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Analysis of Roller Shaft Pad Steam Machine

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Abstract: Machine component shaft is a rotating machine element, usually circular in section. Generally shaft are manufacturing by mild steel, when high strength is required alloy steel used. Exiting shaft AISI 1040 used in pad steam machine failed after 2600 hrs due to crack generation. This paper work represented to analysis of roller shaft used in steam pad machine used in textile industry. The FEA was done in Ansys software by using selected three materials Carbon Steel (AISI 1040), EN8, EN24 based on their composition. FEA show that the EN24 Material is best suggested material among all material.
Keywords: AISI 1040, EN8, EN24, Endurance limit, Fatigue.

I. INTRODUCTION

A shaft is a rotating member, usually of circular cross-section, used to transmit power or motion. The power is delivered to shaft by some tangential force and the resultant torque (T) set up within the shaft transmit power to machine linked up to the shaft. In order to transmit power from one shaft to another, the various member such as a gears, pulleys, flywheels, crank sprockets etc. are mounted on it. A shaft subjected to torsion, bending or axial load or a combination of these loads. Therefore shaft must be strong enough to resist these loads individually or in combination. The main cause of failure of shaft is fatigue, which arise due to presences of cyclic overloads, due to wrong adjustment of bearing and their insufficient clearance due to stress concentration arise due to undercut, keyways and holes.

This project presents the optimization and failure analysis of carbon steel roller shaft of continuous pad steam machine used in textile industry. The fracture position was located at a stepped diameter. The failed component was the shaft made of carbon steel AISI 1040.

In this paper replacing exiting shaft material with three different material used in heavy duty application. Using Ansys find out area of failure in shaft and using this failure analysis, we pinpointed the root cause of failure and developed a means of solving this type of failure.

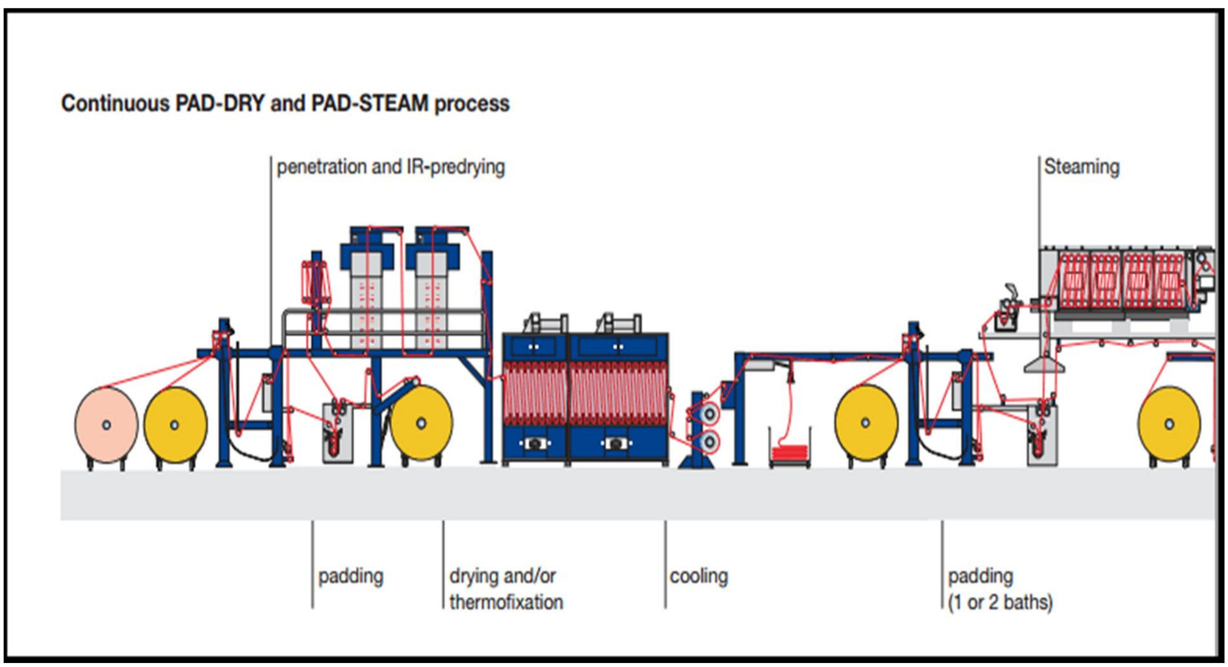

Fig. 1- Continuous pad steam process

Pad-Steam dyeing is a process of continuous dyeing in which the fabric in open width is padded with dyestuff and is then steamed. Pad steam is an ideal machine for reactive dyeing of cotton and its blended fabrics. Light, pale and medium shades can be dyed in this machine. Continuous roller steamer is used for diffusion of reactive and direct dyes into cellulosic fibers in an atmosphere of heat and moisture that is created by saturated steam injected into the steamer.

1) *Purpose of this Machine:* It can be used as a pad batch for reactive dyeing in which batch is left for 12-18 hours for the completion of the reaction. For time saving the fabric passes through the steamer for 1 minute and the reaction is completed.
2) It can also be used for reduction clearance (RC) in which we treat PC fabric with caustic and sodium hydrosulphide to remove the disperse dye from cotton.
3) Stripping of the fabric can also be done on this machine that is, color can be removed completely by adding higher amount of caustic and sodium hydrosulphide.
4) It can be used for the development of Vat dyes.
5) The dyed fabric can be washed in this machine.

A. Main section of this machine

1) Inlet Section

a) Plaited/batcher
b) Tensioner rollers
c) Free guide roller
d) Stationary rollers

2) Padding Section

a) Padders use for padding.
b) The pressure of the padders are 1.5 - 2 bar.
c) Two types of pressure used in Kuster padders, hydraulic and pneumatic.
d) The central pressure is hydraulic and side pressure is pneumatic.
e) We can adjust the pressure of the padders, to prevent the listing problem.
f) Liquor is picked in the fabric; afterwards the excessive liquor is squeezed out by means of padders at predetermined pick-up% set by applying pressure on the padders.
g) *Steamer:* Here in steamer temperature required for the fixation is given to the fabric. This temperature is achieved by saturated steam. The purpose of using saturated steam is that the chemicals used for developing should not dry on the surface of fabric preventing fabric from stains. Here roof temperature is given to avoid water dropping that causes spotty dyeing. Here water is not given at the entry of steamer because to prevent developing chemicals that just applied before going into steamer so water lock is given at the end of steamer.
h) *Process:* A process of continuous dyeing in which the fabric in open width padded with dyestuff and is then steamed, Continuous roller steamer is used for diffusion of reactive, vat, Sulphur and direct dyes into cellulosic fiber in an atmosphere of heat and moisture that is created by steam injected into the steamer.

II. PROBLEM STATEMENT

Roller shaft which is used in Steam Pad Machine used in textile industry found to be failure after 2600 hrs service. Initiation of cracks and wear of the shaft lead to the crack propagation. Untimely failure of the shaft can drastically reduce the productivity and affects financially due to down time and unusually high maintenance costs.

III. THEORETICAL CALCULATION AND FEA ANALYSIS.

In many application machine component are subjected to forces, which are not static, but vary in magnitude with respect to time. The stresses induced due to such forces are called fluctuating stresses. It has been observed that materials fail under fluctuating stresses at a stress magnitude which is lower than the ultimate tensile strength of the material. Sometimes it has been found that the magnitude even lower than yield strength; it has been found that the magnitude of stress causing fatigue failure decreases as the number of stress cycle increases. It has been observed that about 80% of failure of mechanical component are due to the fatigue failure.

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The roller shaft of a continuous pad steam machine suddenly appeared the abnormal phenomenon when it was running in condition. These paper represent the material analysis weight optimization and stiffness characteristic of steam pad machine roller shaft maintaining the integrity of the specification.

Roller shaft is connected to the gear box shaft through universal coupling; gear box is driven by VFD controlled motor 15KW running at 2900 rpm. Considering these parameter we are twisting moment for FEA 1250 N-m with applying the load 170KN. Service life of the component was only 2600hrs.

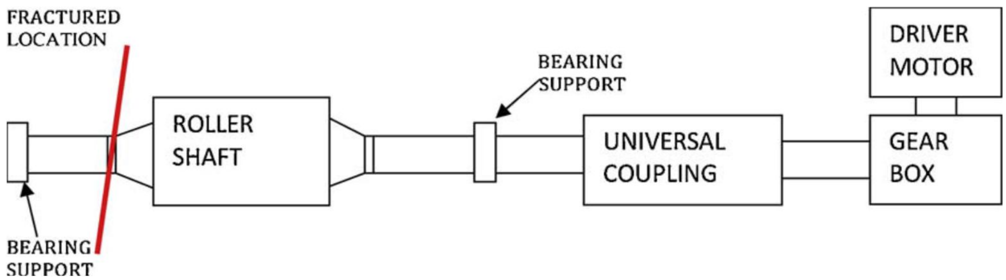

Fig. 2-Schematic illustration of the roller shaft.

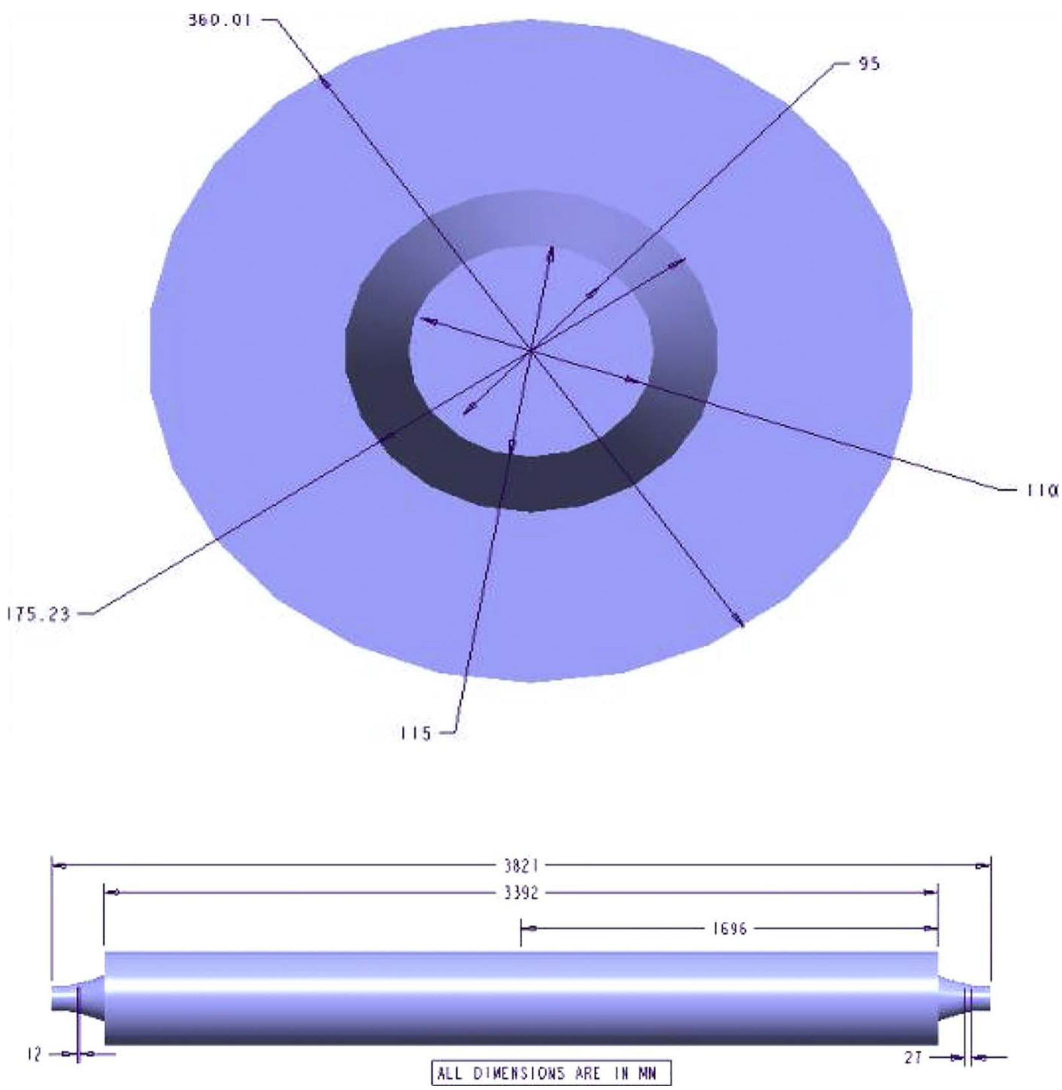

Fig. 3- Shaft Dimensions

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A. Material Selection Based on Following Point

1) When high strength is required.
2) Load is applied on shaft.
3) Manufacture process on shaft.
4) Different machining process on shaft.
5) Operating time is considered for different application of shaft.

In this project I used four different materials based on their composition viz. Carbon steel AISI 1040, EN8, and EN24. For material selection we take some general point into consideration such as mechanical and chemical composition of material, Easy availability, cost, machinability etc.

Table I – Chemical composition of material

Material Name	Chemical Composition of Material						
	C	Mn	S	P	Si	Cr	Fe
Carbon Steel	0.39	0.70	0.045	0.035	----	-----	Balance
EN8	0.38	0.81	0.02	0.012	0.12	----	
EN 24	0.4	0.6	0.03	0.02	0.015	1.3	

Table II- Material Property Details

Sr. No.	Material Name	Tensile yield strength	Young's Modules(E)(N/mm^2)	Density(ρ) (kg/mm^3)	Poisson ratio
1	Carbon Steel (AISI 1040)	659	200×10^6	7845	0.3
2	EN 8	660	190×10^6	7850	0.28
3	EN 24	850	207×10^6	7840	0.29

B. Theoretical calculation

For Carbon Steel (AISI 1040) steam pad roller shaft material:-
The volume (V) of roller shaft is used is 3.566E+08.
Therefor the Weight (W) of the roller shaft for respective material is
$W = V \times \rho$
= 3.566E+08 x 7.84E-06
= 2797.527 kg.

1) EN8 Material

$W = V \times \rho$
= 3.566E+08 x 7.855E-06
= 2801.093 kg.

2) EN 24 Material

$W = V \times \rho$
= 3.566E+08 x 7.8E-06
= 2781.48 kg.

C. Stiffness of Steam pad Roller Shaft (k)

1) Carbon Steel (AISI 1040) roller Shaft Material

Weight of roller shaft (W) = 2797.527 kg
Deformation (δ) = 32.10 mm
$k = W/\delta$
= 2797.57 / 33.05
= 84.15 kg/mm

2) EN8 roller Shaft Material

Weight of roller shaft (W) = 2801.093kg

Deformation (δ) = 34.81mm

$k = W/\delta$

= 2801.093 / 34.81

= 80 kg/mm

3) EN 24 roller Shaft Material

Weight of roller shaft (W) = 2781.48 kg

Deformation (δ) = 30.58mm

$k = W/\delta$

= 2781.48 / 30.85

= 90.161 kg/mm

D. Theoretical Endurance limit Calculation

$Se^1 = 0.5 \times S_{ut}$

Se^1 = Theoretical endurance limit

S_{ut} = Ultimate Tensile Strength

To determine corrected endurance limit S_e the correction factor to be considered.

$S_e = C_{load} \times C_{size} \times C_{surf} \times C_{temp} \times C_{Reliability} \times Se^1$

$C_{load} = 1$

$C_{size} = 1.189 \times d^{-0.097}$ for 8mm<d<250mm

$C_{surf} = 4.51 \times S_{ut}^{-0.265}$

$C_{temp} = 1$

$C_{reliability} = 1$

1) AISI 1040

$Se^1 = 0.5 \times 620$

$= 325MPa$

$S_e = 1 \times 1.189 \times 115^{-0.097} \times 4.51 \times 650^{-0.265} \times 1 \times 1 \times 325$

2) EN 24

$Se^1 = 0.5 \times 850$

$= 425MPa$

$S_e = 1 \times 1.189 \times 115^{-0.097} \times 4.51 \times 850^{-0.265} \times 1 \times 1 \times 425$

$= 240.7MPa$

3) EN8

$Se^1 = 0.5 \times 775$

$= 387.5MPa$

$S_e = 1 \times 1.189 \times 115^{-0.097} \times 4.51 \times 775^{-0.265} \times 1 \times 1 \times 387.5$

$= 225MPa$

Table III- Theoretical Endurance limit

Sr. No.	Material	Corrected Endurance limit S_e (MPa)
1	AISI 1040	197.6
1	EN8	225
1	EN24	240.7

E. CAD Model

Roller of a steam pad machine is taken for the study work. Dimensions are taken from technical paper. These dimensions used for 3D modeling of steam pad machine roller shaft. Dimension are required for calculation the boundary condition and geometrical of shaft.

Length = 3821mm
Maximum diameter = 360mm
Minimum diameter = 95mm

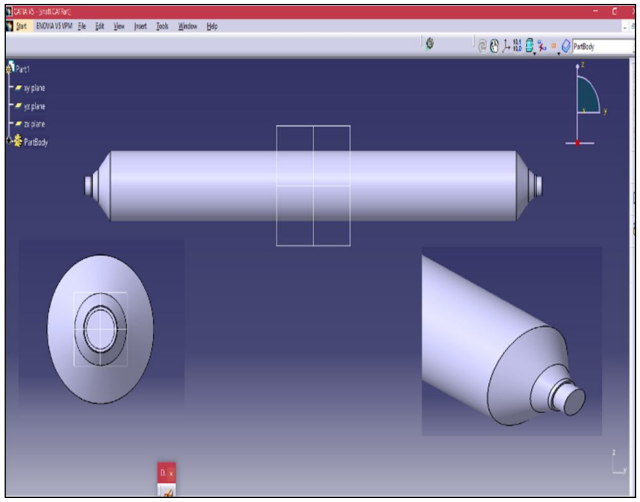

Fig. 4- CAD model for roller shaft

F. FEA Analysis

Hyper work is the general purpose FEA tool with a group of simulation are model geometry in the form of .stp file format, Material properties of selected material, boundary condition

In Finite Element Analysis we examine the parameter like von misses stress, deformation; maximum and minimum principle stress and strain. The main purpose of the stress analysis is to compare material tensile properties, by using volume and density of different material we found out the mass of the shaft; also we found out the stiffness of shaft material after the criteria is decided to suggest the suitable material for the steam pad roller shaft.

1) Meshing of Roller Shaft

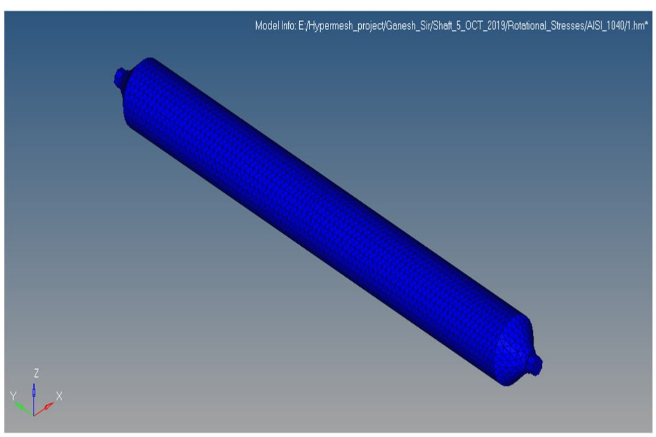

Fig. 5- Meshing of roller shaft

Meshing of shaft in hyper work pre-processing software analysis is shown in fig. solid

5199 mesh element and element size is 40.00 mm, 3d mesh element type R-tria is used for meshing and simulation.
Number of nodes: - 6385, Number of element: - 29462

2) *Apply load and Boundary Conditions:* Boundary condition play an important role in finite element analysis. We use two ends with single point constraint and rotational force =1250.9N-m.

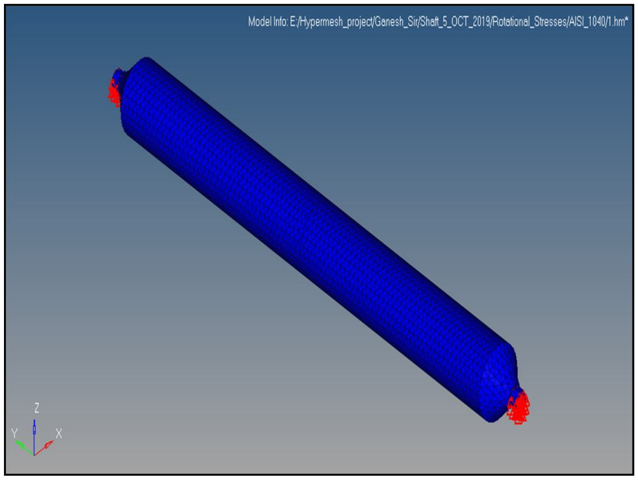

Fig. 6- Boundary condition of roller shaft

3) *Analysis:* In hyper work prepossessing gives the meshing result and post processing done in Nastran & Optistruct section. We find out the result of maximum & minimum principal stress, Displacement, maximum and minimum von-misses stress and strain of four selected materials.

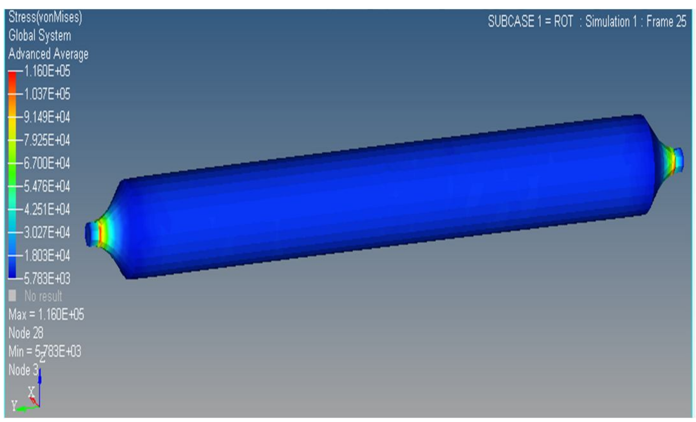

Fig. 7- VonMises Stress for AISI1040

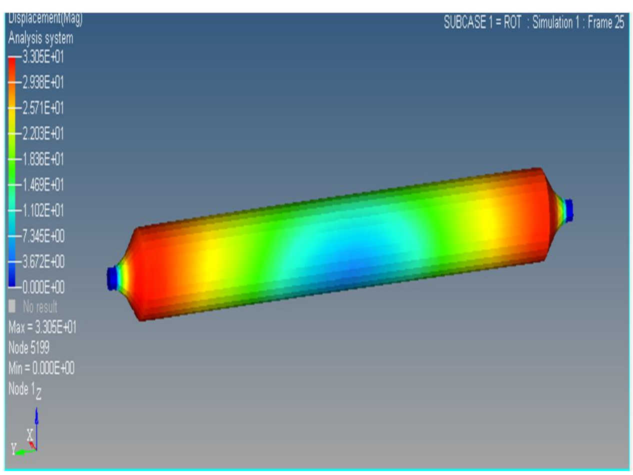

Fig. 8- Shaft Displacement of AISI1040

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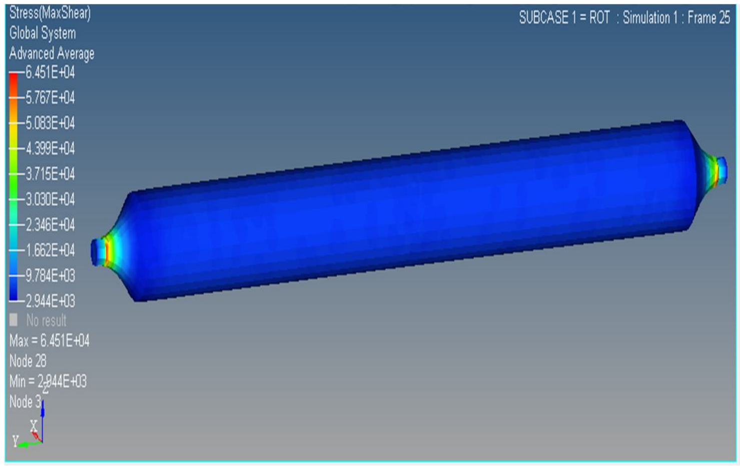

Fig. 9- Max.Shear Stress for AISI1040

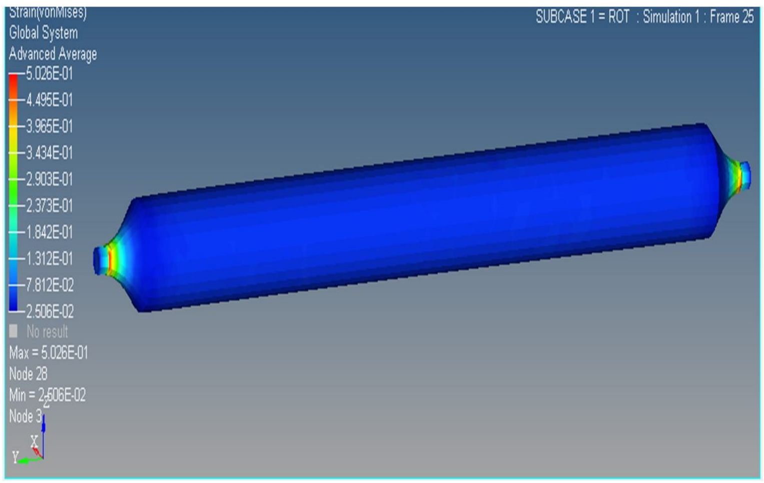

Fig. 10- VonMises Strain for AISI1040

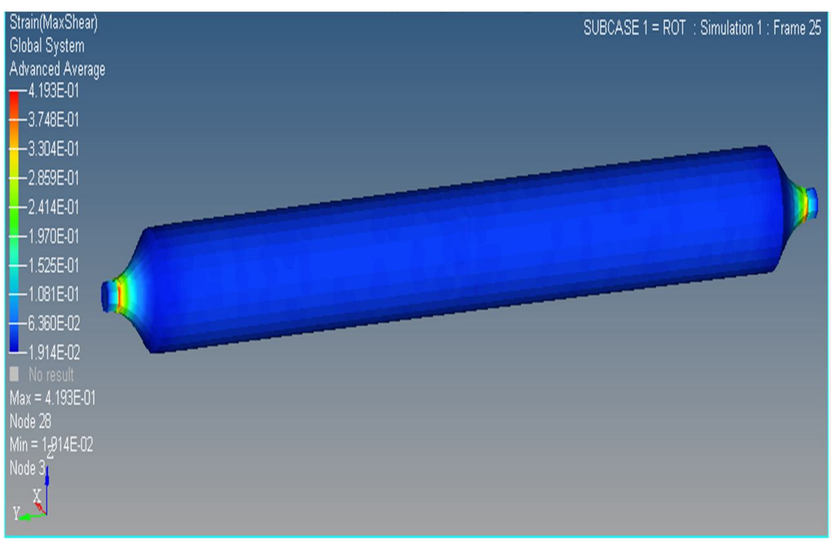

Fig. 11-Max. Shear Strain for AISI1040

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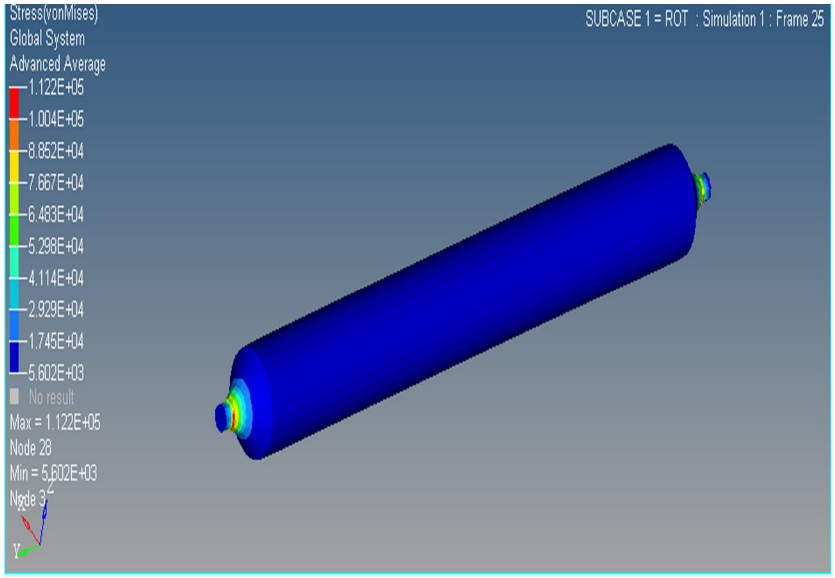

Fig. 12-VonMises Stress for EN24

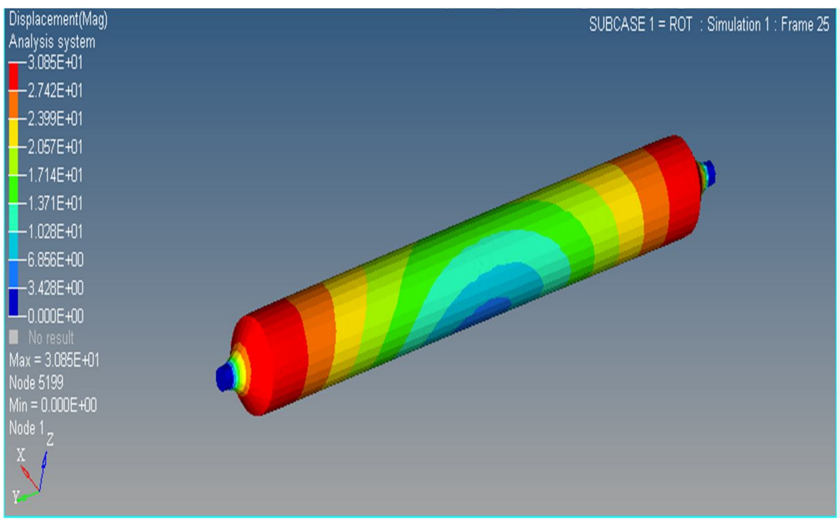

Fig. 13- Shaft Displacement for EN24

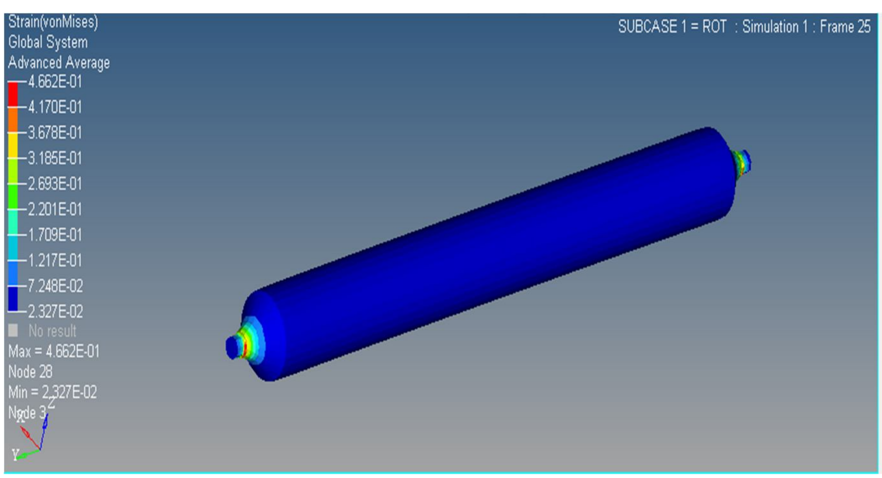

Fig. 14-VonMises Strain for EN24

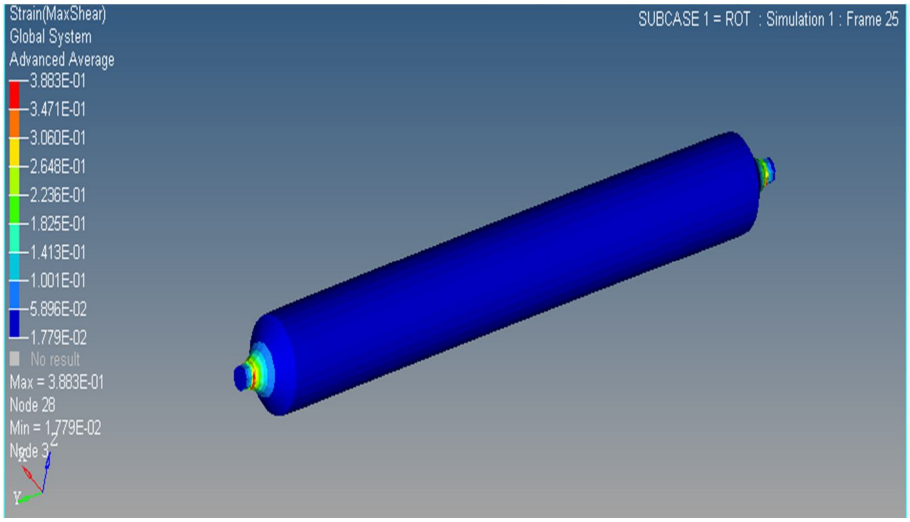

Fig. 15- Max. Shear Strain for EN24

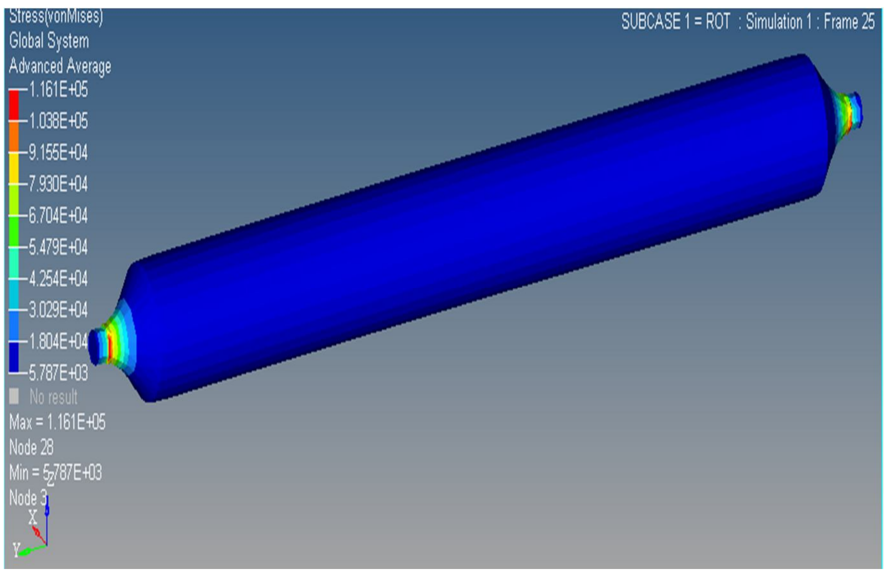

Fig. 16-VonMises Stress for EN8

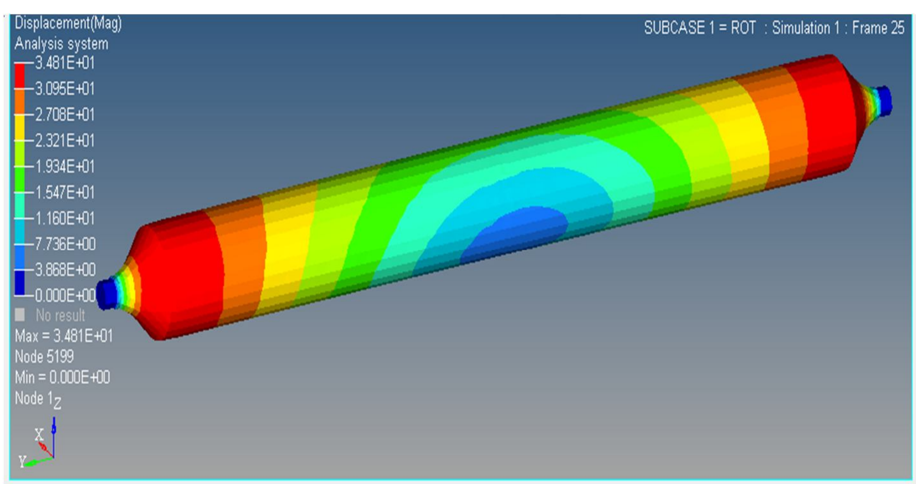

Fig. 17- Shaft Displacement for EN8

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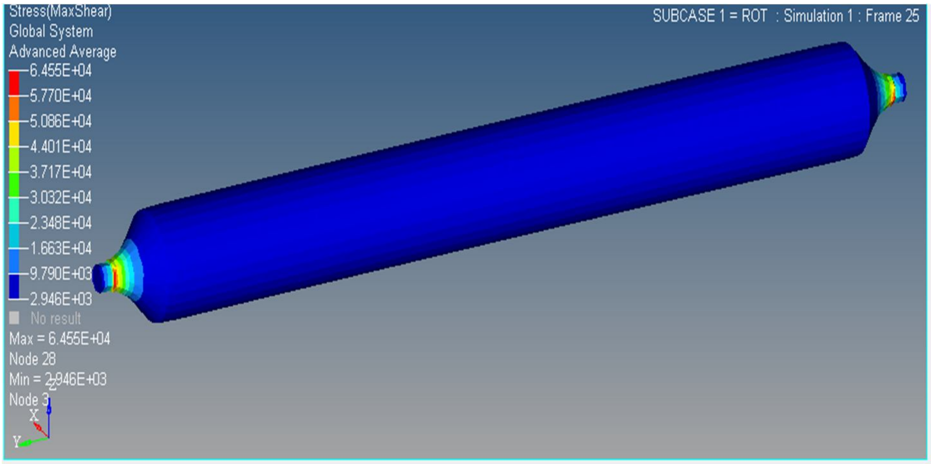

Fig. 18-Max. Shear Stress for EN8

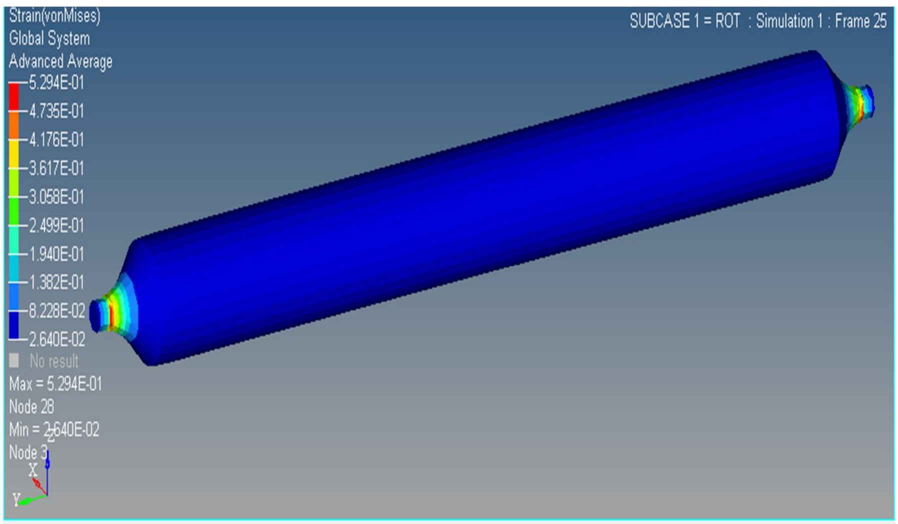

Fig. 19- VonMises Strain for EN8

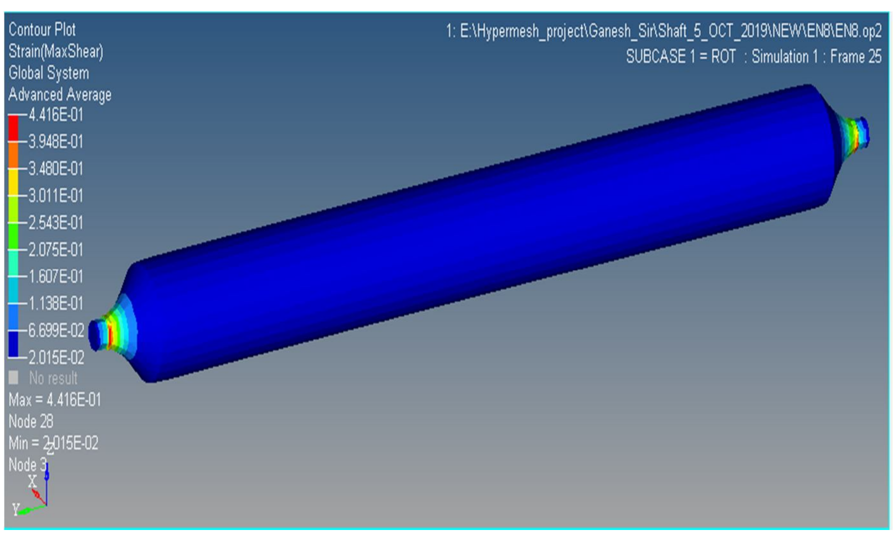

Fig. 20- Max. Shear Strain for EN8

Table IV- FEA Result of Different materials

Sr. No.	Material Name	Maximum Von-Misses Stress (N/mm^2)	Maximum Von-Misses Strain (N/mm^2)	Maximum Displacement (mm)
1	Carbon Steel (AISI 1040)	1.166E+05	5.026E-01	3.305E+01
2	EN8	1.16E+05	5.29E-01	3.481E+01
3	EN24	1.122E+05	4.66E-01	3.08E+01

IV. CONCLUSION

A. From analysis it is conclude that the maximum stress generated at shaft shoulder and step portion.

B. Less deformation, fatigue strength are the criteria used for the optimization roller shaft material.

C. The optimized steam pad roller shaft is lighter than current carbon steel steam pad roller shaft comparatively much stiffer than former Carbon Steel material.

D. EN24 has less elongation and maximum ultimate tensile stress 682 MPa other than selected material.

E. From Theoretical analysis Corrected Endurance limit for EN24 much higher than AISI 1040 and FEA analysis shows stress induced at shoulder of shaft is less in case of shaft EN24 than AISI 1040.

F. Less stress and high endurance limit would cause increase fatigue life of shaft.

V. ACKNOWLEDGMENT

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