

# Weight and Strength Optimization of Sugarcane Trolley Axle FEA and Experimental

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**Abstract-** In the present market scenario, cost reduction technique is playing a signified role to meet the competition in the market. Weight reduction and simplicity in design are application of industrial engineering etc., are used as source of technique. 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. Tractor trolleys are manufactured in small to moderate scale industries. Though tractor trolleys are manufactured of various capacities by various industries, still there is a large variation in manufacturing methods, component design etc. The trolley axle is a central shaft for rotating wheels. The wheels are fixed to the axle, with bearings or bushings provided at the mounting points where the axle is supported. The axle maintains the position of the wheels relative to each other and to the vehicle body.

In this project work survey is made on sugarcane tractor trolley, during survey it is found that most of axles having bending, deformation, weight, strength problems, and common problem are bending. In this project work analysis is done on axle by finite element analysis using ansys15 for checking bending, deformations and weight optimization by using various materials like MS, SAE1020, Inconel, etc.

## I. INTRODUCTION

In India Tractor trolley or trailers is 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. 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.



Fig: typical trolley and its axle unit

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. In the global competition, it is very important for the manufacturer to bring new product designs to market at a faster rate & also at reduced cost. Front axle beam is one of the major parts of vehicle suspension system; it takes about 35-40% of total vehicle weight. Optimization of axle beam is necessary to improve strength to weight ratio for a given factor of safety without altering any assembly parameters. The main purpose of the trolley is to provide a hassle-free mode of transporting firewood. The existing designs of trolleys are enormous due to the fact that they need to carry loads of different sizes. It is a known fact, that the mountain dwellers have great skill in stacking up the firewood collected. The objective of this paper to optimize the axle design using finite element analysis method and to validate the design. The main purpose is to reduce the weight of the axle as the axle is the only component who bears the whole load plus the weight of the trolley and then it transfer to the wheel.

## II. PROBLEM STATEMENT

In this project work survey is made on sugarcane tractor trolley, during survey it is found that most of axles

having bending, deformation, weight, strength problems, and common problem are bending. Almost all tractor trolleys are overloaded as shown in fig 2. Due to this excess loading axle will bend and ultimately fails before the life designed by manufacturer. Bending of axle is shown in following images. In this project work analysis is done on axle by finite element analysis using ansys15 for checking bending stress, strength, deformations and weight by using various materials like MS, SAE1020, Inconel, etc.



Fig. 3 Bending of sugarcane trolley axle

### III. LITERATURE REVIEW

This paper deals with static analysis of tractor trolley axle. In India tractor trolley (or) trailers is very popular and cheaper mode for transport of goods and in rural as well as urban areas. Especially various small scale industries are adopting the crude methodologies for designing and manufacturing machine components. One such industry producing tractor trolleys for agricultural use has been identified for this study. Most of the tractor trolley axle used today is rectangular cross section type which in turn leads to increase in the weight of tractor trolley and axle. The solid modeling of axle is developed by CATIA-V5. Analysis is done using ANSYS work bench. In paper an attempt has made by replacing rectangular cross section with circular section. Further static analysis is done to determine von-mises stress, equivalent elastic strain, maximum shear stress, total deformation. Finally the results of rectangular section axle with circular section axle are compared which result in reducing the 20% weight of the circular axle. [1]

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 analyzed 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.[2]

Tractor trolley (or) trailers are very popular and cheaper mode of goods and transport in rural as well as urban areas. In India, various small scale industries are adopting the crude methodologies for designing and manufacturing machine components. One such industry producing tractor trolleys for agricultural use has been identified for this study. In this paper a static analysis is conducted on a tractor trolley axle. The solid modeling of axle is developed by CATIA-V5. Analysis is done using ANSYS work bench. Most of the tractor trolley axle used today is rectangular cross section type which in turn leads to increase in the weight of tractor trolley and axle. In this paper an attempt has made by replacing rectangular cross section with circular section which result in reducing the weight of the axle and the cost.[3]

The existing Combination axle is safe under the given loading conditions but it involves some problems. It is difficult to manufacture such a design as it needs one hollow shaft and two solid shafts which are inserted into hollow shaft at both ends and then welded for rigidity. The newly designed axle eliminates such problems as it is solid in all. The proposed axle takes less time to produce, so higher production rate is achieved. Further the total weight of combination axle is 56.4 Kg whereas in proposed design it comes to be 49.9 Kg. Thus 11.5% reduction in weight is achieved, which results in reduced cost. [4]

In India Tractor trolley or trailers is 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. 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 and weight and maintains the mechanical strength with easy manufacturability and cost reduction. In this paper we tried to optimize the hollow axle for the ultimate value so that the strength should be maintained with the reduction in cost and weight and we find the weight is reduce 40 to 60 %.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. [5]

**IV. SCOPE AND OBJECTIVE OF WORK**

➤ **SCOPE:**

1. Study of Present sugarcane trolley design
2. Take practical input by survey
3. Literature Survey
4. Design of trolley axle by using CATIA V5 R20
5. Analysis of trolley axle for different material like MS, SAE1020, Inconeletc.
6. Design Modification for weight optimization

➤ **Objectives:**

1. To find bending stress and strain of sugarcane trolley axle, to overcome the axle bending problem
2. To check strength of axle by static analysis
3. To optimize the weight by modifying the design
4. To check the deformations for various material & suggest best one

**V. METHODOLOGY**

**5.1 Analytical Method:**

**5.2 FEA**

**1) Steps :**

- Model
- Geometry
- Part 1
- Mesh

**2) Static Structural Analysis:**

- Analysis Settings
- Loads
- Solution
- Solution Information
- Results
- Stress Tool
- Results

**3) Optimization Technique:**

In optimization technique more stress concentrated material will be change by adding or subtracting the material for the purpose of increasing strength of axle and reducing stress concentrated area of axle to avoid the bending without increasing cost of axle.

**5.1) Analytical Method:**

**STEP 1: FBD**

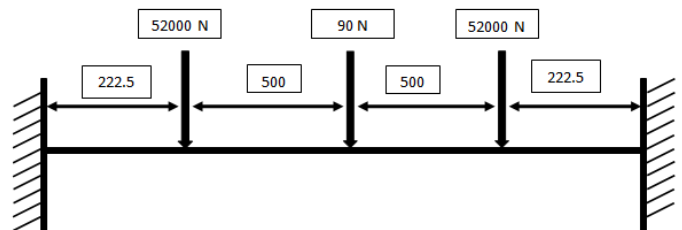


Fig. 4. Free Body Diagram of trolley Axle

**STEP 2: Reactions and Moments:**

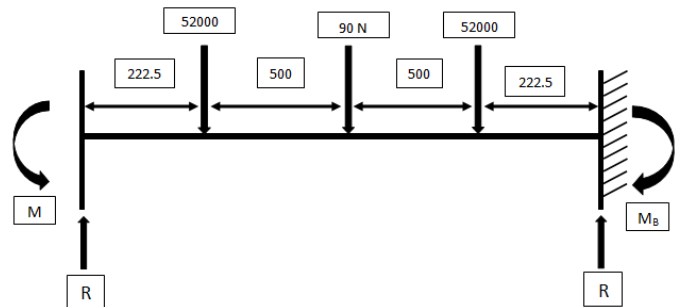


Fig. 4. Free Body Diagram with reactions & moment at trolley Axle

Submitting forces along vertical direction

$$\sum F_Y = 0$$

$$R_A - 52000 - 900 - 52000 + R_B = 0$$

.....Eq. (1)

Since forces are symmetric,  
Reaction on both side is same, hence  $R_A = R_B$ ,  
Hence by solving equation (1),

$$R_A = R_B = 52450 \text{ N}$$

**STEP 3:** Finding Moments at end of beam i.e.  $M_A$

Considering any distance X from point A such that  $0 \leq X \leq L/2$ ,

$$M = (R_A * X) + Pc*(X - 222.5) - M_A,$$

According to double integration method of beam,

$$E.I.Y'' = M,$$

$$E.I.Y'' = (R_A * X) + Pc*(X - 222.5) - M_A,$$

$$E.I.Y' = (R_A + Pc) \frac{X^2}{2} - [(222.5 * Pc) + M_A] * X + C_1,$$

.....Eq. (2)

$$E.I.Y = (R_A + Pc) \frac{X^3}{6} - [(222.5 * Pc) + M_A] * \frac{X^2}{2} + (C_1 * X) + C_2$$

.....Eq. (3)

**Boundary Condition**

At  $X=0$ ;  $Y'=0$ ,

Also  $X=0$ ;  $Y=0$

Putting above boundary conditions in equation 2 and equation 3

We get,

$$C_1 = C_2 = 0,$$

Putting the value of  $C_1$  in equation 2

$$E.I.Y' = (R_A + Pc) \frac{X^2}{2} - [(222.5 * Pc) + M_A] * X$$

After applying boundary condition we get,

$$0 = (R_A + Pc) \frac{L}{2} - [(222.5 * Pc) + M_A]$$

Solving above equation and putting values

$$M_A = 2.62 \times E^7$$

Since beam is symmetric

$$M_A = M_B = 2.62 \times E^7$$

**STEP 4:** Finding Deformation

Solving equation 3 by putting appropriate values in equation

$$E.I.Y = (R_A + Pc) \frac{X^3}{6} - [(222.5 * Pc) + M_A] * \frac{X^2}{2} + (C_1 * X) + C_2,$$

$$E.I.Y = (52450 + 52000) \frac{X^3}{6} - [(222.5 * 52000) + 2.62 * E^7] * \frac{X^2}{2} + (0 * X) + 0$$

Maximum deformation will be at centre i.e. at  $X=722.5$ ,

Hence

$$E.I.Y_{MAX} = (52450 + 52000) \frac{722.5^3}{6} - [(222.5 * 52000) +$$

$$2.62 * E^7] * \frac{722.5^2}{2} + (0 * 722.5) + 0$$

$$E.I. Y_{MAX} = -3.292 \times E^{12}$$

Negative sign shows deformation is downward.

$$Y_{MAX} = \frac{-3.292 \times E^{12}}{E.I.} \dots\dots\dots \text{Eq. (4)}$$

Hence

1. Axle with Material Steel ( $E = 205 \text{ MPa}$ ) and Diameter 80 mm

$$Y_{MAX} = \frac{-3.292 \times E^{12}}{E.I.}$$

$$Y_{MAX} = \frac{-3.292 \times E^{12}}{4.121 \times E^{11}}$$

$$Y_{MAX} = 7.98 \text{ mm}$$

2. Axle with Material Steel ( $E = 205 \text{ MPa}$ ) and Diameter 82 mm

$$Y_{MAX} = \frac{-3.292 \times E^{12}}{E.I.}$$

$$Y_{MAX} = \frac{-3.292 \times E^{12}}{4.55 \times E^{11}}$$

$$Y_{MAX} = 7.235 \text{ mm}$$

3. Axle with Material Steel ( $E = 205 \text{ MPa}$ ) and Diameter 78 mm

$$Y_{MAX} = \frac{-3.292 \times E^{12}}{E.I.}$$

$$Y_{MAX} = \frac{-3.292 \times E^{12}}{3.725 \times E^{11}}$$

$$Y_{MAX} = 8.838 \text{ mm}$$

**STEP 6:** Stress in Beam

$$\text{Maximum Stress } \sigma_{MAX} = \frac{y \cdot M_A}{I}$$

$$\sigma_{MAX} = \frac{40 \times 2.62 \times E^7}{I}$$

Hence

1. Axle with Material Steel ( $E = 205 \text{ MPa}$ ) and Diameter 80 mm

$$\sigma_{MAX} = \frac{40 \times 2.62 \times E^7}{I}$$

$$\sigma_{MAX} = \frac{40 \times 2.62 \times E^7}{2.01 \times E^6}$$

$$\sigma_{MAX} = 521.23 \text{ MPa}$$

2. Axle with Material Steel ( $E = 205 \text{ MPa}$ ) and Diameter 82 mm

$$\sigma_{MAX} = \frac{40 \times 2.62 \times E^7}{I}$$



$$\sigma_{MAX} = \frac{40 \times 2.62 \times E^7}{2.22 \times E^6}$$

$$\sigma_{MAX} = 472.21 \text{ MPa}$$

3. Axle with Material Steel (E = 205 MPa) and Diameter 78 mm

$$\sigma_{MAX} = \frac{40 \times 2.62 \times E^7}{I}$$

$$\sigma_{MAX} = \frac{40 \times 2.62 \times E^7}{1.82 \times E^6}$$

$$\sigma_{MAX} = 576.78 \text{ MPa}$$

### VI. ANALYSIS OF TROLLEY AXLE BY MODIFYING DESIGN

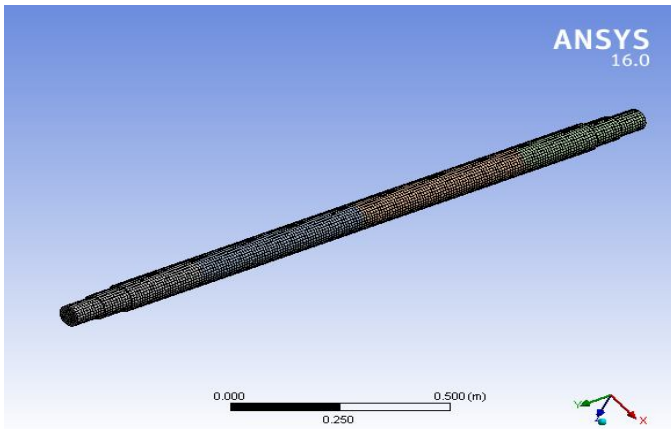
In order to optimize weight, strength following trial were conducted by using suitable software as mentioned in chapter 5

6.1 By decreasing 2mm thickness of entire Axle

6.2 By making fine slots in Axle

6.1 By decreasing 2mm thickness of entire Axle:

➤ **FEA Model**



<b>NO. OF ELEMENTS</b>	<b>40060</b>
<b>NO. OF NODES</b>	<b>142739</b>

➤ **Material: MS**

➤ **BENDING STRESS:**

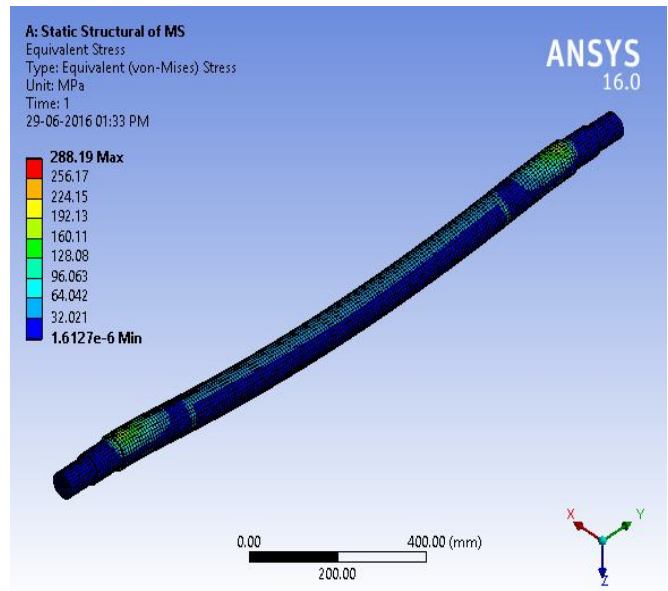


Fig: Bending Stress of MS Axle, MPa 2mm less thickness

➤ **STRAIN:**

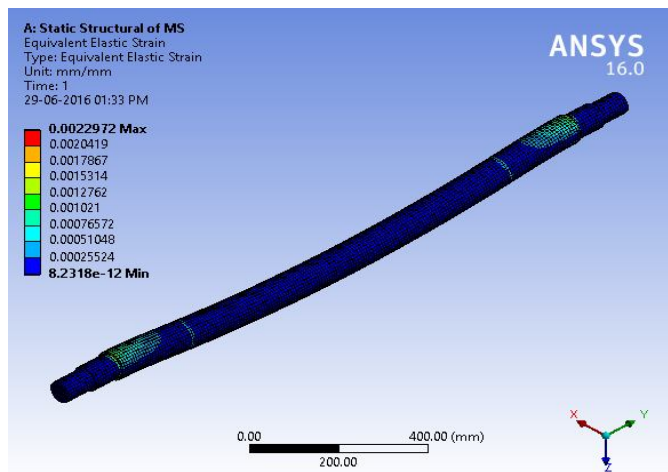


Fig: Bending Strain of MS Axle, MPa 2mm less thickness

➤ **TOTAL DEFORMATION:**

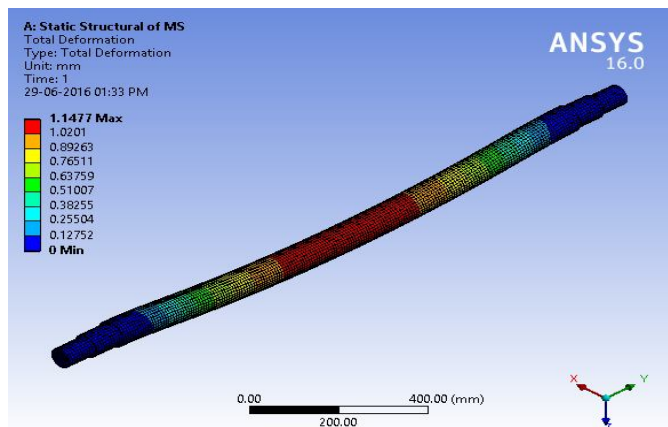


Fig: Total Deformations of MS Axle, MPa 2mm less thickness

➤ **Material: SAE 1020**

➤ **Material: Incoel 625**

➤ **BENDING STRESS:**

➤ **BENDING STRESS**

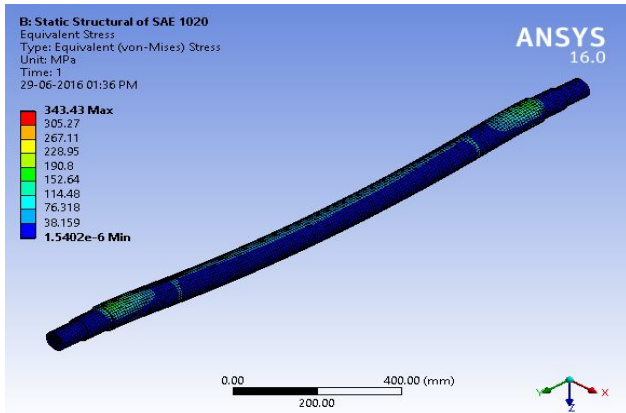


Fig: Bending Stress in of SAE1020 Axle, MPa 2mm less thickness

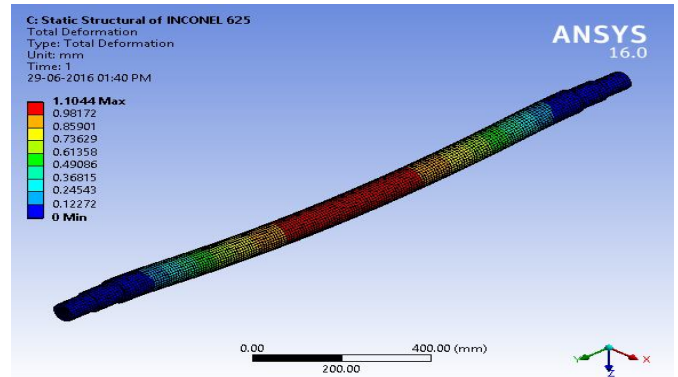


Fig: Bending Stress in Inconel625 Axle, MPa 2mm less thickness

➤ **VON-MISES STRAIN**

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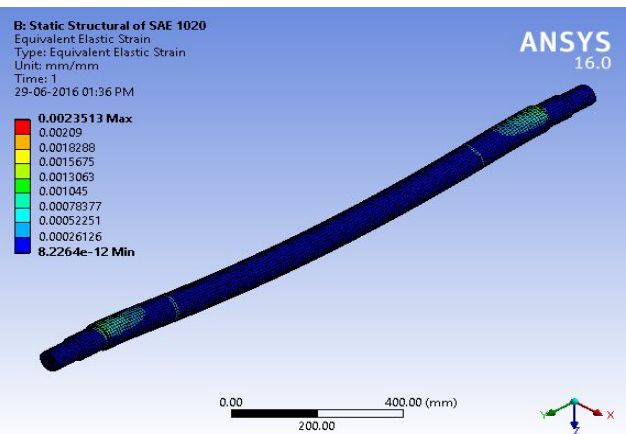


Fig: Bending Strain in of SAE1020 Axle, MPa 2mm less thickness

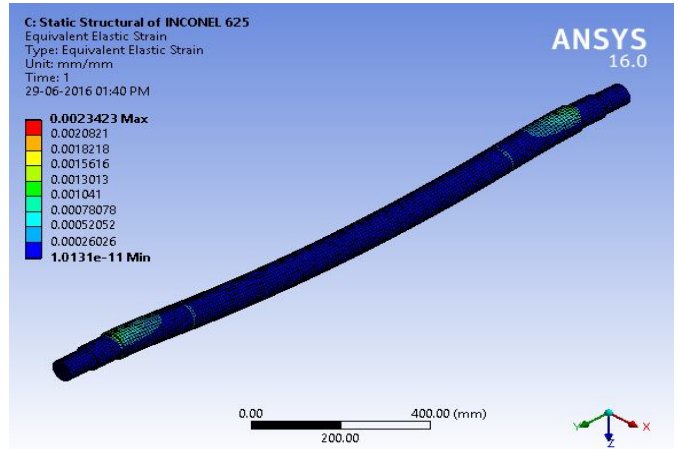


Fig: Bending Strain in Inconel 625 Axle, MPa 2mm less thickness

➤ **TOTAL DEFORMATION**

➤ **TOTAL DEFORMATION:**

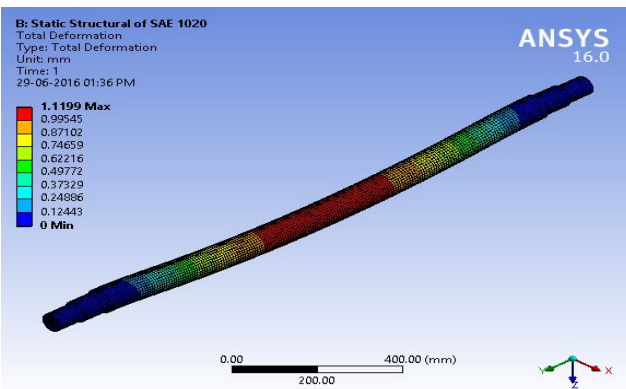


Fig: Total deformation of SAE1020 Axle, MPa 2mm less thickness

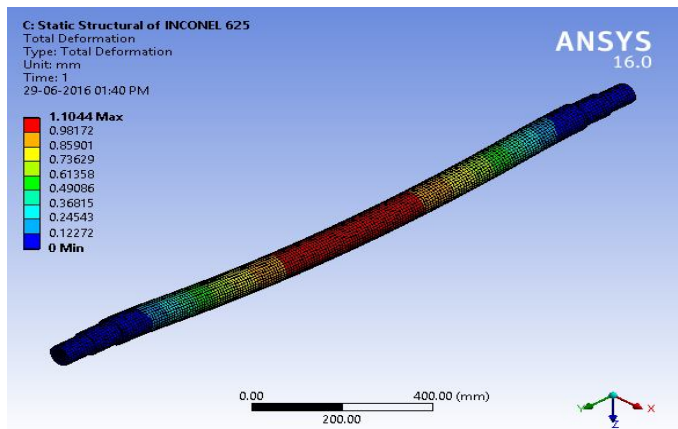


Fig: Total deformation of Inconel 625 Axle, MPa 2mm less thickness

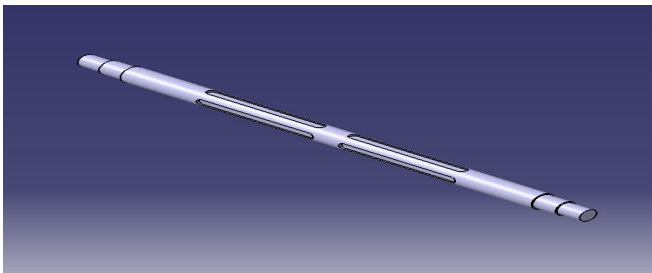
6.1.1 RESULT TABLE:

PARAMETER	MS	SAE1020	INCONEL 625
STRESS (MPa)	288.19	343.43	352.78
DEFORMATION (mm)	1.1477	1.1199	1.1044
WEIGHT (kg)	62.082 kg	62.24 kg	66.748 kg

The maximum deflection induced in MS trolley axle is 1.147 mm, which is in safe limits (1% of total span). Hence based on rigidity the design is safe, but if we compare deflections induced in SAE1020 (1.119), it is more in MS. If we use SAE1020 material failure or bending of axle will reduced. The maximum bending stress induced for both the material is 288.19 Mpa and 343.43 MPa respectively which is less than the allowable stress (350Mpa).Hence the design is safe based on strength. Compare to MS axle SAE1020 is more rigid & ultimately strength of SAE1020 axle is increases due to its rigidity. At the same time bending stress (352) for Inconel 625 is more & deflection is less. On reducing thickness of trolley axle by 2 mm weight of axle is reduced by 3 kg.

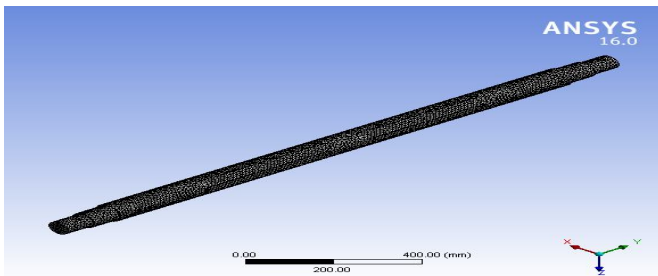
6.1 Weight Optimization by making fine slots in Axle:

➤ CAD MODEL



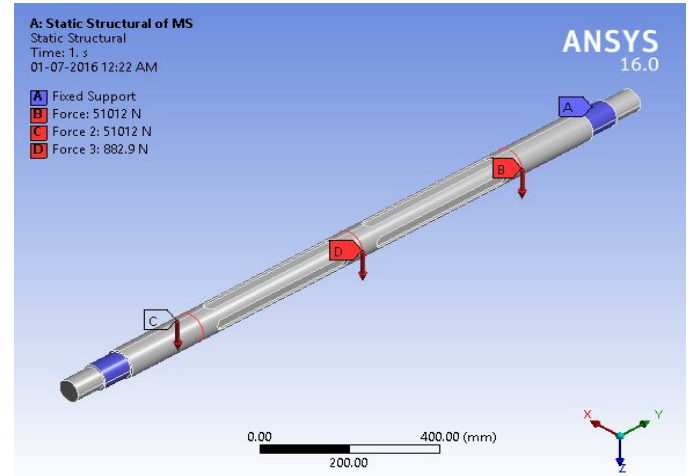
➤ MATERIAL: MS

➤ FEA MODEL:

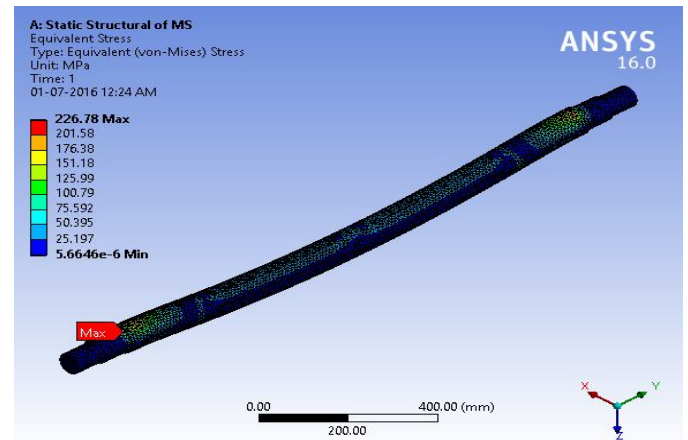


NO. OF ELEMENTS	65629
NO. OF NODES	99276

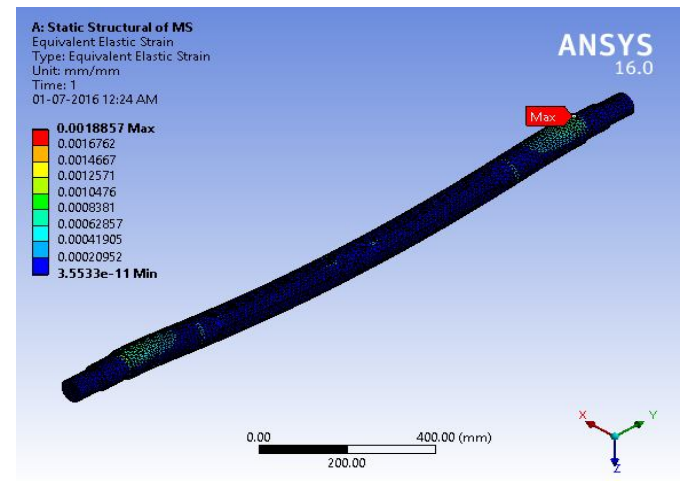
➤ SUPPORT AND FORCE



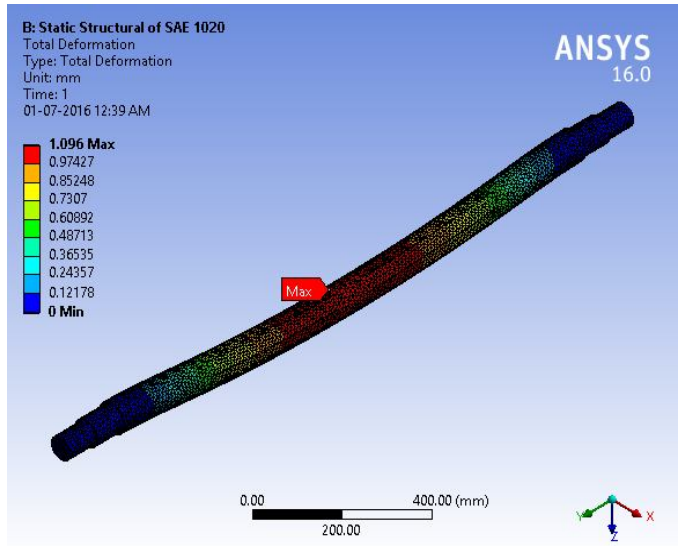
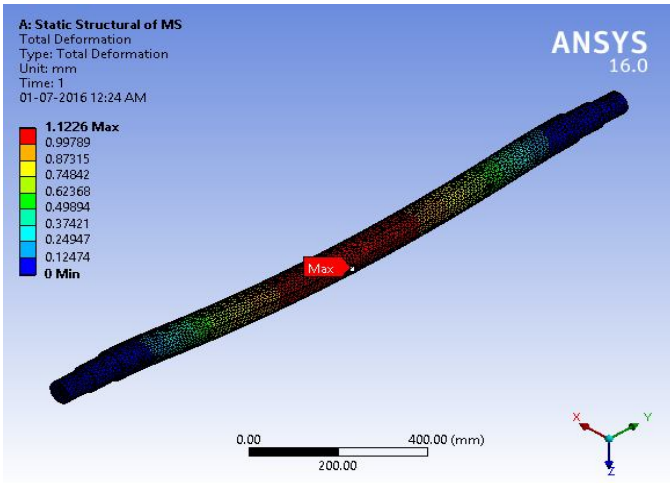
➤ BENDING STRESS



➤ VON-MISES STRAIN:



➤ TOTAL DEFORMATION

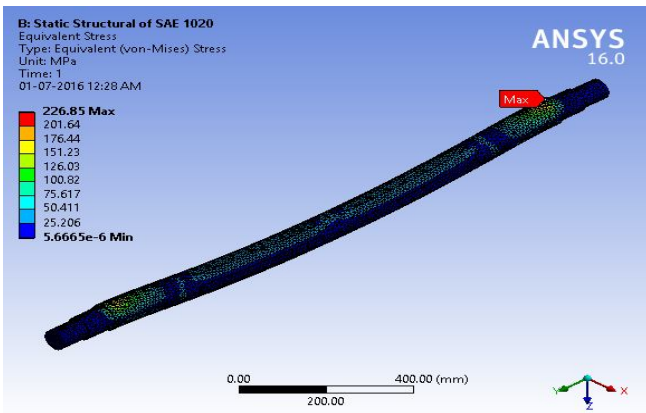


➤ MATERIAL: SAE1020

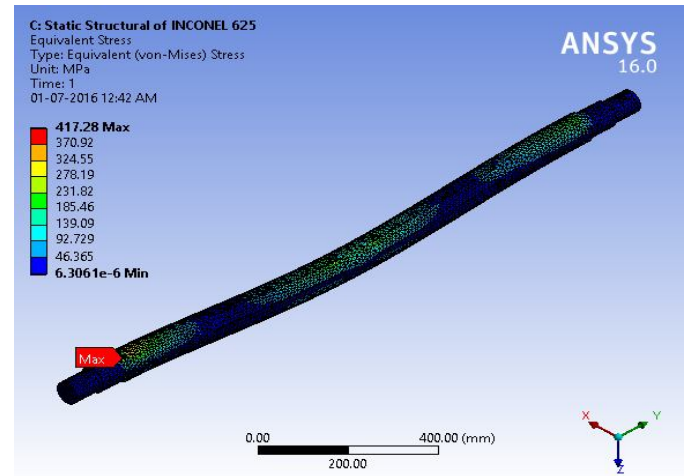
➤ BENDING STRESS

➤ MATERIAL: Inconel 625

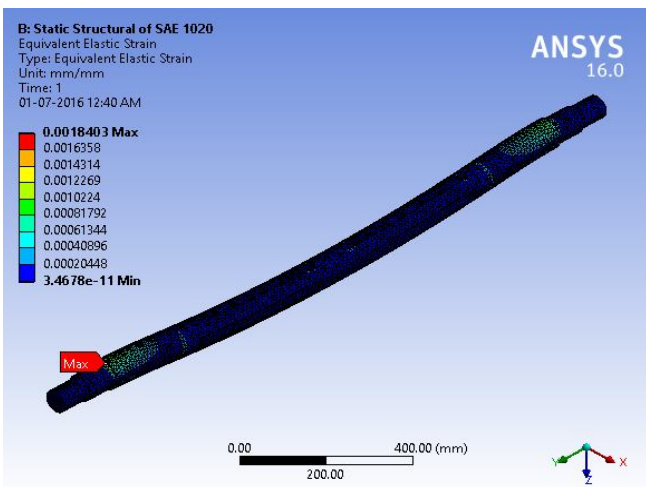
➤ BENDING STRESS:



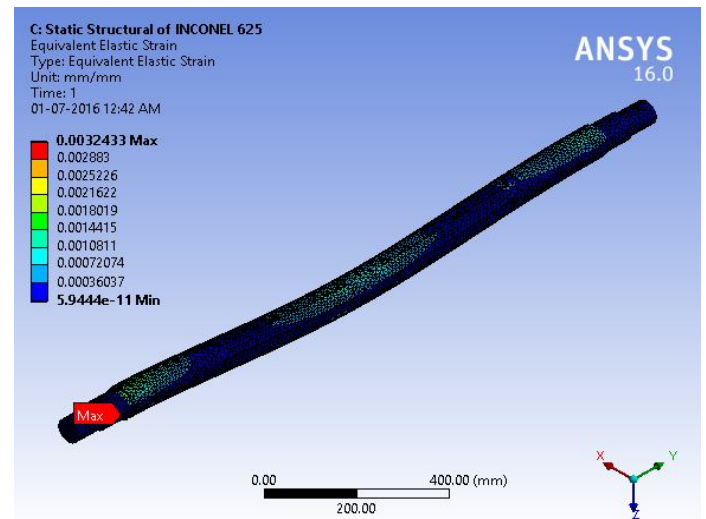
➤ VON-MISES STRAIN



➤ STRAIN:

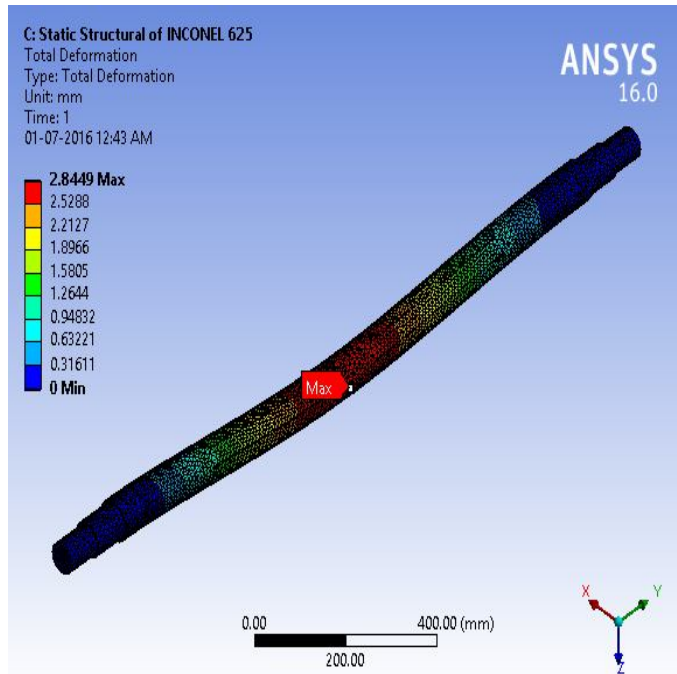


➤ TOTAL DEFORMATION





➤ **TOTAL DEFORMATION**



**6.2.1 RESULT :**

TABLE NO.6 RESULT TABLE AFTER MAKING SLOT OF 15 ×10×410

PARAMETER	MILD STEEL	SAE1020	INCONEL 625
STRESS (MPa)	226.78	226.85	417.28
DEFORMATION (mm)	1.1226	1.096	2.8449
WEIGHT (kg)	58.51 kg	58.659 kg	62.907 kg

After doing trial error for making fine slots to obtain optimum results it is found that at 15×10×410 slot results are good enough. From above result table it is clear that bending stress induced for MS trolley axle and SAE 1020 are almost same i.e. 226.78 MPa and 226.85 MPa respectively which is less than the allowable stress (350Mpa).Hence the design is safe based on strength. Deflections induced in the same axles are 1.126 and 1.096 respectively. Compare to MS and Inconel 625 deflections for SAE1020 are less, hence less chances of failure as compare to other. After making slots weight of trolley axle get reduced (58.65 Kg). Detail Comparison of all materials after analysis is shown in following tables

➤ **AFTER 2 MM REDUCTION:**

PARAMETER	MS	SAE1020	INCONEL 625
STRESS (MPa)	288.19	343.43	352.78
DEFORMATION (mm)	1.1477	1.1199	1.1044
WEIGHT (kg)	62.082kg	62.24 kg	66.748kg

➤ **AFTER MAKING SLOT OF 15\*10\*410:**

PARAMETER	MS	SAE1020	INCONEL 625
STRESS (MPa)	226.78	226.85	417.28
DEFORMATION (mm)	1.1226	1.096	2.8449
WEIGHT (kg)	58.51 kg	58.659 kg	62.907kg

**VII. TESTING AND DESIGN OF EXPERIMENTS**

Testing on modified sugarcane trolley axle is done at M.S. Bidve College of Engineering, Latur in SOM lab on digital UTM. Also trials were conducted on the modified model at Om Sai Engineering, Pune major supplier of trolley axle. The results are Successful and positive. The details are given below. Instruments used during testing with there specifications are given below:

➤ **Actual Experiment Conducted at SOM lab**



➤ **During Observation:**



## ➤ Recording Results in Computer:



Table10. Testing Results of Trolley Axle

Sr. No.	Testing Parameters	Old Results (MS)	New FEA Results (SAE1020)	New Expt. Results (SAE1020)	Testing Instrument
01	Weight of Trolley Axle in Kg	65.402	58.659	58.983	Digital Weighing Machine
02	Bending Stress, MPa	283.91	226.85	249.48	Computerized UTM
03	Strain	0.002185	0.00188	0.0021	UTM, Strain Gauge
04	Total Deformations, mm	1.0394	1.096	1.283	UTM, Strain Gauge

Table10. Errors of Experimental Testing

Sr. No.	Testing Parameters	New FEA Results (SAE1020)	New Expt. Results (SAE1020)	Error
01	Weight of Trolley Axle in Kg	58.659	58.983	0.324
02	Bending Stress, MPa	226.85	249.48	22.63
03	Strain	0.00188	0.0022	0.00032
04	Total Deformations, mm	1.096	1.283	0.187

### VIII. CONCLUSIONS

1. Bending problem of trolley axle is reduced by using SAE1020 material axle, because based on the strength and rigidity of material.
2. Deflections induced in SAE 1020 material axle is less as compared to MS axle hence failure of trolley axle minimizes
3. On reducing 2mm thickness of axle weight of SAE 1020 axle get optimized
4. On making fine slots instead of reducing thickness weight will further optimizes, and stress concentration reduces due to abrupt change in area by slots. This method gives the optimum results, but it slightly increases the machining cost compare to previous method, but it reduces the running cost.
5. As failure and bending stress for SAE1020 trolley axle reduced, ultimately we can say that strength increases.

### IX. FUTURE SCOPE

As we know nothing is perfect in this world and technology needs continuous innovation. Also for this work there was some time constraint, so future development and possible changes are proposed. In this project work shape optimization is not done, in future one can do it and can check strength, weight by trail error method. In this work Ansys 16 is used for analysis, but one can do this work by using Hypermesh CAE tool to get appropriate results.

### REFERENCES

- [1] P.Manasa, Dr. C.Vijaya Bhaskar Reddy“Static Analysis Of Tractor Trolley Axle Installment” IJETT-volume-4
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