Fatigue Analysis of A Rear Axle of A Tractor Trolley By Finite Elemet Analysis

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Abstract*-The Tractor trolleys are mostly used to transport the agriculture produce, building construction materials as well as industrial products. When these trailers move on uneven surface and bumpy roads cyclic load is applied on the axles. Due to this cyclic loading there is a complete reversal of stresses which starts producing crack in the rear axle which leads for the fatigue failure of a rear axle.*

Failed axle has been investigated and it was observed that, the axle failed at the stress raiser area and it was bending failure.

In this paper the attempt is made to calculate the life of a rear axle and factor of safety with the help of Ansys for various cases by changing the geometry of an axle. Study is further extended to see the effect of material change on the same. Validation of Design of rear axle had been successfully performed for fatigue life cycles by finite element analysis.

Keywords-Finite Element Analysis, Rear axle, fatigue failure analysis, fatigue life, Goodman criteria, S-N Curve approach.

I. INTRODUCTION

In automobiles, axle shafts are used to connect wheel and differential at their ends for the purpose of transmitting power and rotational motion [6]. Farm tractor is an off road vehicle shown in fig. 1, used as a portable machine to do various useful works such as farming, haulage, heavy earthmoving & 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 (e.g. rear axle) [2] [7]. 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.

Fig. 1 Tractor trolley

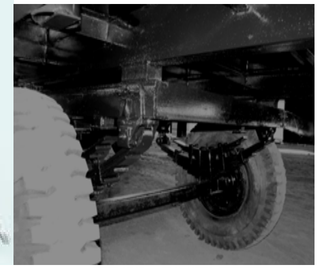

Fig. 2 Axle location

Though tractor trolleys are manufactured of various capacities by various industries such as local fabricators of tractor trolley, there is a variation in manufacturing methods [8]. Trolley axle under consideration shown in fig. 3 is a supporting shaft on which a wheel revolves. The axle is fixed to the wheels, fixed to its surroundings & as shown in fig.5 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 fig. 2 [2].

Fatigue failure starts at the most vulnerable point in a dynamically stressed area particularly where there is a stress raiser. The stress raiser may be mechanical or metallurgical in nature, or sometimes a combination of the two. Mechanical stress raisers are non-uniformities in the shape of the shafts such as step changes in diameter, sharp corners, keyways, grooves, threads, splines, press-fitted or shrink-fitted members and surface discontinuities like seams, nicks, notches and machining marks. Metallurgical stress raisers may be quench cracks, corrosion pits, gross metallic inclusions, brittle second-phase particles, weld defects, or arc strikes. Also, the microstructure of the shaft material plays a vital role not only in the initiation of fatigue failures but also during the progressive growth of the fatigue crack to cause failure of the component [1].

Fig. 3 Rear axle of a Tractor trolley

Fig. 4 failed axle of Tractor trolley

Fig. 5 Bearing location

Visual examination of the failed axle revealed that the fracture had been initiated at the root from where the step turning starts for fitting of hub as shown in fig. 4.

The main objective of this work was to analyze the rear axle of a tractor trolley used for transportation of sugarcane to find the life and factor of safety.

II. DESCRIPTION OF TRACTOR TROLLEY

Dimensions and gross load for selected tractor trolley are tabulated in Table 1. It is circular in cross section of diameter 90mm and length 1775mm. The maximum load of 6 ton acts on tractor trolley.

Table 1 Trolley Details

Length (mm)	Width (mm)	Height (mm)	Load acting (N)	Self Weight (N)	Gross Load Acting (N)
3730	1880	500	58860	14715	73575

III. 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 reduction of the cost of material we compare the two materials (a) SAE-1040, (b) SAE 1045.

Material Properties:

The failed axle shaft is inspected visually and macroscopically for material properties.

Table 2 material property [4] [5]

Material	SAE 1040 (Existing Axle)	SAE 1045 (Proposed Axle)
Ultimate strength(MPa)	595	585
Yield strength (MPa)	515	515
Density(Kg/m^3)	7845	7987
Modulus of Elasticity(MPa)	200000	210000
Poisson's ratio	0.30	0.29

IV. FATIGUE ANALYSIS

Definition of Fatigue

Fatigue is a phenomenon in which a repetitively loaded structure fractures at a load level less than its ultimate strength. For instance, a steel bar might successfully resist a single static application of a 200 KN tensile load, but might fail after 1,000,000 repetitions of a 100 KN load.

The main factors that contribute to fatigue failures include:

- Mean stress experienced in each load cycle.
- Presence of local stress concentrations.
- Number of load cycles experienced.
- Range of stress experienced in each load cycle.

Fatigue is a failure under a repeated or varying load, never reaching a high enough level to cause failure in a single application. The fatigue process embraces two basic domains of cyclic stressing or straining, differing distinctly in character. To implement a fatigue study, the determination of the stress distribution is needed. There are different techniques to do it. The simplest one is the analytical technique, used mostly for theoretical purposes and in order to solve simple problems. It is difficult to apply it to real problems because the stress distribution calculated is, most of the times, a rough approach. The experimental technique is the only one that let the analyst to reproduce the real working conditions, but the fatigue tests of prototypes are extremely expensive and expanded in the time.

The most popular of these methods to solve the equations of Solids Mechanics, is the Finite Elements Method (FEM). The results of these models allow knowing accurately how the stresses and strains distributed along the component are, but the procedure to elaborate the appropriate fatigue calculations is not yet properly developed.

A. Types of Fatigue:

a) Low cycle fatigue b) High cycle fatigue

B. Mean Stress calculations:

For Stress Life, if experimental data is not available, several empirical options may be chosen including Gerber, Goodman and Soderberg theories which uses static material properties (yield stress, tensile strength) along with S-N data to account for any mean stress.

For calculation purpose Goodman theory was used as follows.

$$\sigma_m = \frac{\sigma_{max}+\sigma_{min}}{2} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$\sigma_a = \frac{\sigma_{max}-\sigma_{min}}{2} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

$$\frac{\sigma_A}{S_E} + \frac{\sigma_m}{S_{Ut}} = 1 \quad \ldots\ldots\ldots\ldots\ldots (3)$$

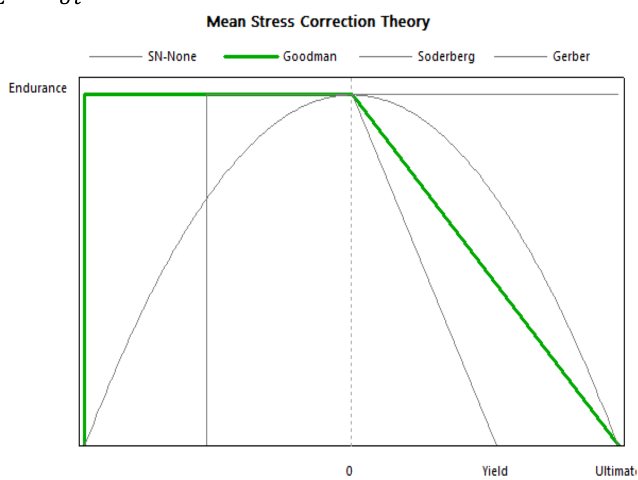

Fig. 6 Mean stress correction theory

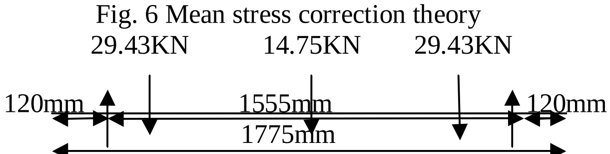

Fig. 7 loading diagram

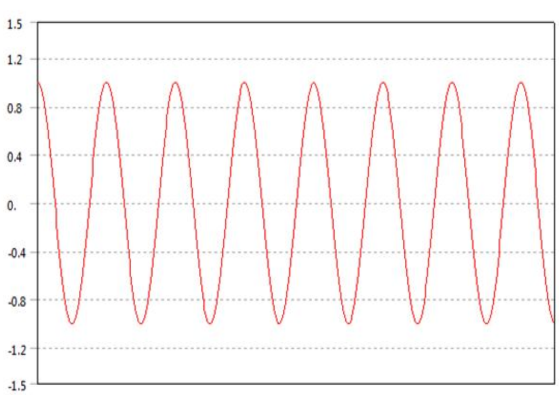

Fig. 8 Constant amplitude load fully reversed

V. FATIGUE ANALYSIS BY FINITE ELEMENT ANALYSIS

A. Modeling:

Model of rear axle was drawn by using PRO-E software.

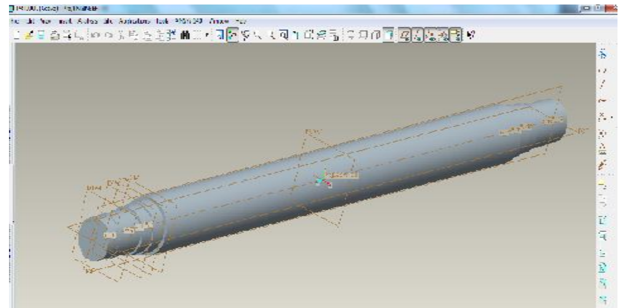

Fig. 9 Rear axle drawn in PROE-E

B. Ansys Steps:

The following are the steps followed in Ansys:

- Preprocessing
- Solving
- Post processing

Importing Geometry in Ansys:
IGES file saved in PROE was imported in Ansys.

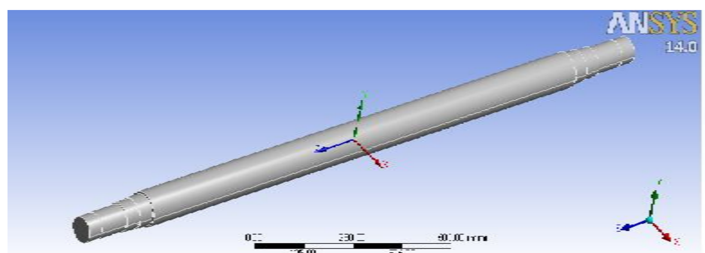

Fig. 10 Model imported in Ansys

C. Meshing of model:

Fig. 11 shows meshed model of a rear axle. Tetrahedral element was used for meshing. The number of nodes and elements are as follows:
Nodes=233326, Elements=149285

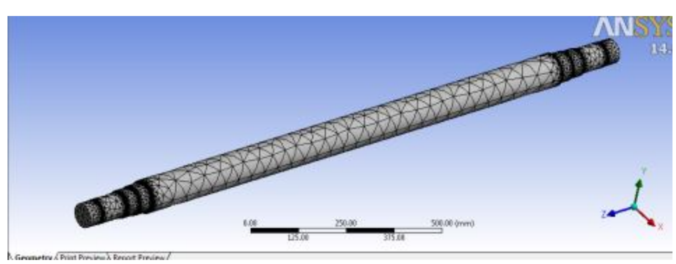

Fig. 11 Meshed model of a rear axle

D. Stress in rear axle:

Stress in existing rear axle:

Fig. 12 shows the maximum and minimum stress induced in a rear axle. The value of maximum stress is 407.87 MPa and minimum value of stress is 0.10377 MPa.

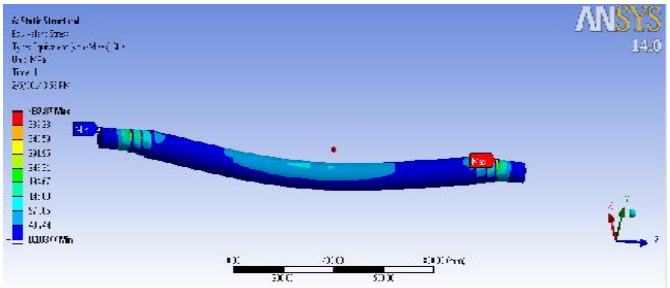

Fig. 12 Stress in existing rear axle

Stress in proposed rear axle:

Fig. 13 shows the maximum and minimum stress induced in a rear axle. The value of maximum stress is 407.87 MPa and minimum value of stress is 0.10377 MPa.

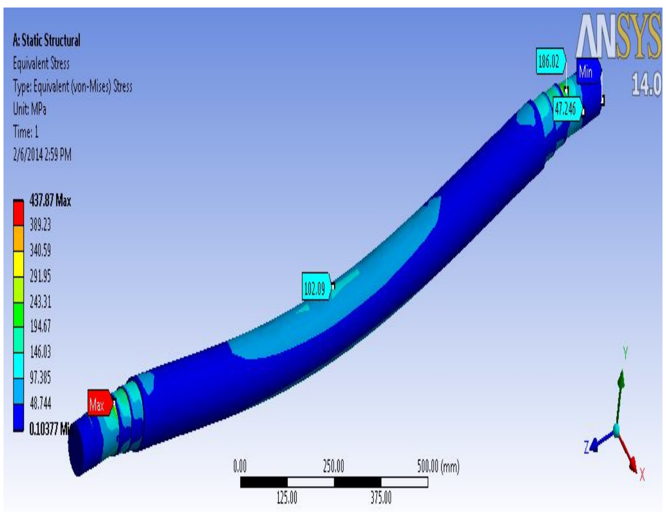

Fig. 13 Stress in proposed rear axle

The maximum stress occurs at stress raisers (where cross section gets changed).

Deformation of a rear axle:

Deformation in existing rear axle:
Deformation in existing rear axle is maximum 0.17814mm.

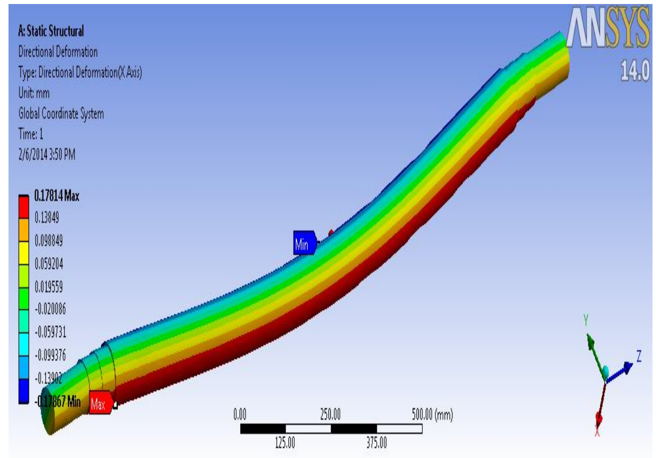

Fig. 14 Deformation in existing rear axle

Deformation in proposed rear axle:

Deformation in proposed rear axle is maximum 0.16966mm.

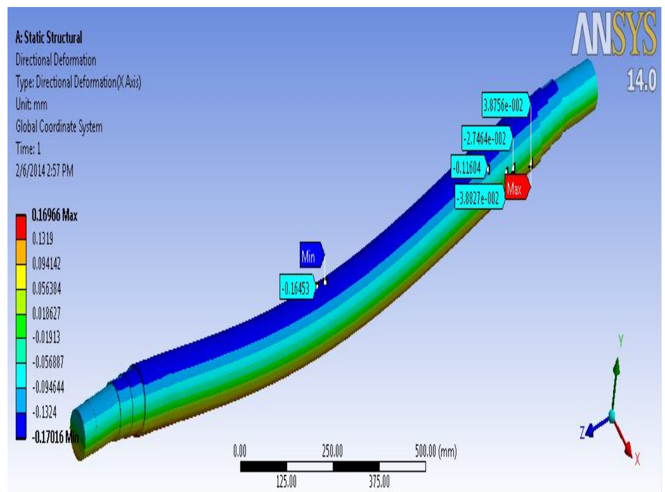

Fig. 15 Deformation in proposed rear axle

Factor of safety:

The factor of safety obtained in fatigue analysis is as follows:
Factor of safety of an existing rear axle is minimum 0.19686.

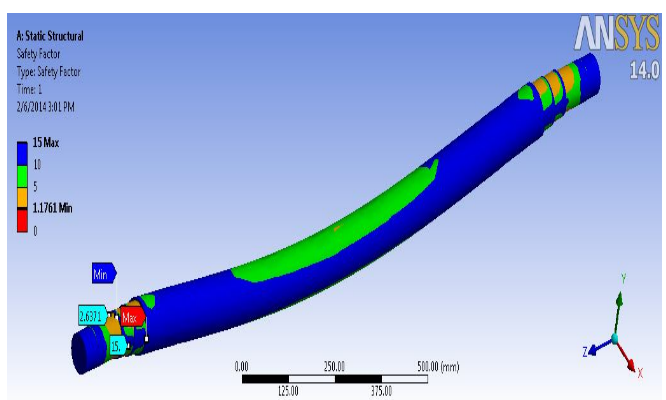

Fig. 16 Factor of safety of an existing rear axle

Factor of safety of a proposed rear axle is minimum 1.1762.

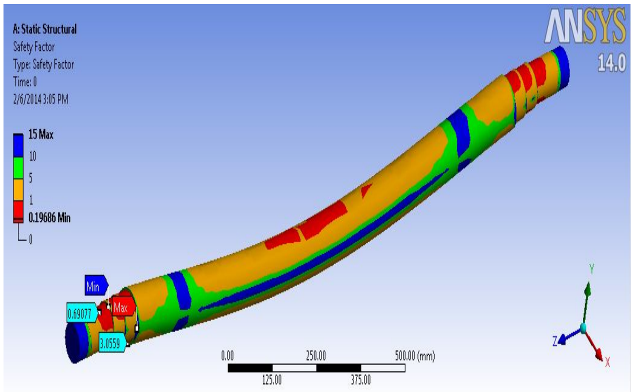

Fig. 17 Factor of safety of a proposed rear axle

Fatigue life of a rear axle:

The designed life of an existing rear axle is 2.55e+5 cycles. Rear axle minimum life is 21399 cycles.

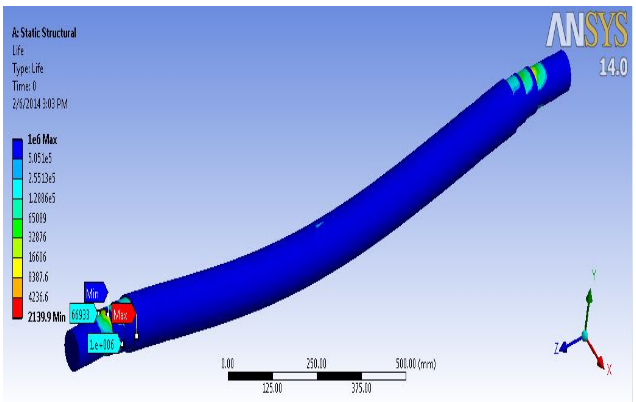

Fig. 18 Fatigue life of an existing rear axle

The designed life of a proposed rear axle is5.05e+005 cycles. The rear axle life is achieved 35799 cycles.

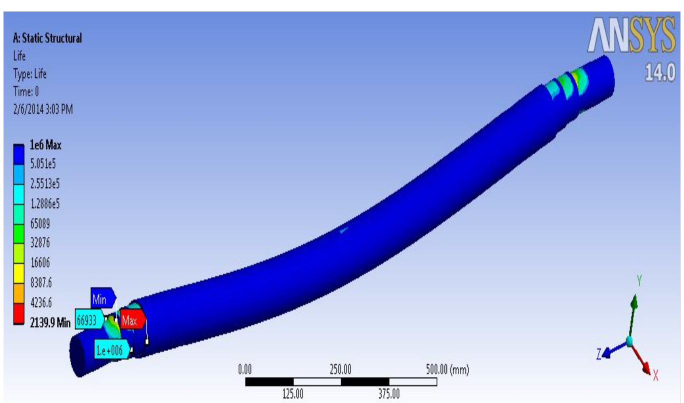

Fig. 19 Fatigue life of a proposed rear axle

As shown in fig.18 and 19 the life of rear axle is less at the location of hub and where the cross section of axle gets changed.

VI. RESULT

Table 3 shows the result for existing and proposed rear axle.

Table 3Result

		Existing Axle	*Proposed Axle*
Material		SAE1040	SAE1045
Diameter (mm)		90	75
Life of rear axle (Cycles)	***Analytical***	21399.9	28694.58
	FEA (Ansys)	2.55e+5	5.05e+005
Factor of safety	***Analytical***	2.1881	1.2662
	FEA (Ansys)	1.1762	0.19686
Stress (MPa)	***Analytical***	235.36	406.71
	FEA (Ansys)	407.87	407.85
Deformation (mm)	***Analytical***	0.18723	0.17982
	FEA (Ansys)	0.17814	0.16966

VI. CONCLUSION

In this paper the Goodman criteria to find the fatigue life for finite cycles was used with S-N curve approach. The expected life obtained for proposed rear axle by analytical and FEA method was 28694.58 cycles and 5.05e+5 cycles respectively, which were more than the life of existing rear axle. Similarly the factor of safety was calculated which was less than the factor of safety of an existing rear axle.

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