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Structural analysis of Tractor trolley axle for different cross sections

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***Abstract*— This paper is based on structural analysis of tractor trolley axle for different cross section from analysis it can be seen that circular cross section is better in bending than square cross section axle. The total weight reduction due to circular cross section axel is 8.398 Kg with material SAE 2040.**

***Index Terms—Index Terms*— SAE1020 , SAE 1040, Tractor trolley axle, deflection and stress plots.**

I. INTRODUCTION

Tractor trolley axle is subjected to bending load. Most of analysis and work was carried out on square cross section axle. It is possible to replace the square axle with circular cross section axle and analysis can done for different materials. 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.

II. ANALYSIS OF EXISTING SQUARE CROSS SECTION AXLE USING ANSYS

In the present study market available tractor trolley axle is selected and its dimension is noted. The possible loads acting and the place of loads are noted. According to the dimensions tractor trolley axle is modeled using CATIAV5 software

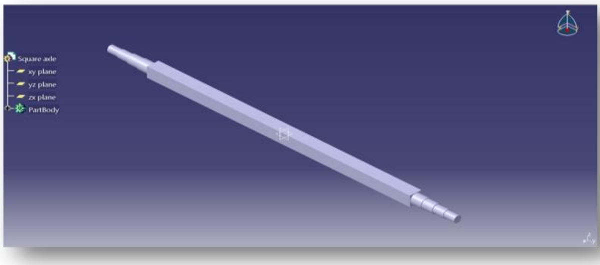


Figure 1 : CAD model of Square axle

Existing shaft is analyzed for loading conditions as shown in figure 2. Boundary conditions are axle is fixed at point A and B and force fo 46 KN is applied at point C and D.

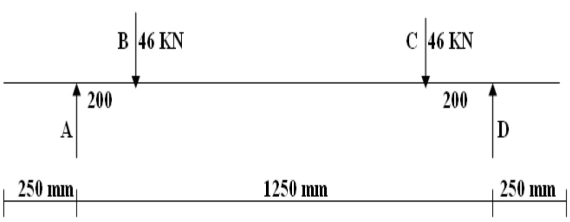


Figure No.2 : Load Distribution Diagram

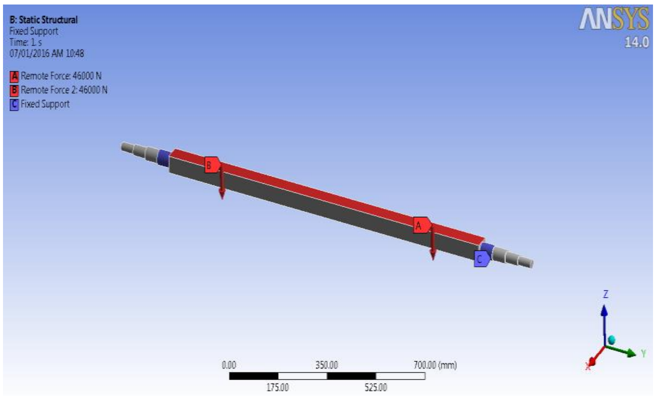


Figure No. 3 : Boundary condition applied in Ansys

Figure No. 3 Shows axle model imported in Ansys with boundary condition. Same model is analyzed for stress and deflection for material SAE 1020 and 1040. Material properties for square cross section given in Table No.1

Table 1: Properties of material SAE-1020

S_{ut}	420 MPa
S_{yt}	370 MPa
E	205 GPa
Density	7890 kg/m^3
Poisson's ratio	0.3

Table 2: Properties of material SAE-1040

S_{ut}	595MPa
S_{yt}	515MPa
E	200GPa
Density	7760 kg/m^3

III. ANALYSIS RESULT FOR SQUARE CROSS SECTION

after analysis it seen that the deformation stress and in square axle with material SAE 1020 are 0.9468 mm and 159.95 respectively. Figure no. 3 and 4 shows the deformation and stress plot for same axle in ansys.

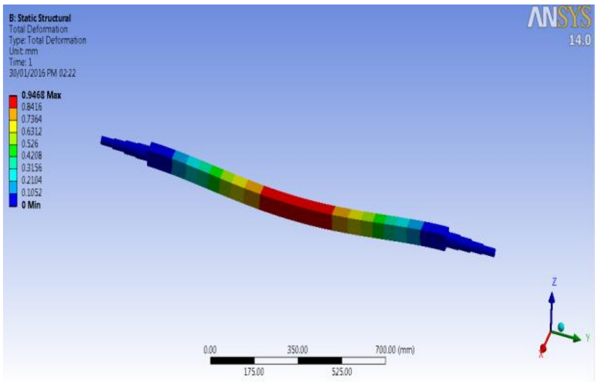


Figure No. 4 : Deformation of the axle

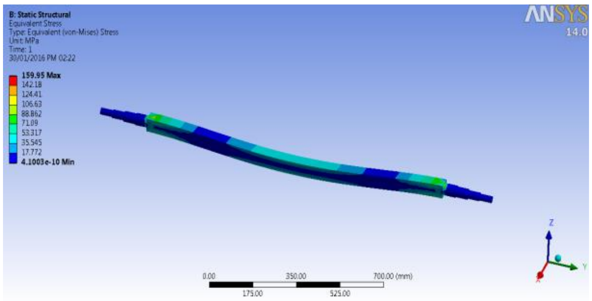


Figure No. 5 : Von-Mises Stress on the axle

IV. ANALYSIS FOR CIRCULAR CROSS SECTION AXLE

Similar to square cross section axle analysis id done for circular cross section axle for material SAE 1020 and SAE 1040.

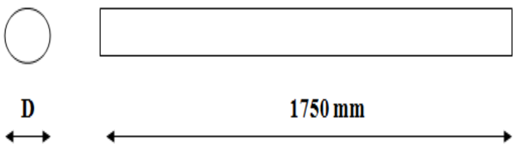


Figure No. 6: Circular cross section axle

Diameter of circular cross section axle is calculated as follows,

$M/I = (f_b)/Y$

M: Bending moment.

I: Moment of inertia.

f_b: Bending stress.

Y: Distance of outer fiber from neutral axis.

We can write above equation as,

The section modulus (z) of the existing axle

$= M/fb$

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

(fb) (Allowable) is 420 MPa.

Maximum Bending moment (M) is found to be 9200000 N-mm

Hence,

Section modulus (z) = M/fb

$= 21904.76$ mm^3

We know that,

Section modulus for circular section (z) = $\pi D^3/32$

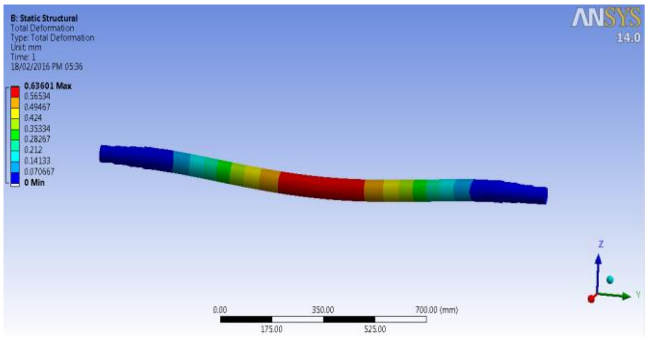
- The obtained value of $z = 21904.76$ mm^3

$= \pi D^3/32$

D = 60.65 mm.

- D = 65 mm

So on the basis of bending moment only we got the cross section of axle as 65 mm.



FigureNo.7 : Deformation of the axle

Figure No. 7 shows deformation plot of circular axle with maximum deformation 0.63601 mm for material SAE 1020

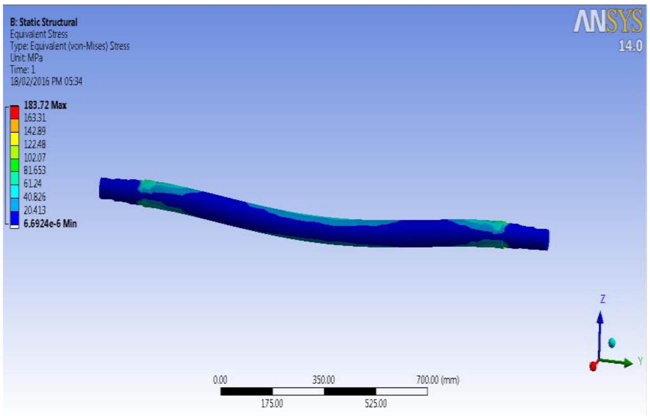


Figure No. 8 : Von-Mises Stress on the axle

Figure No. 8 shows stress plot for circular axle with maximum stress 183.72 MPa and minimum stress 6.6924e^{-6} for material SAE 1020

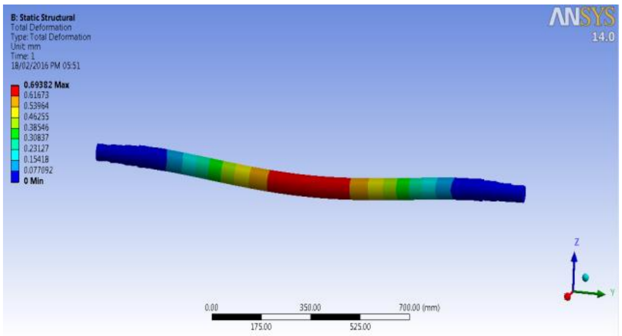


Figure No. 9 : Deformation of the axle

Figure No.9 shows deformation plot of circular axle with maximum deformation 0.69382 mm for material SAE 1040

Figure No.10 shows stress plot for circular axle with maximum stress 200.42 MPa and minimum stress 7.30084e^{-6} for material SAE 1040

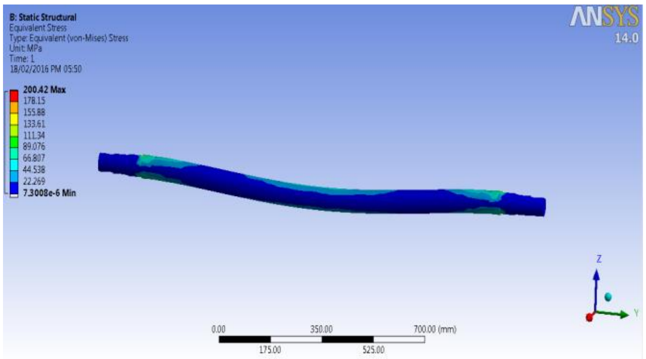
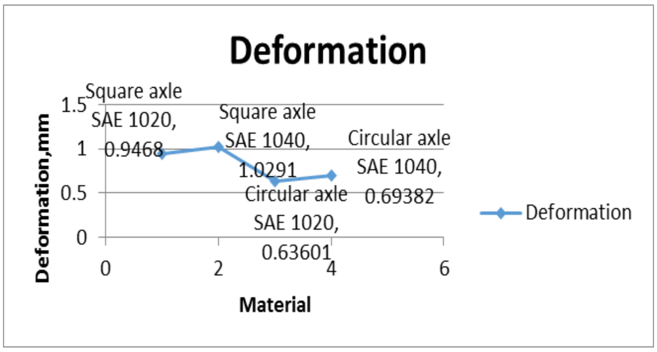


Figure No. 10 : Von-Mises Stress on the axle

Table : 3 Result table for Square and Circular C/S Axle

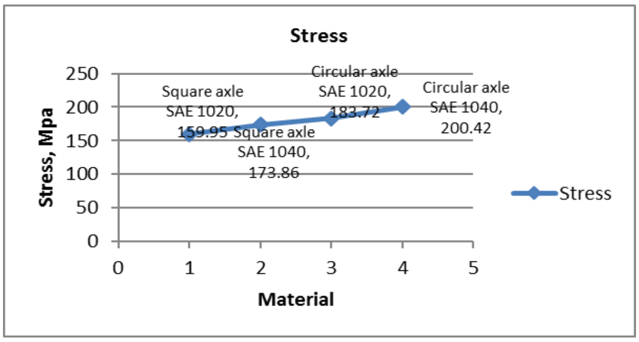
Content	Square axle SAE 1020	Square axle SAE 1040	Circular axle SAE 1020	Circular axle SAE 1040
Deformation	0.9468	1.0291	0.63601	0.69382
Stress	159.95	173.86	183.72	200.42
FOS	1.563	1.4379	1.3608	1.2474
Weight	33.81	29.612	30.247	27.102

From above results we can see that Circular axle with SAE 1040 material gives us better result, and can be used as best option for further testing



Graph: 1 Deformation of different materials

Above graph shows the comparison between square and circular axel for material SAE 1020 and SAE 1040 . It is seen that minimum deformation is 0.63601mm with circular cross section axle and material SAE 1020



Graph No. 2: Stresses in different materials

Graph No. 2 shows the comparison between square and circular axel for material SAE 1020 and SAE 1040 for stress . It is seen that minimum stress is 159.95 MPa with square cross section axle and material SAE 1020 and maximum stress in Circular cross section with SAE 1040 is 200.42 MPa

V. EXPERIMENTATION RESULTS

Circular cross section axle is tested on Universal testing machine with 4 point bending attachment. the procedure is as follows,

The required gauge length is set by adjusting the upper knife edges. A scale is provided for this purpose. Hold the specimen in the upper and lower jaws of Tensile / Universal Testing Machine. Position the extensometer on the specimen. Position upper clamp to press upper knife edges on the specimen. The extensometer will be now fixed to the specimen by spring pressure. Set zero on both the dial gauges by zero adjusts screws. Start loading the specimen and take the reading of load on the machine at required elongation or the elongation at required load. Force setter accuracies mean of both the dial gauge readings should be taken as elongation. It is very important to note & follow the practice of removing the extensometer from the specimen before the specimen breaks otherwise the instrument will be totally damage.

Table No. 4 Test Results for Final selection

Condition	Axle type	Material	Deformation, mm (Experimental)			
			Reading 1	Reading 2	Reading 3	Avg. Reading
New Design	Circular	SAE 1040	0.750	0.760	0.730	0.750

VI. RESULT AND COMPARISON

Table No. 5 Result Comparison for existing and optimized Axle

Parameters	Existing Square Axle SAE 1020	Suggested Circular Axle SAE 1040
Material	SAE 1020	SAE 1040
Von-Mises Stress	278.18 MPa	200.42 MPa
% Change in Stress	Circular axle has 27.95 % less Stress than Square axle	
Deformation	1.6466 mm	0.69382 mm
% Change in Deformation	Circular axle has 57.86 % less deformation than Square axle	
Weight	35.5 kg	27.102 kg
% Change in Stress	Circular axle has 23.65 % less weight than Square axle	

VII. CONCLUSION

- From the analysis and experimentation it is seen that Circular cross section with SAE 1040 material is having more positive points and less weight (23.65 %) compare to existing square cross section and SAE 1020 material.
- The stress induced in previous square cross section axle with material SAE 1020 is 278.18 MPa and the suggested optimized circular cross section with material SAE 1040 axle have 200.42 MPa that is stresses is reduced by 27.95%
- Deformation is also reduced to 0.69382 mm from 1.6466 mm in Circular cross section axle with material SAE 1040 compared to square cross section with material SAE 1020.
- The total weight reduction is 8.398 Kg when square cross section axle replaced with circular cross section axle

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