Development of Process for Replacement of Mill Roller

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Abstract - *Finite Element Method (FEM) as a numerical method is widely used as a calculation method in the field of engineering analysis, it gets widely developed with its unique advantages of computing, ANSYS software with its multi-physics field coupled analysis function has become mainstream of software applications and it is widely used in the engineering analysis. At the same time ANSYS software has powerful features dealing with thermal analysis; Mill roller, shaft and shell are assembled by shrink fitting method. In that case interference fit is generated. After some cycles the shell of mill roller is wear out. For better performance we have to re-machine the mill roller. Conventional dismantling method is difficult and very expensive. To provide experimental solution for this problem is very costly and time-consuming procedure. So, there is need to do analysis on mill roller. For that drawn the 3D model according to 2D drawing. Did the manual meshing using body sizing command. As not getting the results so did geometry refinement process and find out the meshing properties i.e., skewness and orthogonal quality. Doing analysis of separation condition for shrink fitting of existing mill roller in Ansys by cooling the shaft of a mill roller at -10°C in cooler chamber by using ice cubes or liquid nitrogen. Heating the shell of the mill roller at 400°C in a furnace by giving or introducing supports to avoid no constraints error. Then at what cooling and heating temperature the assembly of shaft and shell of the mill roller gets separated needs to find out. Numerical results will be validated by using Analytical method.*

***Key Words*: Shrink fit, Skewness, Orthogonal quality, ANSYS, FEM.**

1. INTRODUCTION

Mill roller shells are among the main assembling line components in the sugar production process. They are painstakingly planned by many surface rules among which wear resistance is the most significant [1]. To increase the life of the mill roller shells, the resistance of the surface to failure by abrasion should be increased.

A shrink-fit is a semi-permanent assembly system between two parts without utilizing another fastening device. It gives a minimal expense strategy to attaching parts and is generally utilized in industry, with applications to cutting tool holders, wheels and bands for railway stock, gears, turbine discs, rotors for electric motors and for locating ball and roller bearings. The underlying principle involves establishing a pressure between the inside diameter of a part such as a hub and the outside diameter of a shaft through interference in dimensions at their radial interface [2]. Commonly, expansion of the external part by heating or cooling of the shaft is utilized, The parts are found and afterward the entire assembly is gotten back to the working temperature, where upon the pressure keeps up high with part area (resistance to pressure or compression) and additionally permits transmission of a torque.

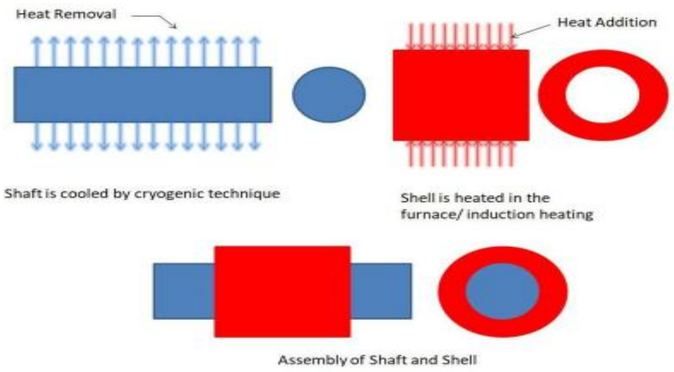


Fig -1: Assembly procedure of shaft and shell of mill roller.

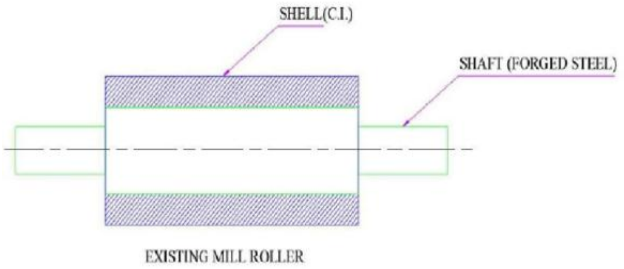


Fig -2: Shaft and Shell Dismantling procedure.

As the figure 1 shows the assembly procedure of shaft and shell of mill roller. The shaft is cooled by removal of heat using cryogenic technique in which this shaft is kept in the ice box of liquid nitrogen for cooling purpose. Then shell of mill roller is heated in the induction furnace. Once it reaches to certain temperature the shell of mill roller expands, at that time the shaft is inserted in the shell while this process is happening and due to expansion of shell of mill roller and contraction of shaft the assembly of both takes place simultaneously. In figure 2 conventional dismantling procedure of shaft and shell of mill roller, the shell of mill roller is cut down and shaft is reused. The cut down part of shell of mill roller is then waste or scrap.

Related Work

The static structural analysis of roller shaft is carried out using analysis software ANSYS Workbench. The results for maximum shear stress on the top, Feed and Discharge roller are calculated analytically and compared with the results from software. R. K. Jain [3] briefly discussed tolerances and its importance. In this paper explained interchangeability thoroughly. Also described different types of limits with the examples. Crawford, W.R. [4] presented known theories for shell shrink (interference) fits with regard to stresses induced and also shrink fits required to ensure desired mill roller operation. Mr. Crawford stated that the essential requirement of the shrink was to ensure that the friction between the shaft and shell was sufficient to transmit the torque necessary for crushing, including transient torque peaks and the reduction in transmittable torque due to roller wear. Walmiki S Rathod [5] has presented work related to two roller sugar mill using FEA technique. They have calculated bending moment analytically and by software. Also have given results that taper gives less value of stress than the fillet. R. V. Ramachandran [6] was one of the early investigators to study the influence of surface finish on interference fits. The materials used for shrink fits were mild steel for both the hub and the shaft. The bore in the hub was reamed in all cases with a suitable reamer. The shaft finish was varied using different processes such as course/fine, turning and grinding. He found that the load carrying capacity of the press and shrink fitted assemblies, among other factors, depends appreciably on the roughness of the mating parts. The results show that, in general, surfaces with fine finishes can carry higher loads. However, in case of shrink fits, above a certain roughness the load carrying capacity increases with roughness. Where Interference fits are to be dismantled and resembled; finer surfaces are capable of maintaining their load carrying capacity. None of the commonly established a geometrical roughness parameters are very useful in describing the effect of roughness on interference fits.

1.1 Problem Definition:

Shaft and shell of the mill roller are assembled by shrink fitting method. In that case interference fit is generated. After some cycles the shell of mill roller is wear out. For better performance we have to re-machine the mill roller. Conventional dismantling method is difficult and very expensive. To provide experimental solution for this problem is very costly and time-consuming procedure. So, there is need to do analysis on mill roller.

1.2 Objective

The proposed work included following steps:

1) To study assembly procedure and conventional dismantling procedure of mill roller.

2) To do numerical analysis of separation conditions for shrink fitting of existing mill roller in ANSYS software.

3) To give solution for the problem and do numerical analysis for the same.

4) To compare or check the results of analysis and comment on the same.

2. Methodology

Finite Element Method (FEM) is a computer-based numerical technique for calculating the Strength and behavior of engineering structures. It can be used to calculate deflection, stress, vibration, Buckling behavior and many other phenomena. In the finite element method, a structure is broken down into many small simple blocks or elements. The behavior of an individual element can be described with a relatively simple set of equations. Just as the set of elements would be joined together to build the whole structure, the equation describing the behaviors of the individual elements are joined into an extremely large set of equations that describe the behavior of the whole structure. The computer can solve this set of simultaneous equations. From the solution, the computer extracts the behavior of the individual elements. From this, it can get the stress and deflection of all the parts of the structure. The stresses will be compared to allowed values of stress.

2.1 Basic steps in FEM

1. Discretization of the design.
2. Selection of appropriate addition or removal model.
3. Derivation of element stiffness matrices and load vectors.
4. Solution for the unknown nodal displacements.
5. Computational elemental stress and strains.

2.2 Deciding Parameters

Metals ordinarily expand when heated and contract when cooled. This reaction to a change of temperature is known as thermal extension. With induction shrink fitting, use thermal expansion to fit or remove parts. A metal part is warmed to 150-400 °C (305-752°F), and that makes it to expand. This allows the removal or insertion of a part. for example, for disassembly the induction is used to create thermal expansion for loosning of the joint. For assembly, one part might be heated until its diameter expands sufficiently for it to fit over the other part of the assembly. Then, the heated part cools and the joint get strong, which is "shrink fitting." A wide array of metals is used when shrink fitting, whether it's steel-to- steel, steel-to-copper, aluminum-to-steel, etc. Crushing roll shells are currently shrink-fitted onto roll hubs by heating the shell until it expands, sliding it onto the hub and letting it cool, so that the shell shrinks tightly onto the hub. Crawford (1970) [4] presented known theories for shell shrink (interference) fits with regard to stresses induced and also shrink fits required to ensure desired mill roller operation. In this paper stated that the essential requirement of the shrink fit was to ensure that the friction between the shaft and shell was sufficient to transmit the torque necessary for crushing, including transient torque peaks and the reduction in transmittable torque due to roller wear. Crawford, using simple interference fit theory, calculated the tensile hoop stresses, compressive radial stresses and axial stresses induced in the shell. The relationships between material parameters and shell geometry on induced shell stress and transmittable torque were plotted.

Table - 1: Composition of Shaft material

Carbon, C	0.37 - 0.44 %
Iron, Fe	98.6 - 99 %
Manganese, Mn	0.60 - 0.90 %
Phosphorus, P	<= 0.040 %
Sulfur, S	<= 0.050 %

Table - 2: Composition of Shell material

Total carbon	3.2 to 3.6
Sulphur	0:15 percent,
Phosphorus	0.5 percent, *Max*
Manganese	2.2 to 3.2 percent
Silicon	1.2 to 2.2

2.3 Material Properties

Table - 3: Shaft AISI 1040 Material Properties [8]

Density	7845 kg/m³
Tensile Strength Ultimate	620 mpa
Tensile Strength Yield	415 mpa
Modulus Of Elasticity	200 gpa
Bulk Modulus	160 gpa
Poisson's Ratio	0.29
Shear Modulus	80 gpa
Electrical Resistivity	0.0000493 ohm-cm
Coefficient of Thermal Expansion	13.3 µm/m°C
Specific Heat Capacity	0.586 j/g°C
Thermal Conductivity	50.7 w/mk

Table - 4: Shell AISI 1030 Material Properties [9]

Density	7850 kg/m³
Tensile Strength Ultimate	525 mpa
Tensile Strength Yield	440 mpa
Modulus Of Elasticity	200 gpa
Bulk Modulus	140 gpa
Poisson's Ratio	0.285
Shear Modulus	80 gpa
Electrical Resistivity	0.000034 ohm-cm
Coefficient of Thermal Expansion	11.7 µm/m°C
Specific Heat Capacity	0.223 j/g°C
Thermal Conductivity	51.9 w/mk

2.4 Optimization using FEA

Optimization of a designing plan is an improvement of a proposed plan that outcomes in the best properties for least expense. Perhaps the simplest examples is determining the shape of a fence that will enclose the most area. On the off chance that the wall can be any shape, however just a specific measure of fencing is accessible, then, at that point, a circle will encase the most region with the given measure of fencing. To limit how much steel utilized in assembling a barrel shaped metal can a specific connection between the distance across can and the level of the can is found. This will encase a volume with minimal measure of steel utilized for the surface region.

2.5 Geometry

For mathematical review 3D model of shaft and shell is required. Geometry of shaft and shell was made according to real aspects utilizing Ansys Design Modeler. Figure 3 Shows 3D model of shaft. Geometry is drawn in Ansys Design Modeler in 3D as per true scale.

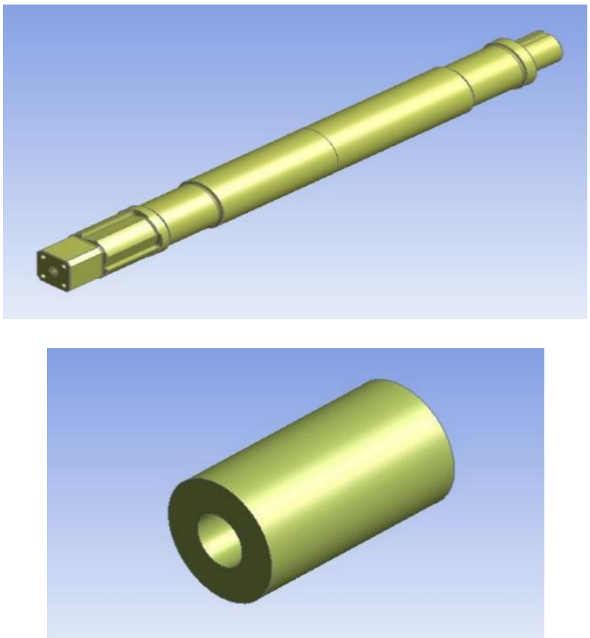


Fig -3: Shaft and Shell 3D drawing

The use of contact algorithm to detect the penetration and apply contact forces to push the parts apart until there is no more penetration. Figure 4 shows the actual assembly drawing of shaft and shell.

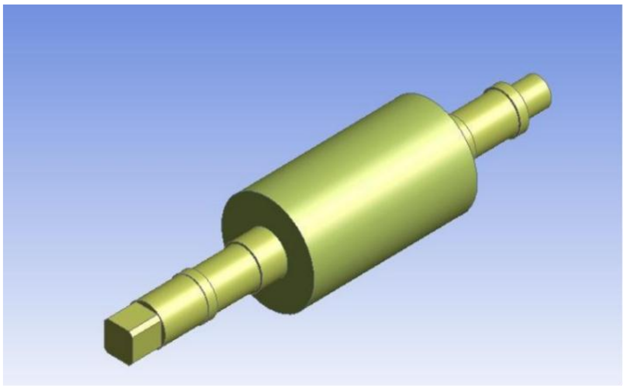


Fig -4: Assembly drawing of shaft and shell.

2.5.1 Meshing

Steady-state thermal stress analysis were executed to study the thermal stress effect of on the shaft and shell various materials. The variations of temperature and thermal stress on the parts are investigated for materials named as AISI 1040 for shaft and AISI 1030 for shell of the mill roller. Thermal stress analysis were performed by using the general-purpose package software ANSYS, produced by ANSYS Inc. Meshing is the process of turning irregular shapes into more recognizable volumes called elements. Before start meshing, we must first upload a geometry or model into, for example, Ansys mechanical to begin the meshing process. It is also process in which the continuous geometric space of an object is broken down into thousands or more of shapes to properly define the physical shape of the object. The more detailed any mesh is, the more accurate the 3 D model will be, allowing for high simulations. Figure 5 shows meshing of assembly using automesh command and figure 6 gives details about mesh quality spectrum.

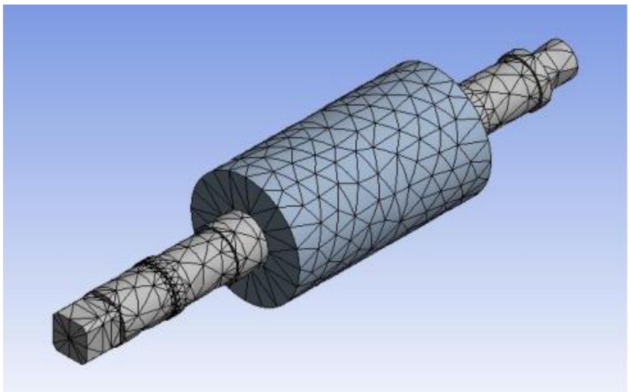
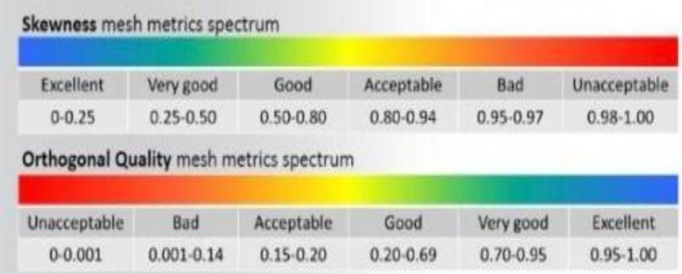


Fig -5: Meshing using Automesh



Skewness mesh metrics spectrum

Excellent	Very good	Good	Acceptable	Bad	Unacceptable
0-0.25	0.25-0.50	0.50-0.80	0.80-0.94	0.95-0.97	0.98-1.00

Orthogonal Quality mesh metrics spectrum

Unacceptable	Bad	Acceptable	Good	Very good	Excellent
0-0.001	0.001-0.14	0.15-0.20	0.20-0.69	0.70-0.95	0.95-1.00

Fig -6: Mesh Quality Spectrum

2.5.2 Skewness

Skewness is the difference between the state of the cell and the state of a symmetrical cell of comparable volume. Highly skewed cells can decrease accuracy and destabilize the solution. Figure 6 gives the details of mesh quality spectrum where we get acceptable and unacceptable values of skewness mesh. Figure 7 shows auto mesh skewness where min value is 0.0031979 and max value is 0.98263 which is unacceptable according to mesh quality spectrum.

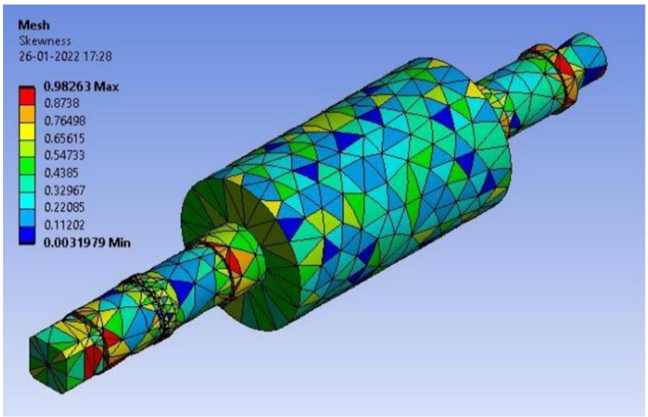


Fig -7: Skewness

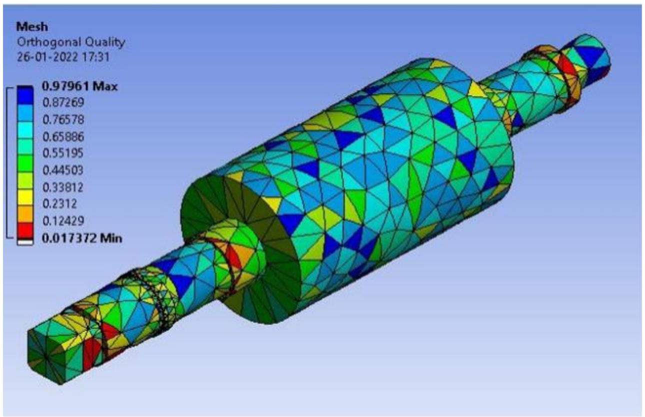


Fig -8: Orthogonal Quality

2.5.3 Orthogonal Quality

Orthogonal Quality is likewise commonly used to evaluate the mesh shape quality as skewness of mesh structure. It sounds complex but what we need to know about "Orthogonal Quality" is, 0 is worst and 1 is the best. Figure 8 shows auto mesh orthogonal quality where min value is 0.017372 and max value is 0.97961 which is unaccepted according to mesh quality spectrum.

2.6 Refined Geometry

As we do not get the actual result as we expected from auto mesh and manual mesh, We chose to do refinement to come by definite outcome which need. In this is needed eliminate 1mm edges, steps, by refining other parts by making it same size as they are undersize of the interference fit value. Figure 9 shows refined shaft geometry and figure 10 shows refined shell geometry, we also remove the steps in the shell for better to get results in meshing and analysis.

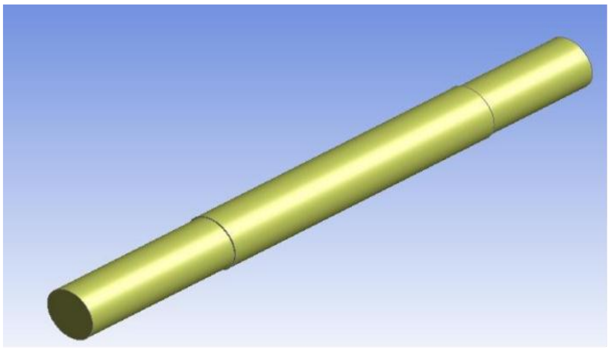


Fig -9: Refined Shaft Geometry

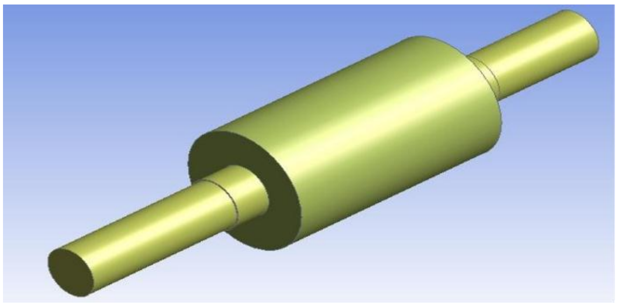


Fig -10: Assembly of Refined Geometry

2.6.1 Refined Geometry Skewness

To check the skewness value of refined mesh geometry we have to run the Mesh command then mesh metric shows the skewness value i.e., 0.00020023 min and 0.79814 max that it is in good condition according to mesh quality spectrum figure 6. The skewness value of refined geometry is shown in figure 11.

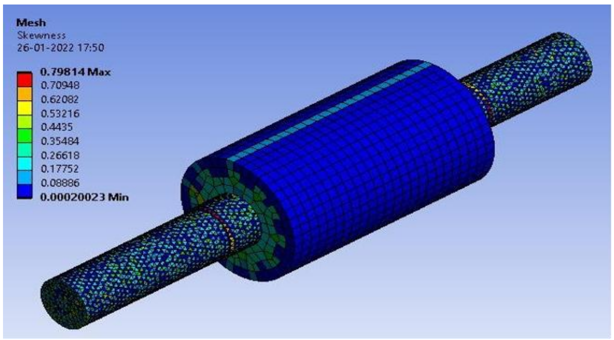


Fig -11: Refined Geometry Skewness

2.6.2 Refined Geometry Orthogonal Quality

After skewness by checking orthogonal quality of refined geometry it gives 0.20186 min and 0.99927 max that is in excellent condition according to orthogonal mesh quality spectrum. figure 12 shows orthogonal quality of refined geometry.

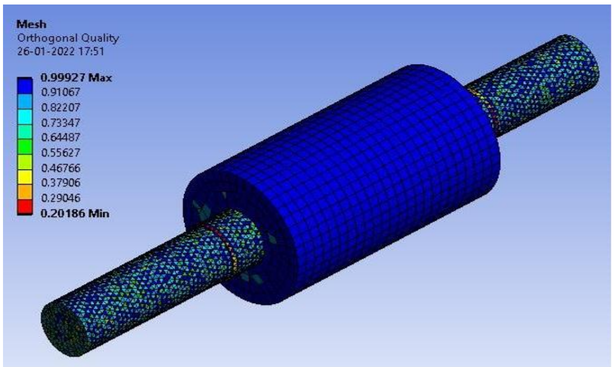


Fig -12: Refined Geometry Orthogonal Quality

2.7 Shaft Analysis using Supports

As the meshing of refining geometry done then need to do analysis of existing mill roller at seperate conditions for that tentative supports introduced. Taking the shaft first and cooling it at -10°C in a ice box or using liquid nitrogen as shown in figure 13. Solving the solution in steady state thermal importing its results into static structural where we could find out directional deformation through shrink fit length and after running the solution got the results as the shaft gets shrink or contracted by -0.84mm as shown in figure 14. Figure 14 (a) and (b) gives the information about deformation at the edge throughout length.

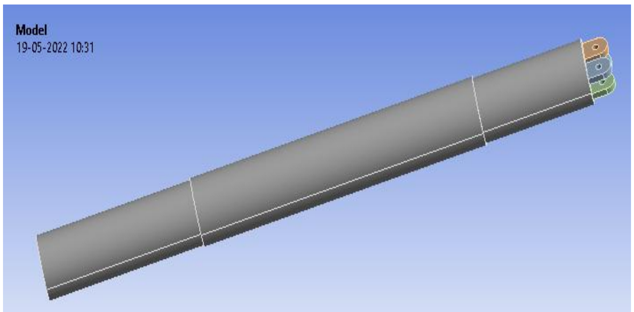
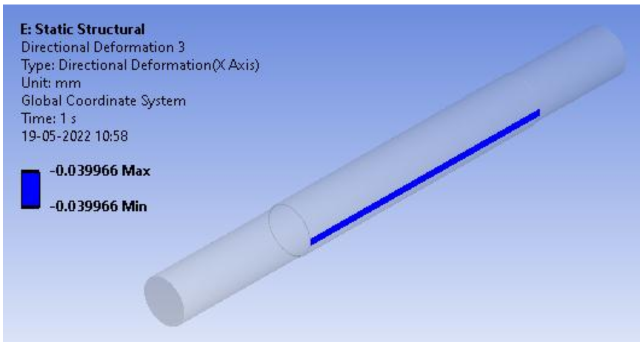
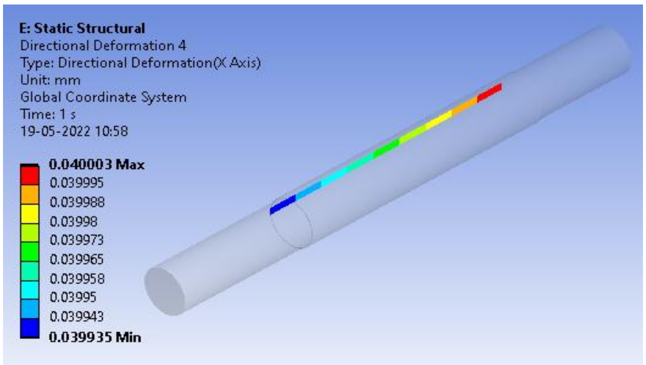


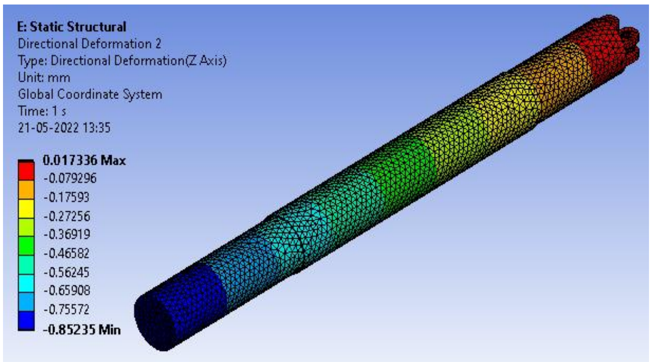
Fig -13: Shaft Analysis with hook Supports



(a)



(b)



(c)

Fig -14: Directional Deformation of Shaft

2.8 Shell Analysis with Supports

After Shaft analysis is done the shell analysis using supports as shown in fig 15. Now here used heating process where shell is heated at 400°C in pit type furnace.

Now solving the solution in steady state thermal and importing its results into static structural. After solving the solution in static structural it gives directional deformation at edge throughout length in figure (a) and (b). By heating the shell at 400°C it gets expanded by 4.67mm as shown in figure (c).

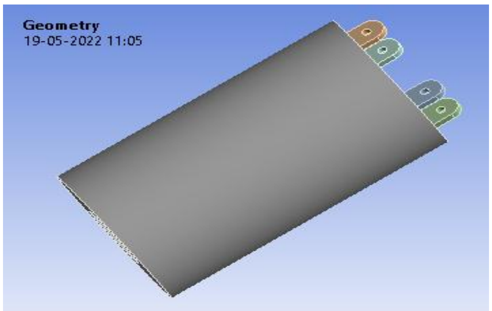
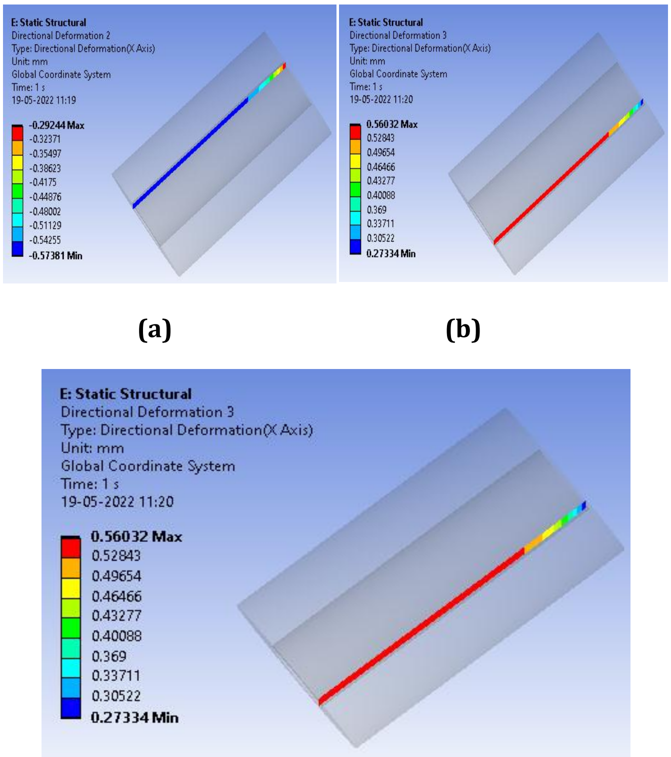


Fig -15: Shell Analysis with hook Supports



(a) (b)

(c)

Fig -16: Directional Deformation of Shell

3. CONCLUSIONS

The deformation of FEM shaft and shell of the mill roller is calculated using steady state thermal and static structural process. Static structural process is more efficient for measurement of directional deformation of mill roller parts, as it is numerical, non-contact and reliable method. It can be concluded as static structural process has middle-level accuracy and provides results with acceptable tolerance. The proposed system gives the results in less time compared to conventional method that is used in the industries so it can be used to measure and analyse the directional deformation of the specimen.

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