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Optimization Of Tractor Trolley Axle Using Fem

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Abstract:- Tractor trailers are very popular mode of transport, especially in rural area & used for transport of various materials like building construction material, agricultural crops, heavy machineries & other miscellaneous material. In rural area 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. 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 redesigned considering the static and dynamic load conditions. Based on finite element analysis, redesign of axle was carried out for reducing the cost, weight and maintains the mechanical strength with easy manufacturability and cost reduction. Results of static, modal and transient analysis of proposed axle under loading due to modified combine showed that the proposed model is suitable to install on trolley. The design is optimized based on the manufacturing cost of the axle. The failure analysis is performed on the axle of trolley used in agricultural area. These results provide a technical basis to prevent future damage to the location axle.
keywords: Trolley axle, optimization, Ansys, weight reduction.

INTRODUCTION

Small scale industries play a strategic role in the progress of the whole country. These industries by and large represent a stage in economic transition from traditional to modern technology. The challenge of economic growth is to accelerate the productivity of agriculture and industry through their techniques of production. This will improve the adoption of a progressively superior technology in semi urban and rural areas particularly. [1] Tractor trailers are very popular mode of transport, especially in rural area and used for transport of various materials like building construction material, agricultural crops, heavy machineries and other miscellaneous material. In rural area 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. , it is noticed that the rear axle beam of trailer is a weak member, having negligible deflection, but having premature failure problem, even though the number of failures is small, they are important because they may affect the manufacturer's reputation for reliability.[4,5] Trolley axle is a supporting shaft or member on which a wheel revolves. The axle is fixed to its surroundings with the wheels rotating around the axle. A bearing or bushing sits inside the hub with which a wheel or a set of wheels revolves around the axle. A premature fatigue failure analysis that occurred prior to the expected load cycles in the tractor trolley rear axle is done in the present work. [1, 2]

Fatigue failures occur due to the application of fluctuating stresses those are much lower than the stress required causing failure during a single application of stress. It has been estimated that fatigue contributes to approximately 90% of all mechanical service failures. Fatigue is a problem that can affect any part or component that moves. [2, 3, 4]

II. PROBLEM DEFINITION

- Due to end movements are created in tractor trolley rear axle, the beam is considered as fix supported beam for this study.
- Modified Goodman method is used to fatigue failure analysis of rear axle of tractor trolley.
- Static analysis results and hand calculation results are matched.[5,7]

III. PROBLEM IDENTIFICATION

Especially in the small and middle scale agricultural machinery industry, insufficient awareness and use of new technology, and new design features can cause problems such as breakdowns and failures during field operations. Failure of machinery devices is one of the major problems in engineering. Tractor is one of the multifunctional machines that are used for different agricultural operations. Because the tractors work on difficult conditions than other machines, components of that should have high safety of factor. Its main components must be resistant to tolerate additional stress and loads as some of its component may face additional stress. This additional stresses may cause the parts to failure or face permanent deformation. [5, 7]

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. The dynamic load i.e. sudden or impact load due to off road condition and is almost equal to static load. In the present work axle is identified as weak member of the tractor trolley and investigations are carried out on its failure. The investigation of failure mainly covers three areas as follows. [4, 5, 7]

a. Initial observation and background data
b. Laboratory studies
c. Synthesis of failure

IV. DYNAMIC LOAD FOR AXLE

Due to their higher loading capacity, solid axles are typically used in the commercial vehicles. Solid axles are loaded with dynamic load when vehicle runs on road. Dynamic stress is generated in the solid axles. The dynamic load is the major cause leading to solid axle's fatigue failure when vehicle runs.

At present when designers design the vehicle solid axle housing, the dynamic load generated in axle has to be considering due to influence of random road roughness. When vehicle runs on the road and carries heavy load, the inertia load caused by vibration and impact load increase greatly. Influence of road roughness and variation of the loading must to be taken into consideration. Because of the vertical acceleration of lumped mass of the vehicle body due to the road surface roughness, maximum dynamic loading on each coil spring seat is estimated about twice as much as static loading. [4, 8]

4.1. Analytical Calculation

The dynamic load conditions are used to for the calculation
Total static load on axle in N = 7300 X 9.81 N = 71613 N
Dynamic load factor on axle due to suddenly applied load = 2
Total dynamic load on the axle in N= 71613 X 2 = 143226 N
Dynamic load at each leaf spring in N = 14326/ 2= 71613N

Reaction at Support

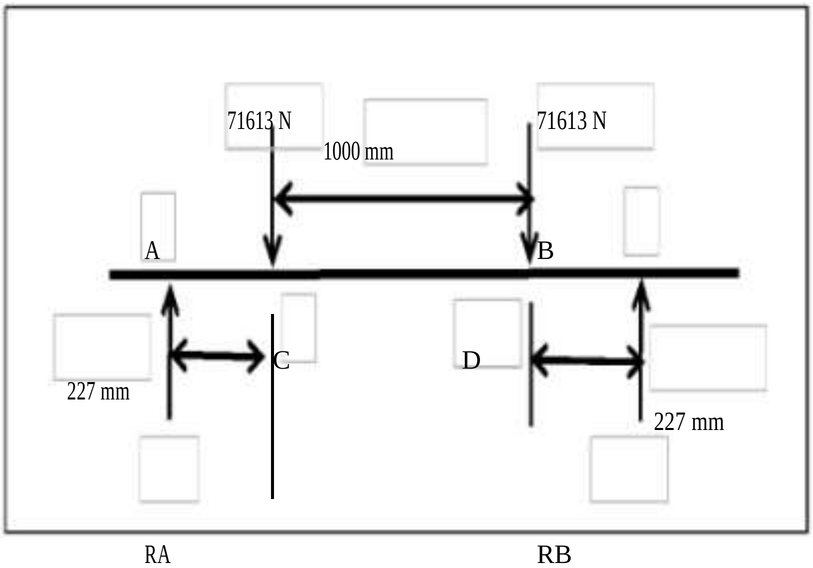

Figure.1 Loading for Simply Supported Beam

* $\sum M_A = 0$
* RBX 1454 - 71613 X 1227 -71613 X 227 = 0
* RB = 71613 N

And now finding the reaction at point B, we take the summation of the vertical forces,

* RA + RB – 71613- 71613 = 0

* * RA = 71613 N
Bending moments are zero at the end of simply supported beam Bending moment at point A = 0 KN- mm

Bending moment at point B = 0 KN- mm
Now we find the bending moment at point C, D Bending moment at point C = RA X 227
= 16256151 N- mm = 16.256151 KN-m
Bending moment at point D = RA X 1227 – 71613 X 1000 = 16256151 N- mm = 16.256151 KN-m

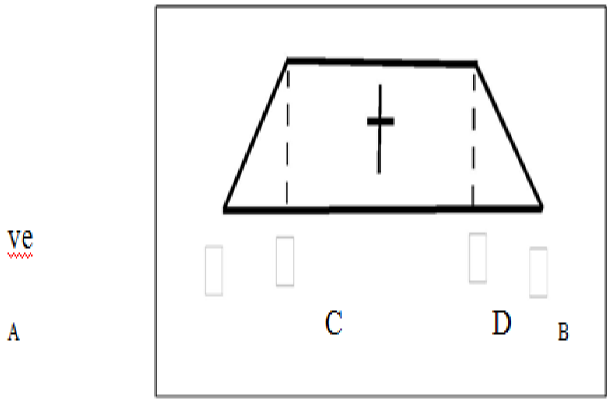

Figure.2 Bending Moment Diagram for Simply Supported Beam.

According to Mohr's theorem
EI (θA - θB) = A1 + A2
A1 = Area of free bending moment diagram
= ½ X 227 X 16256151 + 1000 X 16256151+ ½ X 227 X 16256151
= 19946297277

A2 = Area of fixed bending moment diagram = - MA X 1454
For a fixed beam difference slopes at A and B is zero.
A1 + A2 = 0
MA = 19946297277 / 1454
= 13718223.7 N- mm= 13.7182237 KN- mm

MC MD

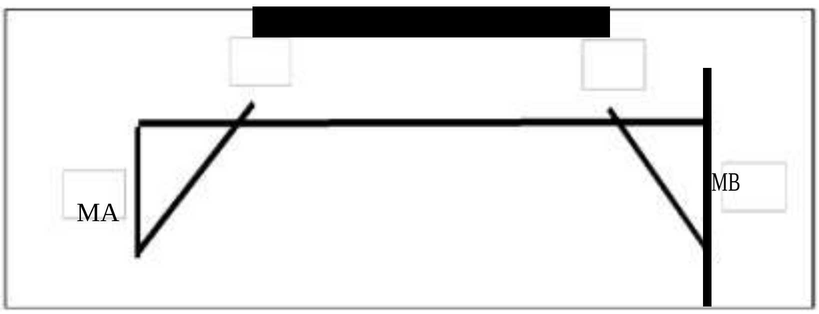

Figure.3 Bending Moment Diagram for Axle

Bending moment at C = -MA + RA X 0.227 = 2.537927 KN-m
Bending moment at D = -MA + RA X 1.227 – 71613 X 1 = 2.537927 KN-m

4.2. Stresses at Change in Cross Section
Cross section of axle at change in cross section = 75 mm X 75 mm
Section modulus = (75 X75^3/ 12) / (75 /2)
= 70312.5 mm^3
Bending moment at change in cross section = 12.286 kNm

Bending stress = Max bending stress / Section modulus
= 174.73Mpa
Diameter = 69 mm
Section modulus = π X $d^3/32$
= 3234.95 mm^3
Bending moment at Change in Cross section
= 12.286 KNm
Bending stress = Max bending stress / Section modulus
= 381.14Mpa.

V. FINITE ELEMENT ANALYSIS OF EXISTING AXLE

For the FE Analysis, it is necessary to create a solid model of axle and also to create a FE model. In the present work, static analysis and dynamic analysis to consider sudden load effects has been carried out for the axle. The model has a solid axle shaft of square cross sectional area of 75mm x 75mm, machined at both ends with length 1700 mm. The model is discretized using hex meshing with 123059 elements & 472102 nodes.

5.1. Loads on Rear Axle

5.1.1. Static Loading Case Loads

The total weight of fully loaded trailer including self-weight of trolley is 7300 kg i.e. load capacity of 6000 Kg & trolley weight of 1300 Kg. This load is concentrated at two mounting points for leaf spring on the axle as shown in Figure 6.6 & axle is shown in Figure 6.5
Y = 9810 mm/s²- Gravity for self- weight of axle Y = - 35807 N - Gross load at leaf spring
= (Pay load + Trolley load) x 9810 / 2
= (6 + 1.3) x 9810 / 2

Steps

- Model
- Geometry
  Part 1
- Mesh
- Static Structural
  Analysis settings
  Loads
  Supports

IV. Result

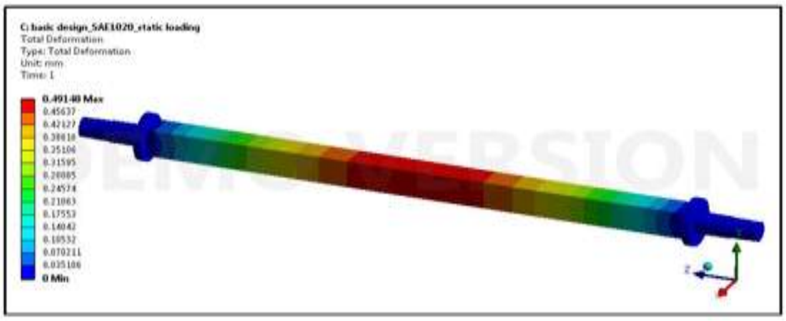

Figure 4 Total Deformation of Axle

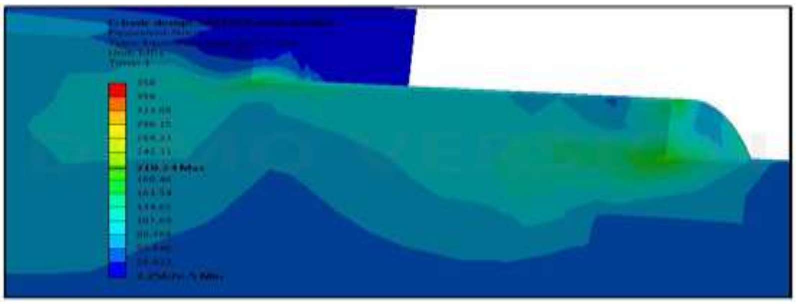

Figure 5 Sectional view of Von-Mises Stress for Axle.

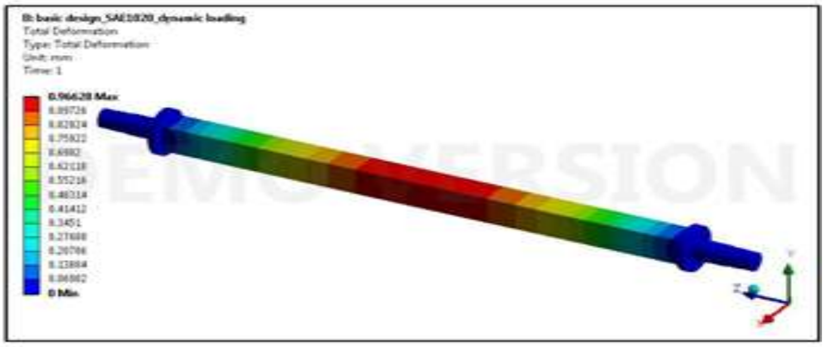

Figure.6 Total Deformation of Axle

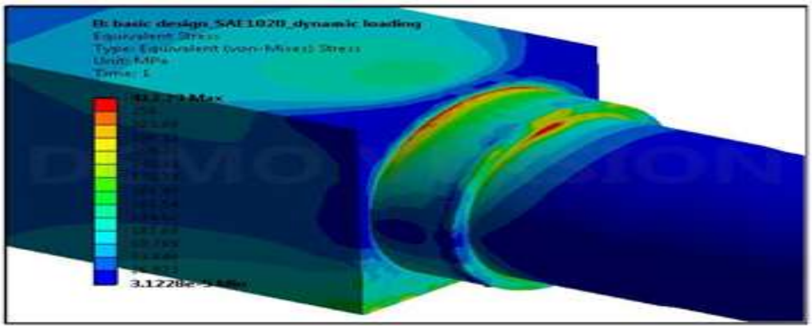

Figure.7 Von-Mises Stress for Axle

1.2. Dynamic Loading Case

5.1.2.1. Loads

The total weight of fully loaded trailer including self-weight of trolley is 7300 kg i.e. load capacity of 6000 Kg & trolley weight of 1300 Kg. This load is concentrated at two mounting points for leaf spring on the axle as shown in figure 6.13 Because of the vertical acceleration of lumped mass of the vehicle body due to the road surface roughness, maximum dynamic loading estimated about twice as much as static loading & load acting at each point is 7300 x 9.81 =71613 N.

Y = 9810 mm/s2 - Gravity for self- weight of axle

Y = - 71613 N: Gross load at leaf spring

= (Pay load + Trolley load) x 9810 x Dynamic Factor / 2= (6 + 1.3) x 9810 x 2 / 2

V. RESULT

Figure.6 Total Deformation of Axle

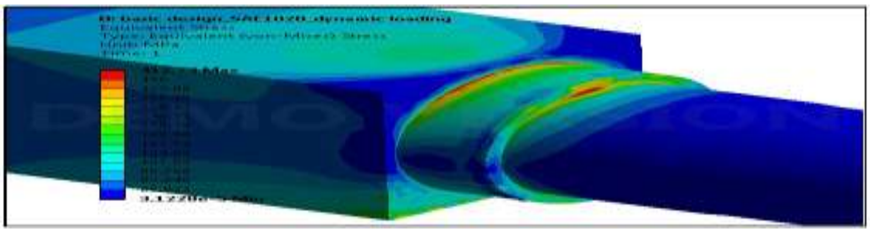

Table.1 Principal Stresses at Static and Dynamic Loading

Location of Stress	Static Loading		Dynamic Loading	
	Max. Principal Stress (S1) MPa	Min. Principal Stress (S2) MPa	Max. Principal Stress (S1) MPa	Min. Principal Stress (S2) MPa
A	290	96	625	212
B	250	50	500	100

VI. MODIFICATION IN EXISTING AXLE

From the investigation of material, manufacturing process and FE analysis it is seen that tensile stress concentrated regions are at transition area of axle hub mountings due to sharp corner at the start of step turning to facilitate proper seating of bearing locking ring or spacer before bearing assembly and this results into stress concentration area. Modification of existing axle is done aiming to strengthen this stress concentration region & avoid stress concentration which is possible if existing rear axle is manufactured with casting process and subsequently finished by machining operations at both ends for fitment of hub, as it is done in this work.

The design flexibility offered by the casting process far exceeds that of any other process used for the production of engineering components. This flexibility enables the design engineer to match the design of the component to its function. Metal can be placed where it is required to optimize the load carrying capacity of the part, and can be removed from unstressed areas to reduce weight. Changes in cross-section can be streamlined to reduce stress concentrations. The result of both initial and life-cycle costs are reduced through material and energy conservation and increased component performance.

6.1. Selection of Material

Ductile Iron is not a single material, but a family of versatile cast irons exhibiting a wide range of properties which are obtained through microstructure control. The most important and distinguishing micro structural feature of all ductile irons is the presence of graphite nodules which act as "crack-arresters" and give ductile iron ductility and toughness superior to all other cast irons, and equal to many cast and forged steels.

Matrix control, obtained in conventional ductile iron either "as-cast" through a combination of composition and process control, or through heat treatment, gives the designer the option of selecting the grade of ductile iron which provides the most suitable combination of properties. [11, 12]

Table.2 Specifications of DI 65-45-12

Specifications	**Grade 65/45/12**
Tensile strength, min MPa	448
Yield strength, min, MPa	310
Elongation in 5 0 mm, min, %	12
Endurance Strength Mpa	180

6.2. Loads on Modified Axle

6.2.1. Static Loading Case Results

Figure.8 Total Deformation of Axle

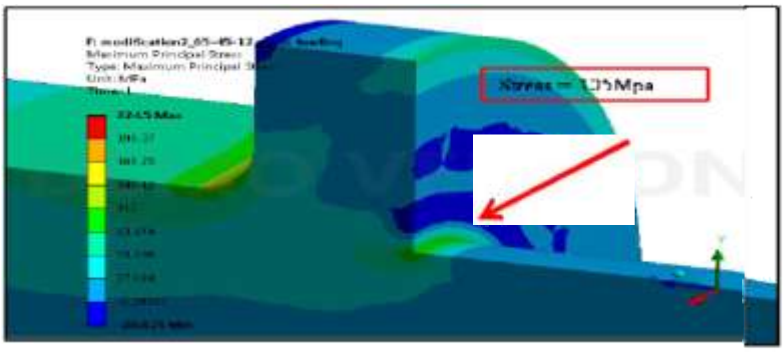

Figure.9 Sec tional view of Maximum Principal Stress for Axlle

Finite Element Analysis and Optimization of Tractor Trolley Axle

6.2.2. Dynamic Loading Case Results

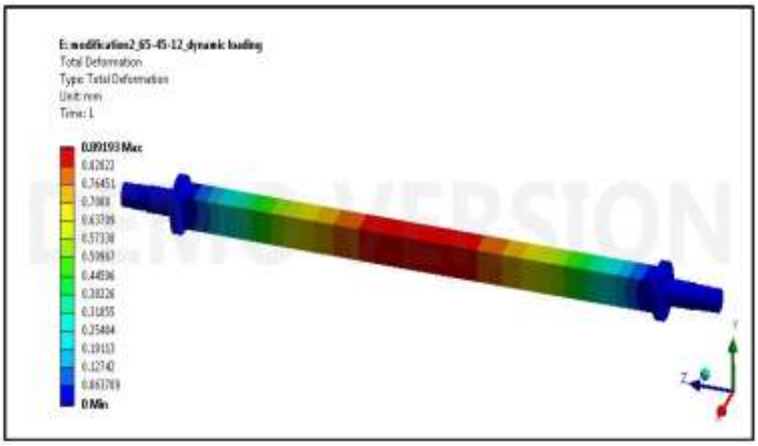

Figure.10 Total Deformation of Axle

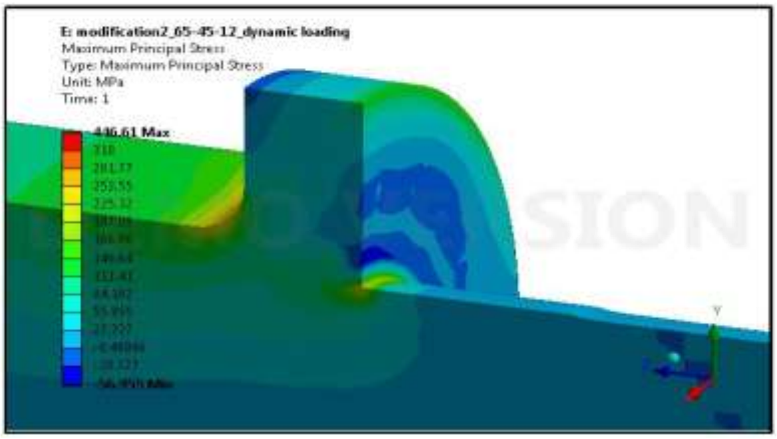

Figure.11 Sectional View of Maximum Principal Stress for Axle

Table.3 Principal Stresses at Static and Dynamic Loading

Location of	Static Loading			Dynamic Loading	
Stress					
	Max. Principal		Min. Principal	Max. Principal	Min. Principal
	Stress (S1)		Stress (S2)	Stress (S1)	Stress (S2)
	MPa		MPa	MPa	MPa
A	-		-	-	-
B	105		28	220	55
At A:					
Stresses are much lower, so no need to consider					
At B					
Max. Stress = σmax = 220 MPa			Min. Stress = σmin = 28 MPa		

Stress amplitude = σa = (220-28) / 2 = 96 MPa
Mean Stress = σm = (220+28) / 2 =124 MPa

Plotting of Stress amplitude and Mean Stress on Modified Goodman Diagram shows that the point B is inside the safe region. So Axle is safe in both Fatigue and Yield.

Equivalent Fully Reversed Stress (EFR) σe for the Point B is 133 Mpa as shown in the Figure. 7.26
Factor of Safety = Endurance Strength / EFR
= 180 / 133
= 1.35
Factor of Safety in Yield = Yield Strength / Von-Mises Stress
= 310 / 160
= 1.94

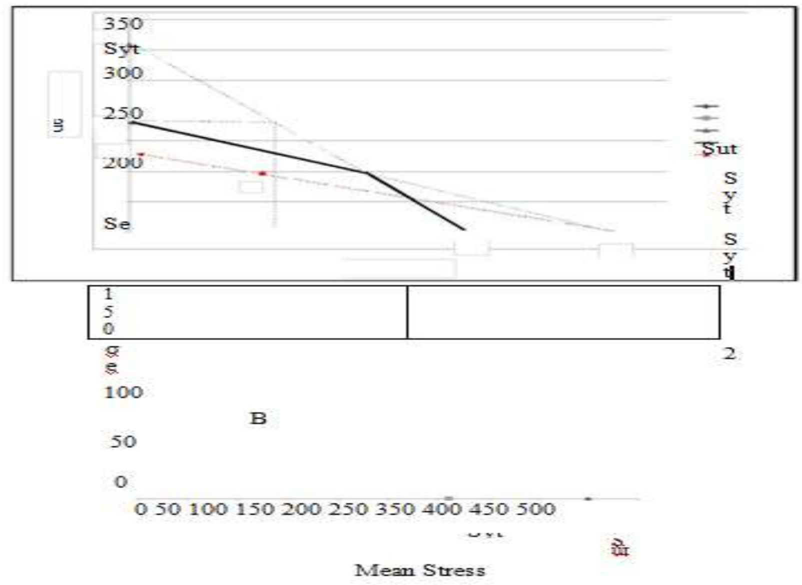

Figure.12 Modified Goodman Diagram for Ductile Iron.

VII. CONCLUSION AND RESULT

Any comparison of materials and its processing to make final product must be justified by comparing the results of material and its process under consideration. In the present work comparative evaluation is done on the basis of following given parameters.

- Results obtained from the finite element analysis for both existing and modified axle.
- Advantages in conversion of material and process
- Cost estimation.

7.1. Evaluation on the Basis of FEA Results

Results obtained from the FE analysis of existing & modified axle are compared as shown in table 8.1 given below.

(1)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 reduce the 9.48% weight as compare to the existing axle shown in comparison table.

(2) Also reduces the cost of trolley axle as the weight of the axle reduces. We reduce the cost of axle and the deformations as well as stresses developed in new designed axle are in within limits the minimum cost obtained for axle of Ductile Iron 65-45-12 material The weight of axle is reduced without compromising with existing hub assembly of wheel, factor of safety and stiffness of the axle

Table 4 Comparative Evaluation

Particular	**Existing Axle**	**Modified Axle**
Material	SAE 1020	Ductile Iron 65-45-12
Process	Machined Hot Rolled Bar	Casting
Weight	70.08 kg	63.44 kg
Factor of Safety in Yield	0.875	1.94
Factor of Safety in Fatigue	0.845	1.35

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