Weight Optimization of Roller Shaft of Pad Steam Machine

Ganesh N. Bhalerao, Atul A Patil, Kishor. B. Waghulde

Abstract— ***the roller shaft of a continuous pad steam machine suddenly appeared the abnormal when it was running condition in textile industry which effects on maintenance of machine, time, cost, productivity importance etc. This paper present the material analysis, weight optimization and stiffness characteristic of roller shaft of pad steam machine maintaining the integrity of the specifications. A 3D model is created in Catia V5RI to mating to design, optimization and finite element analysis of roller shaft used in pad steam machine which is made of carbon steel material. The FEA was done in HYPER WORK software (Nastran & Optistruct) in two parts preprocessing and post processing by using four different materials based on their composition viz. Carbon steel AISI 1040, EN8, EN24, and AISI 6150. The parameter like von misses stress, deformation; maximum and minimum principal stress & strain were obtained from analysis Software. Santosh D Dalvi et. al. also worked on this system in 2017 by comparison of existing and new material AISI 1040. FEA show that the EN24 Material is best suggested material among all also find out results like weight and stiffness parameter. It is resulted of 12.527 % of weight with reduction in deformation. Performed two mechanical test i.e. tensile test and hardness test as per ASTM on sample specimens; results show that the strength and hardness are within the limit. This research work is improving shaft parameters which are used in textile industry, heavy duty application etc.***

Keywords: **Roller Shaft, Fatigue failure, hyper work, Weight optimization, Stiffness.**

I. INTRODUCTION

Machine component shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. The various members such as pulleys and gears are mounted on it [8]. Generally shaft are manufacturing mild steel when high strength is required alloy steel is used. A Shaft is used to transmit power or motion. The power is delivered to a shaft by some tangential force and the resultant torque (T) set up within the shaft transmits power to machines linked up to the shaft. In order to transmit power from one shaft to another, the various members such as gears, pulleys, flywheels, crank sprockets etc. are mounted on it. A shaft is subjected to torsion, bending or axial loads or a combination of these loads. Therefore the shaft must be strong enough to resist these loads individually or in combination. The main cause of failure of shaft is fatigue, which arises due to presence of cyclic overloads, due to wrong adjustment of bearings and their insufficient clearances, due to stress concentration which arises due to undercuts, keyways and holes [2].

Santosh D. Dalvi et. al. [1] they studied on roller shaft of continuous steam pad machine; for finding the fatigue failure in shaft they use some destructive and Non-destructive testing on convention material and suggested material. Visual inspection, chemical analysis, tensile test conducted on UTM, Rockwell hardness machine use to find out the hardness of different material, Microscopic examination also done on material to observe the microstructural of properties. Fractogarphy analysis was conduct on fracture surface of failed shaft. Finite Element analysis was done on material to find the stress concentration at roller shaft step. FEA result shown due to stress concentration micro crack was initiated at weaker surface of the roller shaft it was converted in to major failure of shaft. Their main focus was to find out the root cause failure of steam pad roller shaft machine. To avoid these fatigue failure they suggested some modification of critical geometrical section. For better surface roughness use modified turning process parameter.

Ashvini S. more et.al. [2] their research work is based on the breakage and wear proble2m on shaft which is used in different processing machine. They suggested material selection criteria and process to design analysis and manufacture efficient shaft for the conveyor system. Experimental test was conducted on two different material EN24 and M.S bright. FEA analysis result shows that MS bright materials were more stresses as compared to EN 24. Compare the experimental and FEA result based on this result their conclusion was by using EN24 having efficient mechanical properties than mild steel and material achieve more strength and life for same size of shaft.

Aparna devi et. al. [3] their research work was comparative study on corrosion behavior of En8 and En24 Grade material because they possess low corrosion resistance. Their work objective was to implement different heat treatments such as annealing, normalizing and hardening with different quenchants (water and oil) to witness its effect on corrosion behavior of selected EN8 and EN24 grades of steels. Potentiodynamic polarization & electrochemical impedance tests were carried out to compare corrosion behavior of heat treated samples. Among chosen grades of steels, EN24 grade of steel exhibited better corrosion resistance than EN8**.**

Charnont et. al. [4] their work reports on the failure analysis of a two high gearbox shaft of a gearbox in a hot steel rolling mill. Firstly they observe the failed shaft visually and microscopically, chemical analysis of material was performed to identify the type of steel material was used. From visually examination the shaft was fractured at the wobbler of bottom of shaft. Shape of the fracture surface was slightly curved due to the wear at contact area between wobbler and coupling.

Revised Manuscript Received on October 20, 2019.

Mr. Bhalerao G. N. Assistant Professor in Mechanical Engineering department, Dr. D.Y. Patil Unitech Society's, Dr. D.Y. Patil Institute of Technology, Pimpri Pune, India. Email: bhaleraoganesh35@gmail.com.

Dr. Atul Ashok Patil, Professor in Mechanical Engineering department, Dr. D.Y. Patil Unitech Society's, Dr. D.Y. Patil Institute of Technology, Pimpri Pune, India. Email: Patilatul20@rediffmail.com.

Dr K B Waghulde, Professor in Mechanical Engineering department, Dr. D.Y. Patil Unitech Society's, Dr. D.Y. Patil Institute of Technology, Pimpri Pune, India. Email: kbwpvpit@gmail.com.

Conduct some non-destructive testing on failed shaft material and AISI 1045 material. FEA also performed of two materials to find out the stress. The main purpose of the study was to find out the root cause failure of gear box shaft. They concluded that the shaft failed by fatigue fracture and that premature failure occurred due to high stress concentration at the corners of the wobbler of the shaft which led to fatigue crack initiation, crack growth, and final fracture; also they suggested proper preheat during welding could have prevented failure. Thermal spraying technique used to decrease the wear of the wobbler of the shaft.

Amol Kakadea et. al. [5] their work represented the tribological behavior of sugar mill roller shaft. The cracks initiated on the interference of the surface of the shaft due to the sliding. This research work was undertaken to characterize wear debris formed and study the tribochemical reactions during sliding wear of shaft material EN8 against E52100 steel under different sliding conditions. Fourier transform infrared (FTIR) and Thermo gravimetric analysis (TGA) was used for understanding of physical and chemical changes of shaft material caused by friction. Debris analysis suggests that the compositional changes within the wear particles accelerate the wear.

G. N. Bhalerao et. al. [6] work on the optimization of four cylinder petrol engine crankshaft in their work they performed the experimental test on selected material of crankshaft such as chemical composition, microstructure examination, Tensile test on UTM, izod charpy impact test, hardness test. The finite element analysis was done in ABAQUS software by using six materials based on their composition viz. Cast iron, EN30B, SAE4340, Structural steel, C70 Alloy steel and ALSic. Form their result they conclude that aluminum based composite material reinforced with silicon carbide & fly ash is the suitable material for manufacturing the crankshaft which was light in weight.

Jinfeng Duz et. al. [7] their research was on the failure of the induced draft fan's shaft in a power boiler. They investigated the failure shaft material of the induced draft fan's shaft in a power boiler. The material's composition and mechanical properties were examined. The FEA done based on their shaft design which shows that stress concentration was the remarkable at the shoulder of shaft. They modified the design of shaft increase the radius of the shoulder chamfer. The higher stress concentration and torsional vibration induced the microcrack's initiation along the surface of the shaft; meanwhile the vibration in the induced draft fan's service led to crack.

II. ROLLER SHAFT

A. Failure of Component

In many applications machine components 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 is even lower than the yield strength; it has been found that the magnitude of the stress causing fatigue failure decreases as the number of stress cycle increases. It has been observed that about 80% of failures of mechanical components are due to fatigue failure.

In this work, we will focus on the process of analyzing and understanding the material failure [9].

Given below figure is show the schematic diagram of pad steam machine roller shaft. Roller shaft is connected to the gear box shaft through the universal coupling; gear box is driven by the VFD controlled motor 15KW running at 2900 rpm. Considering these parameter we use twisting moment for FEA 1250 N-m with applying the load 170 KN. In this figure the red line shown the fracture point which is observed in stepped portion of the shaft in service life of the component was only 2600hrs [1].

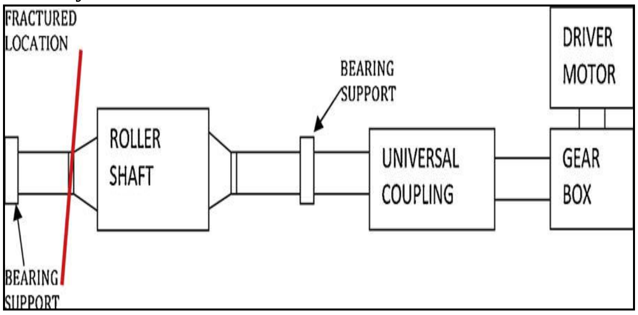


Fig. 1.Schematic diagram of roller shaft of pad steam machine showing the approximate failure location

Fig. 2.filure locations of roller shaft of pad steam machine

The above figure no.2 show the failure zone at A, B, C of failed material carbon steel of roller shaft of pad steam machine.

B. Methodology

To know the existing material failure causes of pad steam machine of roller shaft.

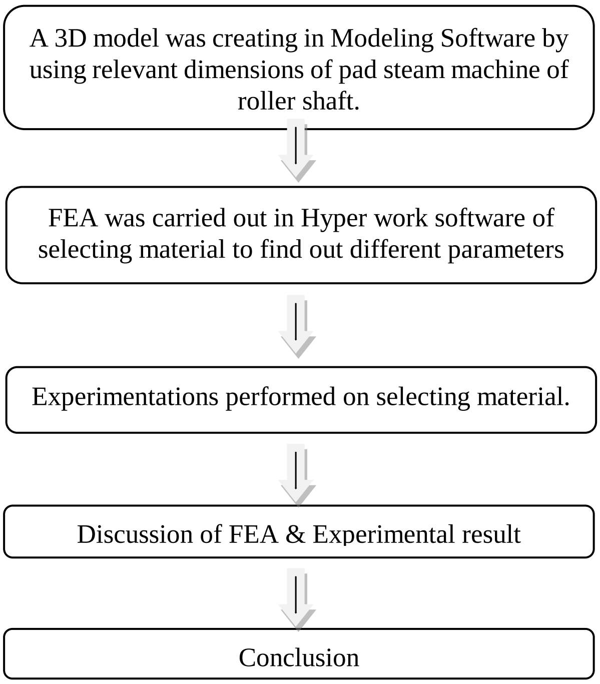
↓

From the research papers studies select suitable method to solve the problem.

↓

Select the different materials with their best compositions and compare it with existing failed material.

↓



The above flow chart shows the methodology which is executes in research work.

C. Objective

- To Study the failure reason of pad steam machine of roller shaft and its design.
- To create 3D geometry of pad steam machine of roller shaft by using CATIA V5.
- To carry out the FEA model using different properties of four material in Hypermesh software.
- Find out the parameter like von misses stress, deformation; maximum and minimum principal stress & strain for different materials.
- Experimental testing on selected material to find out the elongation and ultimate stress
- Find out the hardness of the material.
- Analyze the FEA & Experimental result.
- To suggest suitable material for steam pad roller shaft.

D. Material Selection

Material selection of the shaft is based on following point.

- When high strength is required.
- Load is applied on shaft.
- Manufacturing process on shaft.
- Different machining process on shaft.
- Operating time is considered for different application of shaft.

In this paper work here select four different materials based their composition viz. Carbon steel AISI 1040, EN8, EN24, AISI 6150. For materials selection general points take into consideration such as mechanical & chemical properties of material, Easy Availability, Cost, Machinability etc.

Table- I: Chemical Composition of material (wt %) [1][3].

Material Name	Chemical Composition of material						
	C	*Mn*	*S*	*P*	*Si*	*Cr*	*Fe*
Carbon Steel	0.39	0.70	0.045	0.035	---	---	
EN 8	0.38	0.81	0.02	0.012	0.12	---	Balance
EN 24	0.4	0.6	0.03	0.02	0.15	1.3	
AISI 6150	0.48	0.7	0.035	0.014	0.13	1.1	

Table- II: Material properties details for FEA

Sr. No.	Material Name	Tensile yield strength	Young's Modules (N/mm^2)	Density (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
4	AISI 6150	670	210×10^{6}	8030	0.3

III. CAD MODEL

Roller of a pad steam machine is taken for the study work. Dimensions are taken from technical papers [1]. These dimensions are used for 3D modeling of pad steam machine roller shaft. Dimensions are required for calculating the boundary conditions and geometrical properties of shaft [1].

Length- 3821 mm
Maximum diameter- 360 mm
Minimum diameter- 95 mm
3 fillet radius of R5, R10 and R16This journal uses

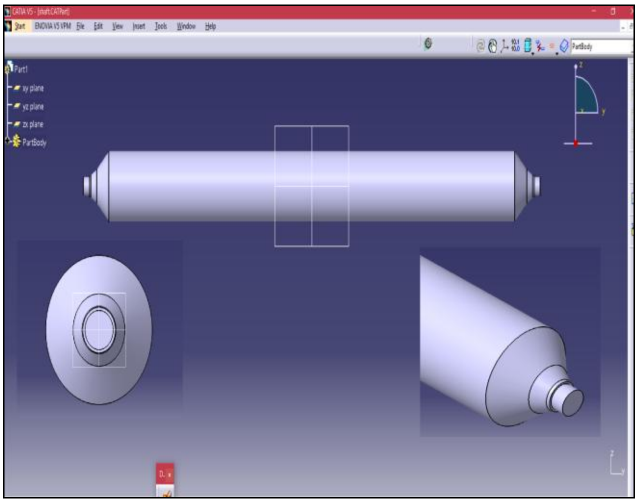


Fig.3.3D model of roller shaft of pad steam machine.

Figure no.3 shows the three dimensional model of pad steam machine roller shaft create in CATIA V5R software with significant dimension.

IV. FEA ANALYSIS

Hyper work is the FEA tool with a group of simulation programs. Input data is required for the simulations are model geometry in the form of .stp file format; next put the material properties of selected materials, apply the load and boundary condition etc.

In Finite Element analysis we examine the parameter like von misses stress, deformation; maximum and minimum principal stress & strain. The main purpose of this stress analysis is to compare the material tensile properties, by using volume and density of different material; find out the mass of the shaft and stiffness of shaft material.

A. Meshing of steam Pad Roller Shaft

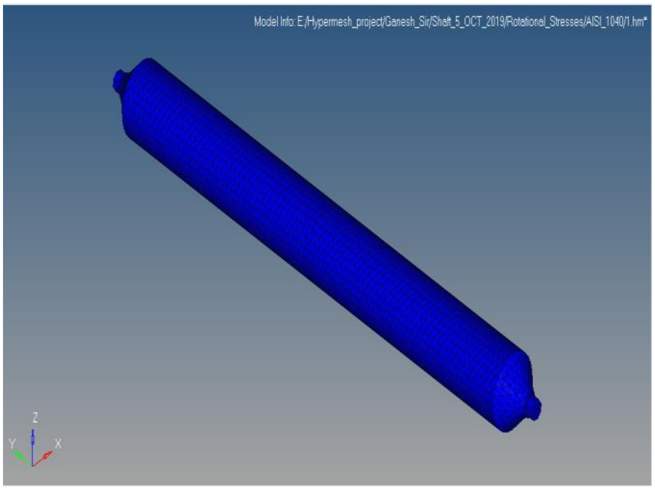


Fig.4.Meshing of roller shaft pad steam machine.

Meshing of shaft in hyper work preprocessing software analysis is shown in Fig. 3 Solid 5199 mesh element and element size is 40.00 mm, 3d mesh element type R-tria is used for the meshing and simulation.

Number of Nodes: 6385

Number of Elements: - 29462

B. Load and Boundary Condition

Boundary conditions play an important role in finite element analysis. Here two ends with single point constraints and Rotational force Rforce= 1250.9 N-m

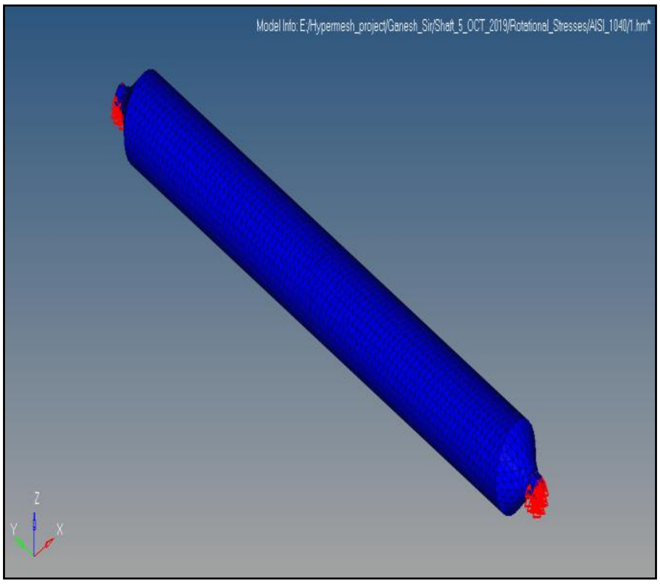


Fig.5.Figure shows boundary condition.

C. Hyper work Analysis

In hype work prepossessing gives the meshing result and post processing done in Nastran & Optistruct section. In analysis find out the result of maximum & minimum von-misses stress and strain, Displacements, Maximum and minimum principal stress and strain of four selected material Out of four materials the EN 24 material meeting the maximum parameter and according to minimum displacements it is suggest the suitable material for Pad Steam machine roller shaft.

Table- III: FEA result of different materials

Sr. No.	Material Name	Maximum Displacement	Maximum Von Misses Stress (N/mm^2)	Maximum Von Misses Strain (N/mm^2)
1	Carbon Steel (AISI 1040)	3.305E+01	1.166E+05	5.026E-01
2	EN 8	3.481E+01	1.161E+05	5.294E01
3	EN 24	3.085E+01	1.122E+05	4.662E-01
4	AISI 6150	3.210E+01	1.183E+05	4.881E-01

Sr. No.	Material Name	Maximum Stress (Shear)	Maximum Strain (Shear)	Stress (Tresca)	Volume
1	Carbon Steel (AISI 1040)	6.451E+04	4.193E-01	1.290E+05	3.56E+08
2	EN 8	6.455E+04	4.416E-01	1.291E+05	3.56E+08
3	EN 24	6.578E+04	3.883E-01	1.246E+05	3.56E+08
4	AISI 6150	6.231E+04	4.072E-01	1.316E+05	3.56E+08

For EN24 Material

1. DISPLACMENT

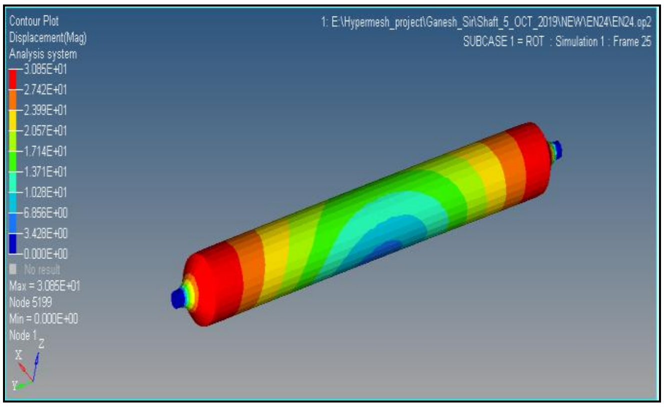


Fig.6 Figure shows the displacement of roller shaft of steam pad machine. The value of maximum displacement is 3.066E+01 and minimum displacement is 0.001

2. VON-MISES STRESS

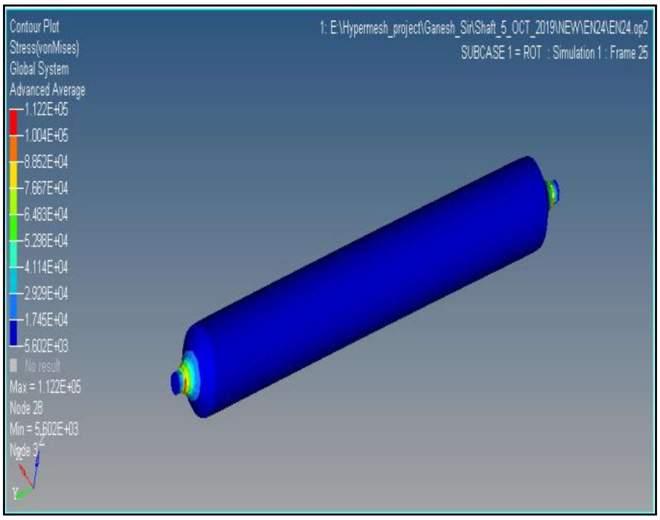


Fig.7. Figure shows the von-mises stress of roller shaft of steam pad machine. The value of maximum von-mises stres is 1.122E+05 and minimum is 5.602E+03.

3. VON-MISES STRAIN

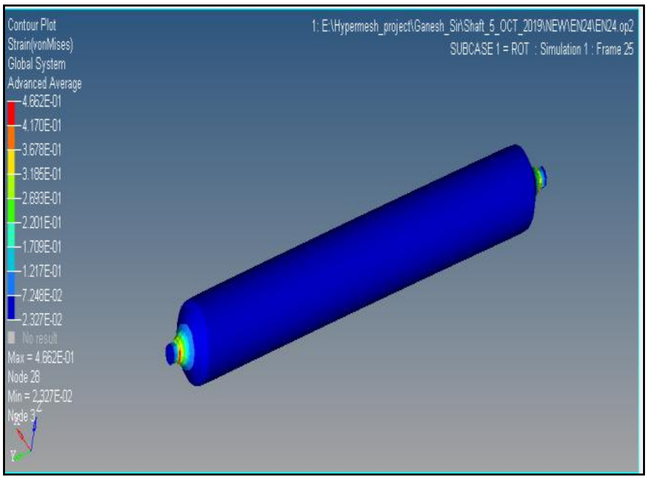


Fig.8 Figure shows the von-mises strain of roller shaft of steam pad machine. The value of maximum von-mises strain is 4.662E-01 and minumm value is 2.327E-02

4. MAXIMUM SHEAR STRESS

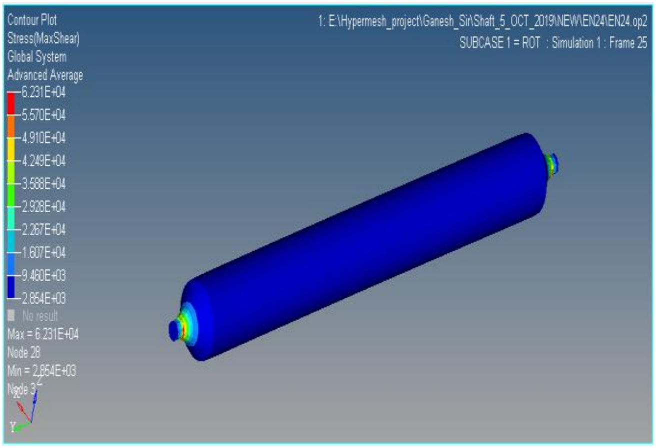


Fig.9 Figure shows the maximum shear stress of roller shaft of steam pad machine. The valu of maximum shear stress is 6.231E+04 and minimum shear stress is 2.854E+03

5. MAXIMUM SHEAR STRAIN

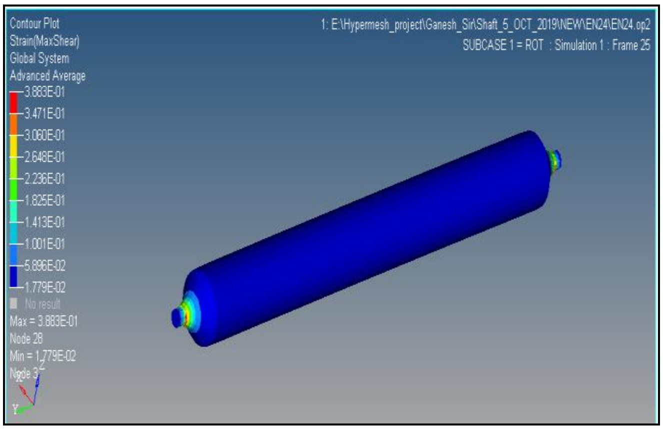


Fig. 10 Figure shows the maximum shear strain of steam pad machine Roller shaft. The value of maximum shear strain is 3.883E-01 and minumim is 1.779E-02

6. STRESS (Tresca)

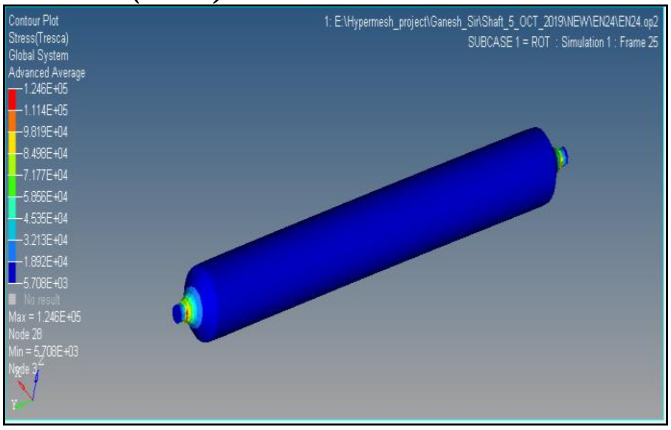


Fig.11 Figure shows the stress (Tresca) of roller shaft of steam pad machine. The value maximu is 1.245E+05.

D. Summary of computational analysis

- Material EN 24 material is meeting the maximum no of requirements.
- The minimum available displacement and the difference between the minimum displacement available and the deformation when EN 24 is used, is 2.2 mm which is too less & ignored.
- EN24 will give optimum results as compared to the other materials given in the case study.

V. WEIGHT AND STIFFNESS OF ROLLER SHAFT

A. Weight of pad steam machine roller shaft

Table- IV: Value of the weight for different materials

Sr. No.	Materia l Name	Volume	Density of material	Weight = (A × B) Kg
1	Carbon Steel	3.566E+08	7.845E-06	2797.527
2	EN 8	3.566E+08	7.855E-06	2801.093
3	EN 24	3.566E+08	7.800E-06	2781.47

Sr. No.	Materia l Name	Volume	Density of material	Weight = (A × B) Kg
4	AISI 6150	3.566E+08	7.803E-06	3167.67

The results were shown in Table IV represent the value of selected materials weight from FEA. It was observed that EN 24 material has low weight as compared to other material.

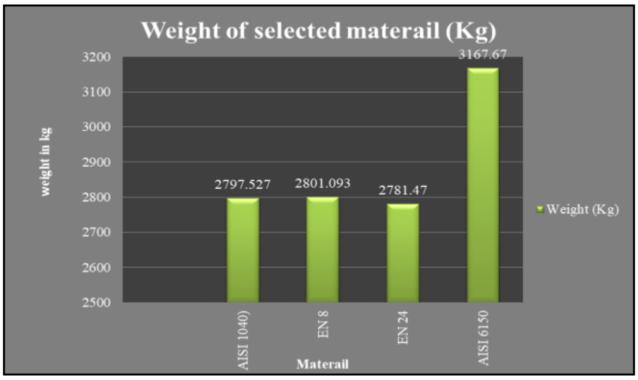


Fig.12 Graph showes the weight of selected materail

B. Stiffness of pad steam machine roller shaft

Table- V: Value of the Stiffness for different materials

Sr. No.	Material Name	Weight (Kg)	Displacements (mm)	Stiffness (Kg/mm)
1	Carbon Steel	2797.527	32.10	84.15
2	EN 8	2801.093	34..81	80
3	EN 24	2781.47	30.58	90.161
4	AISI 6150	3167.67	32.10	98.68

The results were shown in Table V represent the value of stiffness of selected materials. It was observed that EN 24 material has more stiffness as compared to other material.

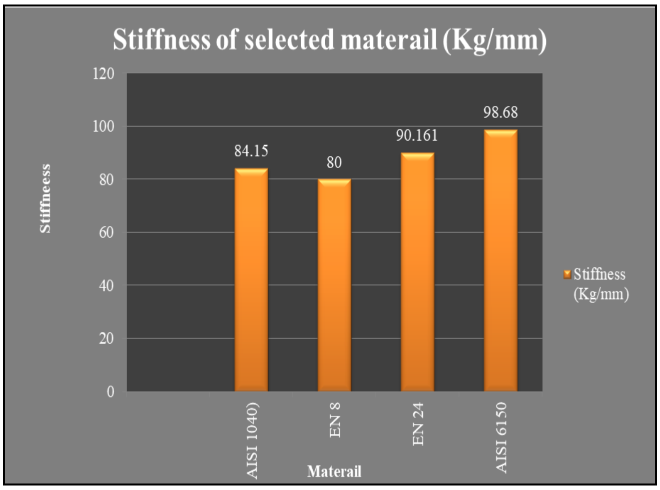


Fig.12 Graph showes the weight of selected materail

VI. EXPERIMENTAL TESTING

A. Tensile Test

Load range was 600KN taken for tensile test. Given below figure no.11 is show the four specimen of roller shaft for UTM test as per ASTM.

Fig.11Prepared sample for Tensile test Specimen

Table- IV: Tensile test result for all specimens

Sr. No.	Material Name	Load at Yield (KN)	Yield Stress (N/mm^2)	Ultimate Strength (N/mm^2)	Elongati on (%)
1	Carbon Steel (AISI 1040)	101.56	425.267	659.596	40
2	EN 8	102.75	519.99	673.19	29
3	EN 24	107.77	515.311	682.105	28
4	AISI 6150	0.981	479.26	658.78	32

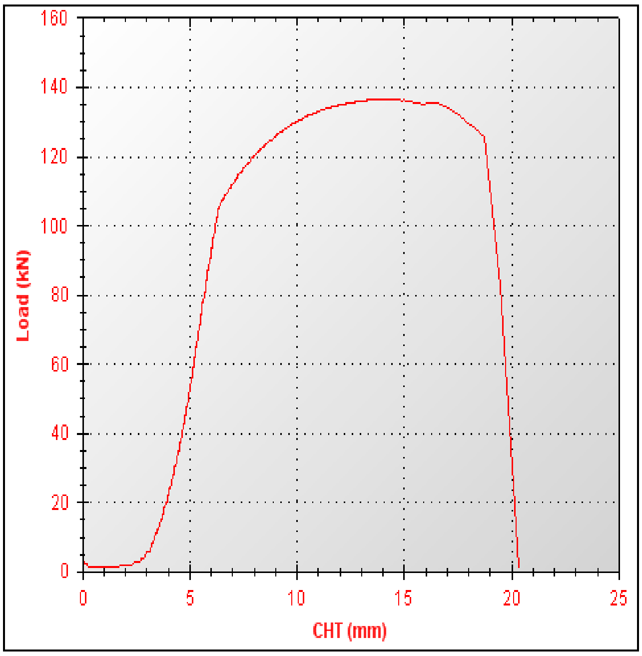


Fig.11 Graph Load Vs CHT of EN 24 (S3) Material

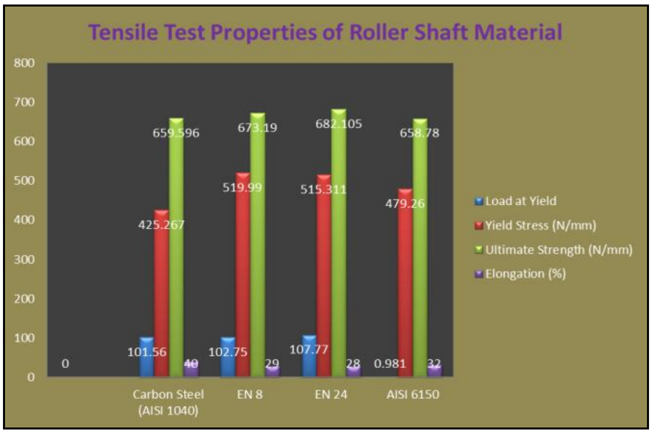


Fig.12 Graph showes the tensile test properties

Above bar chart shows the differnet material properties are obtained to performe tensile test for all four sample on UTM

B. Hardness Test

Apply test measure the diameter of indentation on the surface of test piece with help of Brinell Microscope repeated the steps for different metals to find its Brinell hardness number.

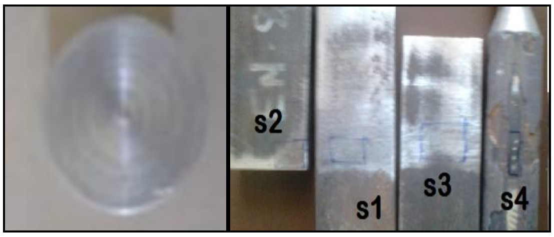


Fig.13Prepared sample for Hardness test.

Table- V: BHN for all specimens

Sr. No.	Material Name	Diameter of in indenter (Ø) in mm	Test load (F) N	Test specification	BHN
1	Carbon Steel	5	100	5/250/20	205
2	EN 8	5	100	5/250/20	212
3	EN 24	5	100	5/250/20	248
4	AISI 6150	5	100	5/250/20	197

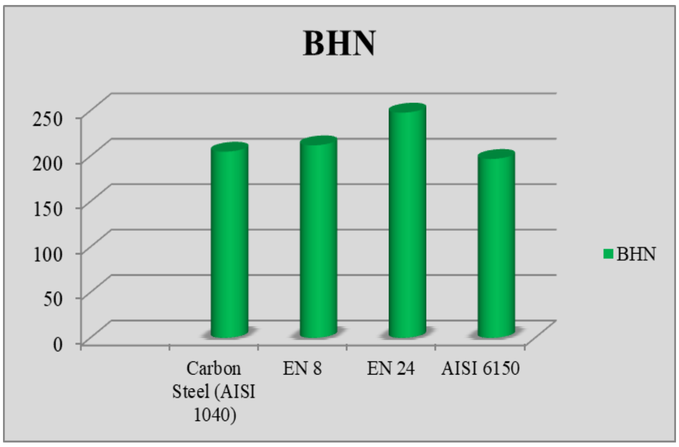


Fig.14 Graph Shows the hardness number of Roller shaft materail.

VII. RESULTS AND DISCUSSION

Study the working principal and application of continuous pad steam machine roller shaft machine then identify the root cause failure of roller shaft. A stress concentration occurs at fillet and step of shoulder which converted into micro crack. Several conditions are responsible to failure of shaft. Select the four material including the failed shaft material carbon steel (AISI 1040). Chemical composition was done on selected material it was match with the required specification. Next examine FEA in hyper work simulation tool result represent the stress concentration factor is considerable for failure of pad steam machine roller shafts which reduce the material reliability in some extent; next from the experimental stress strain properties of material it was found that strength is required capacity.

VIII. CONCLUSION

From hyper work simulation it is conclude that the stress concentration is at pad steam machine of roller shaft shoulder. An experimental stress and FEA results gives the close agreement, within 9% difference. The optimized roller shaft material is 12.5% lighter than the failed carbon steel material. EN24 material is much stiffer than failed carbon steel material. An experimental testing EN24 has less elongation and maximum ultimate tensile stress 682 MPa other than selected material. The percentage of elongation of the EN24 material is 28. On the basis of FEA and experiment work EN24 is suitable material for pad steam machine roller shaft**.**

ACKNOWLEDGMENT

We are take this opportunity to thank our Head of the Department Dr. K K Dhnade Sir, senior member of Mechanical Engineering department, Dr. D.Y. Patil Unitech Society's, Dr. D.Y. Patil Institute of Technology, Pimpri Pune; for their valuable guidance and for providing all the necessary facilities, which were indispensable in the completion of this work .

REFERENCES

1. Santosh D. Dalvi, Hariom, D. Chandrababu, Sunil Satav, Vijoykumar, “Failure analysis of a carbon steel roller shaft of continuous pad steam machine,” Case Studies in Engineering Failure Analysis, vol. 9, 2017 pp. 118–128,.
2. Mrs. Ashvini S. More, Prof.P.V.Jawale, “A Review on Materials for Belt Conveyor Roller Shaft”, IJSART - Volume 3 Issue 12 – DECEMBER 2017, ISSN [ONLINE]: pp.2395-1052.
3. Aparna devi.I, Sudhakar.I, V.S.N. Venkata Ramana, “An Experimental Study on Corrosion Behavior of En8 and En24 Grade Steels”, 3rd ed., vol. 2. 4th International Conference on Materials Processing and Characterization, 2015, pp.1251–1256.
4. Charnont Moolwana, Samroeng Netpu, “Failure Analysis of a Two High Gearbox Shaft,” in Social and Behavioral Sciences Symposium, 4th International Science, Social Science, Engineering and Energy Conference 2012 (I-SEEC 2012), pp. 154-163.
5. Amol Kakade, Sudeep Ingole, D. V. Bhatt , J. V. Menghani, “Tribochemistry of Sugar Mill Roller Shaft Materials,” vol. 4, 2017 pp. 434–441.

6. Mr. G. N. Bhalerao, Dr. S. B. Zope, Prof. A. R.Patil, "*Finite Element Analysis and Optimization of Four Cylinder Petrol Engine Crankshaft".* IJFEAT, International Journal for Engineering Applications and Technology, vol. 4, 2016 pp. 434–441.
7. Jinfeng Du*, Jun Liang, Lei Zhang, "Research on the failure of the induced draft fan's shaft in a power boiler," Case Studies in Engineering Failure Analysis 5–6 (2016) 51–58.
8. (A textbook of Machine Design) R.S. khurmi and J.K. Gupta 25th revised edition S chnad Publication
9. (Machine Design by VB Bhandari) Revised 3rd Edition 2010 Tata McGraw Hill publication:
10. (Data Book of Engineering) PSG College Kalaikatheir Achchagam Coimbatore.

AUTHORS PROFIL

Mr. Bhalero Ganesh Nandkumar
Working at Dr. D.Y. Patil Institute of Engineering & Technology, Pimpri, Pune as an Assistant Professor in Department of Mechanical Engineering since June 2019. Published 5 Research papers in National /International Journals), 02 Research papers in National /International conferences and also attended workshops.

Dr. Atul A. Patil
Working at Dr. D.Y. Patil Institute of Engineering & Technology, Pimpri, Pune as an Associate Professor in Department of Mechanical Engineering since June 2016. Published more than 20 Research papers in National/International Journals), 03 Research papers in National /International conferences and also attended more than 05workshops; Lifetime member of ISTE.

Dr K B Waghulde
Working at Dr. D.Y. Patil Institute of Technology, Pimpri, Pune as a Professor in Department of Mechanical Engineering since November 2017. Published more than 25 Research papers in National/International Journals), 07 Research papers in National /International conferences and also attended more than 08 STTP workshops.