INTERNATIONAL JOURNAL OF RESEARCHES IN BIOSCIENCES, AGRICULTURE AND TECHNOLOGY
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www.vmsindia.org

MODELING AND ANALYSIS OF TRACTOR TROLLEY AXLE USING FINITE ELEMENT ANALYSIS

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Abstract:-
In Central India, various small scale industries are adopting the crude methodologies for designing & 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 redesigned considering the static and dynamic load conditions. A CAD model is prepared using CATIA V5 as a tool. Minimum cross section for the axle is calculated which resulted in the 24.8 % reduction in the weight of the axle. The axle dimensions are redesigned to 75 X 75 mm which is comparatively smaller than the old axle. 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.

Introduction

In the present market scenario, cost reduction technique is playing signification role to meet the competition in the market. Weight reduction, simplicity in design and application of industrial engineering etc. are 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. These products are getting improved by means of feedback of failure as and when it occurs. 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. Thus most of rural products are manufactured without availability of design. Tractor trolleys are manufactured in small to moderate scale industries. Through tractor trolleys are manufactured of various capacities by various industries, still there is a large vibration in manufacturing methods, component design etc. the trolley manufacturers are having no proper design of trolley chassis, leaf spring, axle and other components of the trolley, through these trolleys are to be certified by R.T.O. authority. It is observed that most of the trolleys are design for static conditions by tacking large factor of safety.

1.Steps for manufacturing of existing axle

- The Axle is manufactures from 75 X 75 X 1700mm mild steel bar.
- The main operations done on MS bar :

1. Facing
2. Turning and step turning on both end of the bar.
3. Threading operation.
4. Drilling

- For the assembly of the hub, all these operations are performed at grinding level.
- When manufacturing operations are performed on the 1700mm long bar, it is very difficult to set that bar on the lathe machine requires more time.
- In some cases, as the dimensions of the axle is increases the bending problem is solved but the breaking at end of the axle is not completely solved.
- Weight and the cost of axle is increases due to increases in dimensions.

2. LOAD ANALYSIS

Tractor and tractor trolleys are most popular and cheaper mode of goods transport in rural as well as urban areas. The trolleys are used for carrying different types of material such as bricks, sugarcane, cotton, murum, various consumable, non consumable, industrial, agricultural products etc. these materials are having different shape, size and varying weight density. The material to be transported may be loaded in unitized form or scattered form. The material is loaded at various positions on the platform of the trolley. Thus if trolley is fully filled with one type of material then it may be called as, trolley loaded with uniform distributed load throughout span. This rate of loading may be varying in nature, if the trolley is filled with combination of different material. Thought it is known that the center of gravity of two wheeler trolley generally lies nearer to the wheel, hence in case of scattered type loading, heavy load item must be placed above the wheel.

First we find the reactions at support i.e. R_A and R_B. By taking the moment at point A

- $\sum M_A = 0$
- $- R_B \times 1310 + 36.5 \times 1155 + 0.75 \times 655 + 36.5 \times 155 = 0$
- $R_B = 36.88$ KN

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

- $R_A - 36.5 - 0.75 - 36.5 + R_B = 0$ KN
- $R_A - 36.5 - 0.75 - 36.5 + 36.87 = 0$ KN
- $R_A = 36.87$ KN

3.5 Shear Force diagram

We find the shear force at points A, B, C, D, E by following way:

- Shear force at point A = 36.87 KN
- Shear force at point C = 36.87 – 36.5 = 0.37 KN
- Shear force at point D = 0.37 – 0.75 = - 0.38 KN
- Shear force at point E = -0.38 – 36.5 = - 36.88 KN
- Shear force at point B = - 36.88 + 36.88 = 0 KN

3.6 Bending Moment Diagram

We know that bending moment is zero at the point of reaction occurs, so we take

- 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 and E:

- Bending moment at point C = 36.88 X 155 = 5714.85 KN mm
- Bending moment at point D = 36.88 X 655 – 36.5 X 500 = 5899.85 KN mm
- Bending moment at point E = 36.88 X 1155 – 36.5 X 1000 – 0.75 X 500 = 5709.85 KN mm

3. DESIGN OF 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.

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So the axles are used to transmit bending moment only. Thus axle is designed on the basis of bending moment only.

Axle subjected to bending moment only:

When the axle is subjected to a bending moment only then the maximum stress is given by the bending equation, we know that

$\therefore$ $M / I = F_b / Y$---------------------------- (1)

Where –

M – Bending moment

I - moment of inertia of cross sectional area of them Axle axis of rotation

F_b- bending stress

Y -distance from neutral axis to the outer most fiber.

We know that for a square solid bar, axle, moment of inertia,

- I = bh3/12

as b = h

= $75 \times 75^3/12$

= 2636718.75 mm^4

And Y = b / 2 = 75 / 2 =37.5 mm

Substituting these values in eq^n (1)

- $M / 2636718.75 = F_b / 37.5$

F_b - bending stress (allowable) for SAE 1045 is 430 MPa

F_b = 430 MPa

- M = 430 X 2636718.75 / 37.5

= 30234375 N mm

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 stress is found equal to 5899.85 KN mm.
- When the material is considered and the cross sectional area is considered then the maximum bending moment is found equal to 30234.375 KN mm.

As the axle is not affected by the length because length between two tires is same, so it will not be change. We considered the maximum bending moment is 30234.375 KN mm which is related to the cross sectional area of the square bar axle.

So we find the section modulus (z) of the existing axle (75 X 75 X 1700 mm)

- Section modulus (z) = Maximum bending moment / Bending stress

= M / F_b = 30234.375 / 430 = 70.31 X 10^3 mm^3

We cross check this section modulus by using data book formulae

Section modulus (z) = bh^2 / 6 as b = h

= b^3 / 6 = 75^3 / 6 = 70.31 X 10^3 mm^3

So it is conform that the section modulus of the existing axle is 70.31 X 10^3 mm^3.

Now we find section modulus for required axle….

From the above calculations the maximum bending stress is comes at point D is equal to 5899.85 KN mm.

∴ Section Modulus (Z) = M / F_b

= 5899.85 KN mm / 430 MPa = 13.72 X 10^3 mm^3

∴ Z = b^3 / 6

∴ 13.72 X 10^3 = b^3 / 6

∴ b = 43.50 mm

As per from the above calculations the required dimensions for the axle is 43.50 X 43.50 X 1700mm. But on the considerations of the dynamic and the shock generated in the moving conditions, we considered the dimensions 50 X 50 X 1700 mm.(as the dynamic factor giving for axle in data book is 2.65).

The maximum moment = 5899.85 KN mm

The bending stress (allowable) = 430 MPa (SAE 1045)

Section modulus (z) = M / f_b = 13.72 X 10^3 mm^3

In the existing trolley the square axle of 75 mm X 75 mm of length 1700 mm is used,

Having section modulus (z) = 70.31 10^3 mm^3.

The obtained value of z = 13.73 X 10^3 mm^3 = b^3 / 6 = 43.50mm = 45 mm.

But on the considerations of the dynamic and the shock generated in the moving conditions, we considered the dimensions 50 X 50 X 1700 mm.(as the dynamic factor giving for axle in data book is 2.65).

Thus the presently used axle can be replaced by the suggested square axle of 50 mm X 50 mm as shown in figure (1), but it required the modification in present hub dimensions.

The other alternative suggested is combination of hollow square shaft with solid square shaft as shown in figure (2). The hollow square shaft is of 90 mm X 90 mm and inside square of shaft is of 75mm X 75 mm having length 1300 mm. The section modulus (z) is found to be 64 X 10^3 mm^3 and the solid square shaft of 75 mm X 75 mm of length 800 mm having section modulus (z) = 70.31 X 10^3 mm^3.

The approximate weight of combination axle is 0.55 KN. The combination axle can be made by cutting solid shaft of 400 mm, and then the both piece of 400 mm shaft is machined to shape from one side as per fitment of hub. The inside width of hallow square shaft is 75 mm. and then solid axle is inserted into hollow shaft and then welded.

4.1 Check for bending strength

The combination axle has to be checked for the developed bending stress due to load of 36.5 KN.

$F_b$developed = M / z

M $_{max}$ = 5899.85 X 2.65 (dynamic factor) KN mm

Z = 64 X 10^3 mm^3

F_b =244.29 N / mm^2

The bending stress is less than the permissible value hence combination axle is safe.

4.2 The specification of suggested combination axle

- 75 mm X 75 mm square shaft 0.800 mtr 34 kg
  Weight 44.2 kg / mtr
  Z = 70.31 x 10^3 mm^3
- Hollow shaft 90mm X 90mm x 8 mm 1.100 mtr 22.4 kg
  Weight 20.4 kg / mtr
  Z = 64 X 10^3 mm^3

The total weight of combination axle 56.4 kg

4. STRESS ANALYSIS USING ANSYS TOOL

The suggested combination axle is safe or not, also proved by using ANSYS (Table 4.1). The following are the images for existing axle from industry shows the equivalent (von-mises) stress, equivalent strain, total deformation and factor of safety.Solid axle geometry is generated in ANSYS and get the stress, strain, total deformation, and factor of safety by using the steps given bellow also figure shows the color effect which shows effect of load on the axle

CONCLUSION

- The dimension of the existing axle is change to be reduced as it proved by mathematical calculations.
- There is assembly problem in hub on the axle as the dimension of the axle is change.
- As the dimensions are reduced, the assembly problem is occurred so other solution is given as the hollow shaft, which exist the earlier dimensions for the hub assembly on the newly designed axle.
- This newly designed axle reduces the 22.85% weight as compare to the existing axle shown in comparison table.
- Also reduces in the cost of trolley axle as the weight of the axle reduces.
- Manufacturing time of axle is also reduces.

- The weight of axle is reduced without compromising with existing hub assembly of wheel, factor of safety and stiffness of the axle.

we compare the analysis ANSYS report to prove the suggested axle is better than the existing axle. For making the comparison between existing axle and suggested axle consider the following factors:

- Equivalent Stress
- Equivalent Strain
- Total Deformation
- Factor of Safety
- Weight of Axle

Comparison table is given in Table 5.

Table 1 Specification of 6-tonne 2-wheeler trolley

General	Single axle, 2-wheeler box type trolley	
Overall dimensions	Overall length	3100mm (trolley box) 4025mm (chassis)
	Overall width	1900mm (trolley box)
	Overall height	730mm (trolley box) 1700mm above ground
Load capacity	Pay load	60KN
	Unloaded weight	13KN
	Gross load weight	73KN
Axle	One square axle is used presently 75*75 mm square of length 1700mm. Weight of axle assembly 0.75KN	
Tires	Two no. of 9" (width) X 20" (radius)	

Table 2 Values of shear force and bending moment

Load Point	Shear Force	Bending Moment
A	36.87 KN	0 KN mm
C	0.37 KN	1844 KN mm
D	-0.38 KN	2034 KN mm
E	-36.88 KN	1849 KN mm
B	0 KN	0 KN mm

Table 3 ANALYSIS OF EXISTING AXLE BY USING ANSYS

Sr. No.	Factors	Values
1.	Equivalent Stress	6.3799 MPa
2.	Equivalent Strain	3.19 X10^{-5} m/m
3.	Total Deformation	2.335 X 10^{-5} m
4.	Factor of Safety	15
5.	Mass	69.088 Kg

Table 4 ANALYSIS OF COMBINATION AXLE BY USING ANSYS

Sr. No.	Factors	Values
1.	Equivalent Stress	11.168 MPa
2.	Equivalent Strain	5.5841 X10^{-5} m/m
3.	Total Deformation	1.3565 X 10^{-5} m
4.	Factor of Safety	15
5.	Mass	53.301 Kg

Table 4.1 Comparison between existing axle and proposed axle

Sr. No.	Existing Axle	Proposed Axle
1.	Material selected SAE 1045	Material selected SAE 1045
2.	Section modulus 70.31X10^{3}mm^3	Section modulus 64X10^3 mm^3
3.	Considering available bending stress 430 MPa	Calculating bending stress 317.81 MPa
4.	Weight 75 Kg	Weight Hollow-22.4 Kg Solid Shaft- 34 Kg Total- 56.4Kg

Table 5 COMPARISONS BETWEEN EXISTING AXLE AND PROPOSED AXLE USING ANSYS

Sr. No.	Existing Axle	Proposed Axle
1.	Equivalent Stress = 6.3799 MPa	Equivalent Stress =11.168 MPa
2.	Equivalent Strain = 3.19X10^{-5} m/m	Equivalent Strain =5.5841X10^{-5} m/m
3.	Total Deformation =2.335 X 10^{-5} m	Total Deformation =1.3565 X 10^{-5} m
4.	Factor of Safety =15	Factor of Safety =15
5.	Mass =69.088 Kg	Mass =53.301 Kg

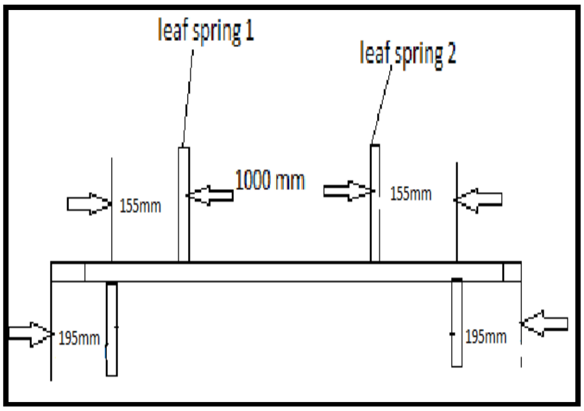

Figure 3.1 Position Diagram

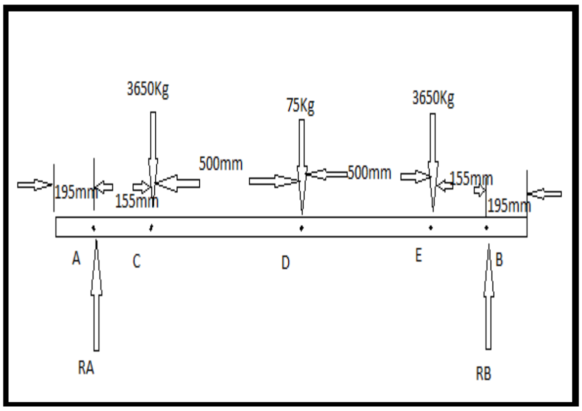

Figure 3.2 Load diagram

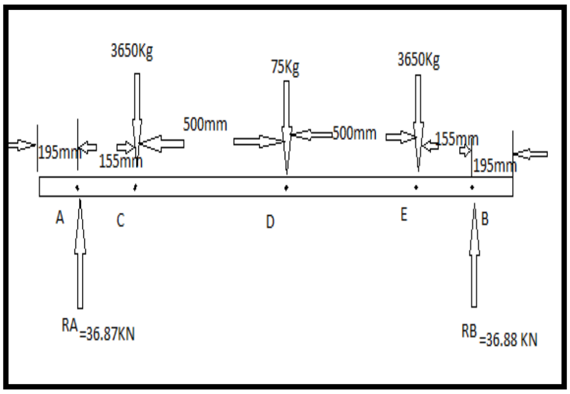

Figure 3.3 Reaction Diagram

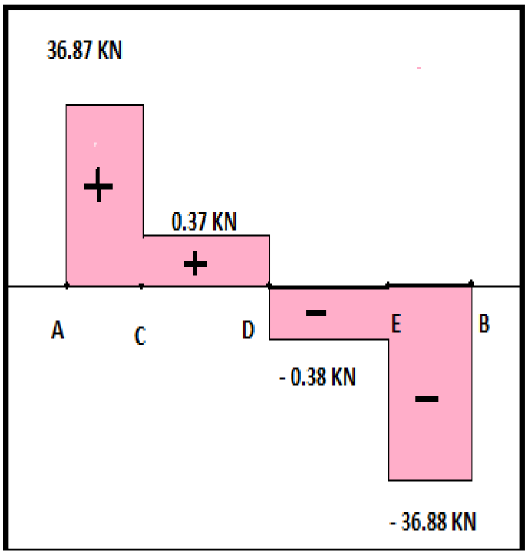

Figure 3.4 SHEAR FORCE DIAGRAM

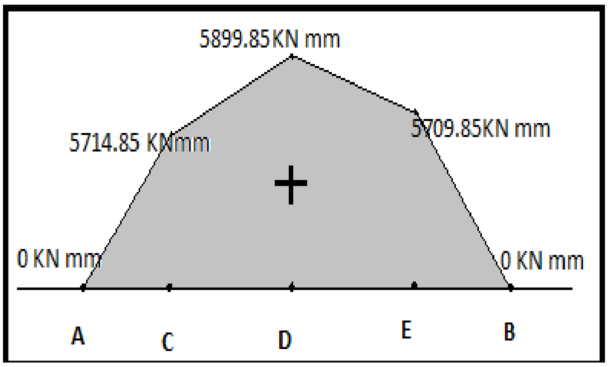

Figure 3.5 BENDING MOMENT DIAGRAM

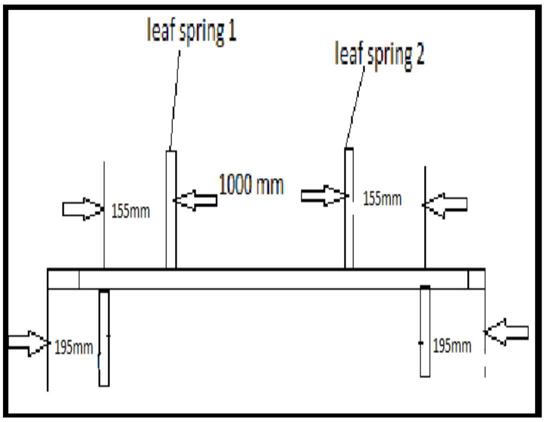

Figure 4.1 POSITION DIAGRAM OF AXLE

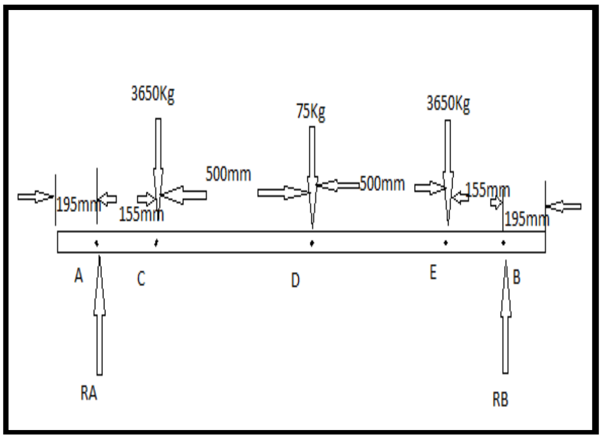

Figure 4.2 LOAD DIAGRAM OF AXLE

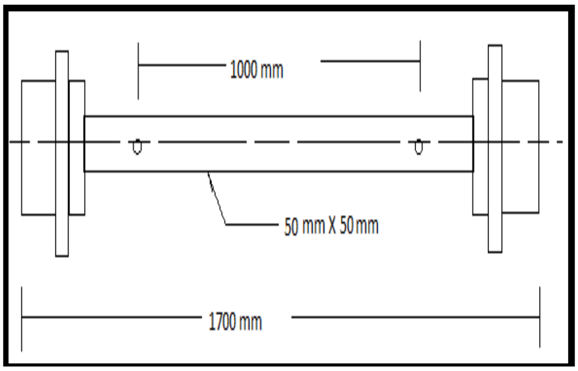

Figure 4.3 SOLID AXLE

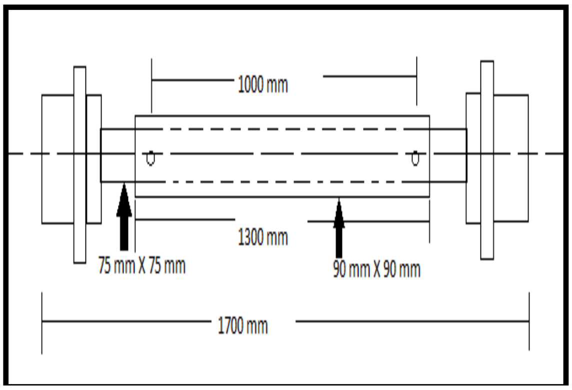

Figure 4.4 COBINATION AXLE

ANALYSIS OF EXISTING AXLE IN ANSYS

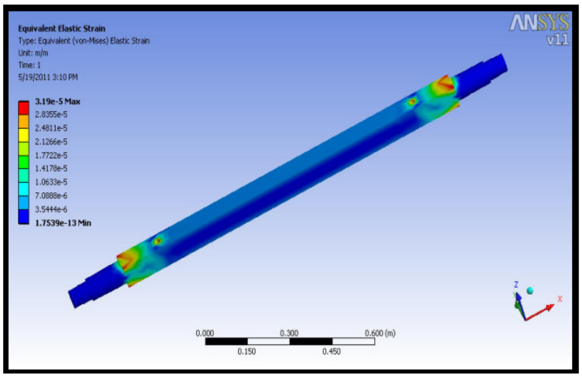

FIGURE .5.3 EQUIVALENT STRESS

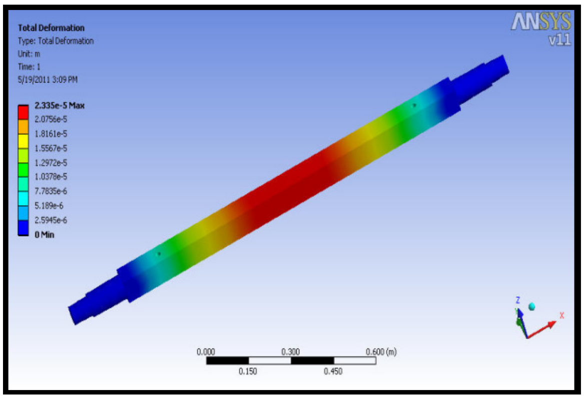

FIGURE 5.4 TOTAL DEFORMATION

5.3 ANALYSIS FOR SUGGESTED AXLE (COMBINATION AXLE)

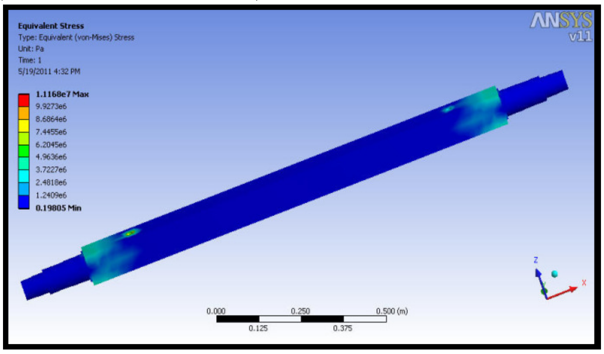

FIGURE 5.7 EQUIVALENT STRESS

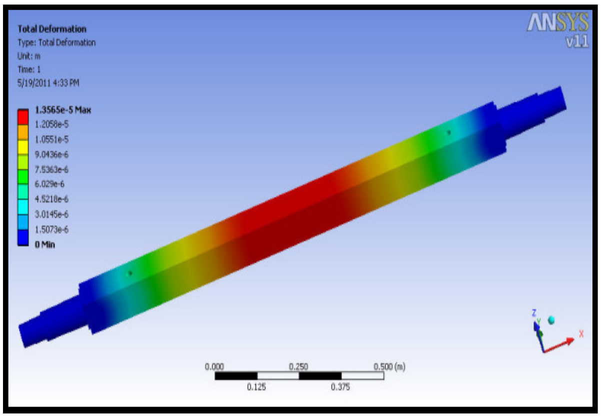

FIGURE 5.9 TOTAL DEFORMATION

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