^3 * 150^3 * 1000^3}{3 * 205000 * 2636718.75 * 1150^3}$$

δ_1 = 0.0685 mm

- Find out the deflection (δ_2) due to load at D point.

a = 575 mm, b = 575 mm

$$\delta_2 = \frac{0.67*10^3 * 575^3 * 575^3}{3 * 205000 * 2636718.75 * 1150^3}$$

δ_2 = 0.0098 mm

- Find out the deflection (δ_3) due to load at E point.

a = 1000 mm, b = 150 mm

$\delta_3 = \dfrac{50*10^3 * 1000^3 * 150^3}{3 * 205000 * 2636718.75 * 1150^3}$

δ_3 = 0.0685 mm

$\delta = \delta_1+\delta_2+\delta_3$

δ = 0.0685 + 0.0098 + 0.0685

δ = 0.147 mm

- Strain = Change in length/Original Length
  = 0.147 / 1150
  = $1.276*10^{-4}$
- E = Stress / Strain
  Stress = Strain * E
  = $1.276*10^{-4}$ * 205000
  Stress = 26.168 N/mm^2

6.2.Deflection And Stress Calculation For Different C/S

Square	**Circular**	**I-Section**
$(I) = \dfrac{bh^3}{12}$	$(I) = \dfrac{\pi D^4}{64}$	$(I) = \dfrac{BH^3 - bh^3}{12}$
$(I) = \dfrac{50*50^3}{12}$	$(I) = \dfrac{\pi 60^4}{64}$	$(I) = \dfrac{45*60^3 - 25*30^3}{12}$
(I)= 520833 mm^4	(I)= 635850 mm^4	(I) =753750

Table 6: Moment of inertia for different axle

6.2.1.For Square Axle Of 50 * 50 C/S

$\delta = \dfrac{W a^3 b^3}{3EIl^3}$

- Find out the deflection (δ_1) due to load at C point.

a = 150 mm, b = 1000 mm

$\delta_1 = \dfrac{50*10^3 * 150^3 * 1000^3}{3 * 205000 * 520833.33* 1150^3}$

δ_1 = 0.346 mm

- Find out the deflection (δ_2) due to load at D point.

a = 575 mm, b = 575 mm

$$\delta_2 = \frac{0.67*10^3 * 575^3 * 575^3}{3 * 205000 * 520833.33 * 1150^3}$$

δ_2 = 0.0497 mm

- Find out the deflection (δ_3) due to load at E point.

a = 1000 mm, b = 150 mm

$$\delta_3 = \frac{50*10^3 * 1000^3 * 150^3}{3 * 205000 * 520833.33 * 1150^3}$$

δ_3 = 0.346 mm

$\delta = \delta_1+\delta_2+\delta_3$

δ = 0.346 + 0.0497 + 0.346

$\underline{\delta = 0.7424 \text{ mm}}$

- Strain = Change in length/Original Length
  = 0.7424 / 1150
  = $6.456*10^{-4}$
- E = Stress / Strain

Stress = Strain * E
= $6.456*10^{-4} * 205000$

Stress = 132.358 N/mm^2

6.2.2. For Round Axle Of 60 Diameter

$$\delta = \frac{W a^3 b^3}{3EIl^3}$$

- Find out the deflection (δ_1) due to load at C point.

a = 150 mm, b = 1000 mm

$$\delta_1 = \frac{50*10^3 * 150^3 * 1000^3}{3 * 205000 * 635850 * 1150^3}$$

δ_1 = 0.284 mm

- Find out the deflection (δ_2) due to load at D point.

a = 575 mm, b = 575 mm

$$\delta_2 = \frac{0.67*10^3 * 575^3 * 575^3}{3 * 205000 * 635850 * 1150^3}$$

δ_2 = 0.0407mm

- ❖ Find out the deflection (δ_3) due to load at E point.

a = 1000 mm, b = 150 mm

$$\delta_3 = \frac{50*10^3 * 1000^3 * 150^3}{3 * 205000 * 635850 * 1150^3}$$

δ_3 = 0.284 mm

δ = 0.608 mm

- ➢ Strain = Change in length/Original Length

= 0.608 / 1150

= $5.293*10^{-4}$

- ➢ E = Stress / Strain

Stress = Strain * E

= $5.293*10^{-4}$ * 205000

Stress = 108.510 N/mm^2

6.2.3. For I- Cross Section Axle

$$\delta = \frac{W a^3 b^3}{3EIl^3}$$

- ❖ Find out the deflection (δ_1) due to load at C point.

a = 150 mm, b = 1000 mm

$$\delta_1 = \frac{50*10^3 * 150^3 * 1000^3}{3 * 205000 * 753750 * 1150^3}$$

δ_1 = 0.239mm

- ❖ Find out the deflection (δ_2) due to load at D point.

a = 575 mm, b = 575 mm

$$\delta_2 = \frac{0.67*10^3 * 575^3 * 575^3}{3 * 205000 * 753750 * 1150^3}$$

δ_2 = 0.034mm

- ❖ Find out the deflection (δ_3) due to load at E point.

a = 1000 mm, b = 150 mm

$$\delta_3 = \frac{50*10^3 * 1000^3 * 150^3}{3 * 205000 * 753750 * 1150^3}$$

δ_3 = 0.239mm

$\underline{\delta = 0.512mm}$

- Strain = Change in length/Original Length

  =0.512 / 1150

  = $4.455*10^{-4}$

- E = Stress / Strain

  Stress = Strain * E

  = $4.455*10^{-4}$ * 205000

  Stress = 91.331N/mm^2

7.Comparison Of Stresses And Price

MATERIAL	SHAPE OF AXLE	MAXIMUM STRESSES (N/mm2)	ELONGATION (MM)	MASS OF AXLE(Kg)	PRICE/PIECE (Rs.)
SAE 1020	SQUARE *(EXISTING AXLE)*	26.168	0.147	68.616	2802.10
SAE 1020	SQUARE	132.358	0.742	30.496	1245.466
	ROUND	108.510	0.608	34.490	1408.589
	I-SECTION	91.331	0.512	25.616	<u>1046.157</u>
SAE 1040	SQUARE	132.339	0.760	30.399	1241.510
	ROUND	108.127	0.621	34.552	1403.900
	I-SECTION	91.340	0.525	25.535	<u>1042.849</u>
DUCTILE CAST IRON	SQUARE	132.158	0.904	27.625	1730.422
	ROUND	108.350	0.742	31.294	1962.511
	I-SECTION	91.528	0.626	23.273	<u>1457.821</u>

Table 7 : Comparison of stresses and price for different cross section axle

7.1.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 1457.821Rs.

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.

7.1.1.<u>Compare The Existing Axle Price And New Designed Axle Minimum Price</u>

- Existing axle price is 2802.10 Rs.
- New designed axle minimum price is 1042.849 Rs.
- So we got the price difference of 1759.25 Rs.
- Means by adopting the new design of axle we can reduce the axle cost up to 1759.251 Rs.

8.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 1759.251 Rs.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 91.340 (N/mm2) which are in within limit.

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