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Optimization and Analysis of Super Finishing Lathe Attachment with Pin on Disk Experiment on Ebonite Coated Disk

Sayyad Layak B., Ch. Sanjay

Abstract- This paper presents the research work done to solve the problem faced by super-finishing attachment used in lathe machine, which cannot be continuously operated for mass production as it is possible in a full-fledged super finishing machine. Research work is implemented in 50LT attachment and converted it into the continuous working machine thereby making it suitable for mass production without having to purchase costly Super finishing machine and getting similar production only with an attachment on a lathe machine. The research work also provides a solution for the problem faced by attachment when operated in cold working condition wherein the shrinking of the part takes place, and the machine gets a jam, and it becomes impossible to operate, the solution thereby makes the attachment to work in the adverse environment also.

Index terms: Friction, heat generated, super-finishing machine, OHNS, Ebonite Coating, Pin on Disk.

I. INTRODUCTION

Superfinishing, also known as micromachining, micro finishing, and short-stroke honing, is a metalworking process that improves surface finish and workpiece geometry. This is achieved by removing just the thin amorphous surface layer left by the last process with an abrasive stone or tape; this layer is usually about one μm in magnitude. Superfinishing produces a mirror finish unlike polishing which produces a mirror finish, creates a cross-hatch pattern on the workpiece.

Superfinishing is an alternative process similar to honing. This also uses a bonded abrasive stick moved with a reciprocating motion and pressed against the surface to be finished. The relative motion between the abrasive stick and the workpiece is varied so that individual grains do not retrace the same path.

Cutting fluid is used in the process for cooling of the tool-workpiece interface. Coolant also washes away the tiny chips produced in the process. The time needed for superfinishing is minimal. The workpiece may be super finished to a roughness of the order of 0.075 μm within 50 seconds.

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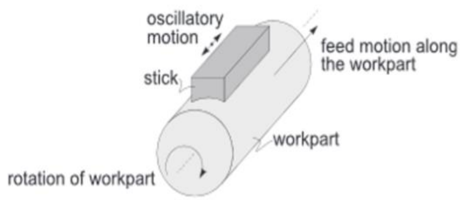
Significant applications of superfinishing are finishing of computer memory drums, sewing machine parts, automotive cylinders, brake drums, bearing components, pistons piston rods, pins, axles, shafts, clutch plates, and guide pins. Sometimes the process of superfinishing can be continued up to 3 minutes for the outstanding quality of finish. Superfinishing can be differentiated from honing in the following ways

(a) Super finishing stroke length is comparatively shorter, but the frequency is more considerable. It is up to 1500 strokes/minute. b) It requires low-pressure application as compared to the honing process. (c) During the process fed is given to workpiece, the fed rate in case of superfinishing operation is smaller than honing. (d) The grit size of abrasive used in the case of superfinishing is smaller than that is used with hones.



Schematics of the superfinishig process.

Fig1: Super finished Components.

II. SUPER FINISHING PROCESS

After a metal piece is ground to an original finish, it is super finished with a finer grit solid abrasive. The abrasive is oscillated or rotated while the workpiece is rotated in the opposite direction; these motions are what causes the cross-hatching.

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The geometry of the abrasive depends on the geometry of the workpiece surface; a stone (rectangular shape) is for cylindrical surfaces and cups and wheels are used for flat and spherical surfaces. A lubricant is used to minimize heat production, which can alter the metallurgical properties, and carry away the swarf; kerosene is a standard lubricant.

The abrasive when operated cuts the surface of the workpiece in three phases. The first phase is when the abrasive first contacts the workpiece surface: dull grains of the abrasive fracture and fall away leaving a new sharp cutting surface. In the second phase the abrasive "self-dresses" while most of the stock is being removed. Finally, the abrasive grains become dull as they work which improves the surface geometry.

The average rotational speed of the abrasive wheel and workpiece is 1 **to** 15 surface m/min, with 6 to 14 m/min preferred; this is much slower as compared to grinding speeds around 1800 to 3500 m/min. The pressure applied to the abrasive is very light, usually between 0.02 to 0.07 MPa (3 to 10 psi), but can be as high as 2.06 MPa (299 psi). Honing is usually 3.4 to 6.9 MPa (490 to 1,000 psi), and grinding is between 13.7 to 137.3 MPa (1,990 to 19,910 psi). When the stone used, it oscillates at 200 to 1000 cycles with an amplitude of 1 to 5 mm (0.039 to 0.197 in) Superfinishing can give a surface finish of 0.01 μm.

III. TYPES

There are three types of superfinishing: Through-feed, plunge, and wheels.

Through-feed

This type of superfinishing used for cylindrical workpieces. The workpiece rotated between two drive rollers, which will also move the machine. Four to eight progressively finer abrasive stones are used to super finish the workpiece. The stones contact the workpiece at a 90° angle and they are oscillated axially. Examples of parts that would be produced by the process include tapered rolls, piston pins, shock absorber rods, shafts, and needles.

Plunge

This type is used to finish irregularly shaped surfaces. The workpiece is rotated while the abrasive plunges onto the desired surface.

Wheels

Abrasive cups or wheels are used to super finish flat and spherical surfaces. The wheel and workpiece are rotated in opposite directions, which creates the cross-hatching. If the two are parallel, then the result if a flat finish, but if the wheel is tilted a convex or concave surface slightly will be formed.

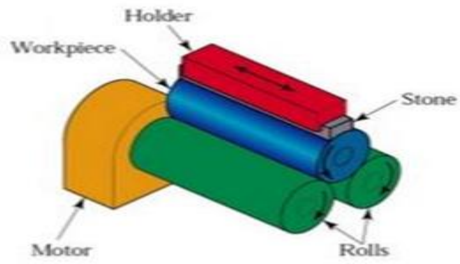

Fig 2: arrangement on complete Super Finishing Machine

SUPER FINISHING MACHINES AND ATTACHMENT USED BASED ON QUANTITY OF SUPER FINISHED WORKPIECE REQUIRED:

A cylindrical workpiece which can be super finished using "Through-feed" type of super-finishing operation in which the workpiece is rotating, and the tool (stone) is oscillated axially, if needed to manufactured in the range of 3-4 lakh pieces per month, needs necessarily to be manufactured on complete Super Finishing Machines which costs about 35-50 lakhs and comes in various ranges.

On the other hand, if the no of super finished workpiece required is around 2 to 3 thousand per month, the same can be achieved by using a Super Finishing attachment on a Lathe Machine. In which the rotation to the workpiece is given by holding it in between the centers of the lathe machine. This attachment costs typically around 2 to 2.5 lakhs and can be quickly brought by small industry.

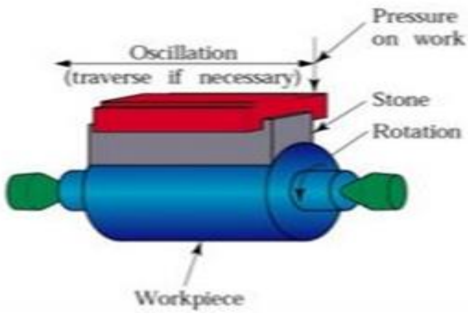

Fig 3: arrangement on Lathe Attachment Superfinishing

IV. SUPER FINISHING LATHE ATTACHMENT:

The above pictures give a clear understanding of how a super finishing attachment is being mounted on a lathe Machine, and the workpiece is being rotated by being mounted between the centers of the Lathe.

The primary principle of working of this attachment is an oscillation of the tool (stone) which does the super finishing work. This oscillation of the tool is achieved by Pneumatic Piston-Cylinder arrangement.

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Fig 4: Super Finishing Lathe attachment.

The cylinder has a unique set of hole arrangement and also the piston has a cylindrical slot which makes it easy for the assembly to create an oscillatory motion which in some instances goes up to 2500 oscillations/minute.

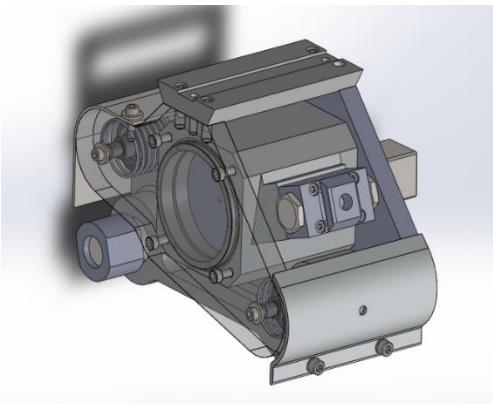


Fig 5: CAD of Super Finishing Lathe Attachment.

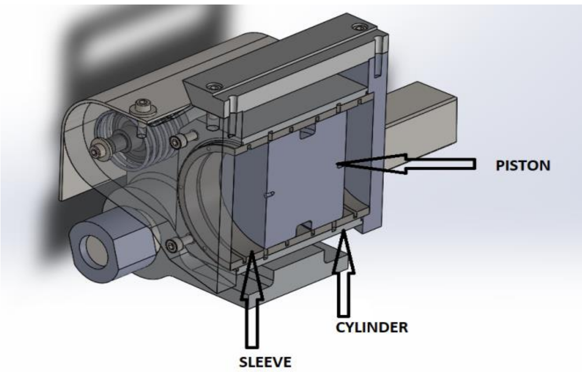


Fig 6: Cut CAD Model of Piston Cylinder and Sleeve Arrangement

V. PROBLEM DEFINITION:

The problem definition draws our attention to the practical working of the Super Finishing Lathe attachment wherein the oscillations are only possible if a gap of 5 microns is being maintained between the piston and sleeve arrangement. To be very frank maintaining this 5-micron gap when in continuous operation is not possible at such high oscillations (2500 /min). The friction between the piston and sleeve produces heat which in turn expands both the materials of the piston and sleeve thereby putting a jam between the two. Because of this attachment cannot be used for continuous operation and need to be given a break for cooling purpose now and then, which ultimately affects the production. Another major problem faced by this attachment is that because of this friction between the sleeve and piston the life of the attachment is only around two years and needs to be reworked by changing the piston and sleeve both which again is a costly affair. To find the exact problem, i.e. the amount of material expansion on FE analysis was conducted, to do the same the heat generated is first calculated manually, and later the same is being used in the Finite Element Analysis.

VI. FORMULA

The formula to calculate Heat Generated "Q."

Q = μ*u*N

Where μ = coefficient of friction (is unitless and its value is 0.0618 for the polish finish of the material.)

U = Velocity of Piston Sleeve arrangement

U = 2500*2.4 mm (stroke length)

U = 6000 mm/min

U = 6 m/min

U = 6/60 = 0.1m/s

N = force (It should be found from pressure)

P = 1 bar = 101325 Pascal = 0.1N/mm2

Pressure = F/A

F = P*A

F (i.e N) = $0.1*\pi/4*(70)^2$

F = N = 3846.5N

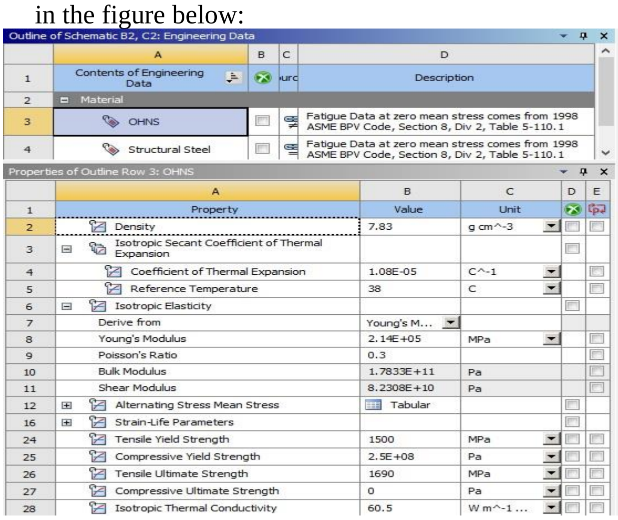
Q = 0.30*0.1*384.65

Q = 11.54W

This value of Q is computed in the analysis in the ANSYS software by performing a Coupled Field Analysis i.e. Coupling of Structural and Thermal Analysis

VII. ANALYSIS (OHNS – OHNS)

1) **Material Properties:** Material Properties of Material OHNS (Oil Hardened Non-Shrinkable Steel) is as given in the figure below:



Outline of Schematic B2, C2: Engineering Data

	A	B	C	D
1	Contents of Engineering Data		urc	Description
2	Material			
3	OHNS			Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
4	Structural Steel			Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

Properties of Outline Row 3: OHNS

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	7.83	g cm^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion	1.08E-05	C^-1		
5	Reference Temperature	38	C		
6	Isotropic Elasticity				
7	Derive from	Young's M...			
8	Young's Modulus	2.14E+05	MPa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	1.7833E+11	Pa		
11	Shear Modulus	8.2308E+10	Pa		
12	Alternating Stress Mean Stress	Tabular			
16	Strain-Life Parameters				
24	Tensile Yield Strength	1500	MPa		
25	Compressive Yield Strength	2.5E+08	Pa		
26	Tensile Ultimate Strength	1690	MPa		
27	Compressive Ultimate Strength	0	Pa		
28	Isotropic Thermal Conductivity	60.5	W m^-1 ...		

Fig 7: Material properties of OHNS

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2) Boundary Condition (Thermal)

a) The thermal boundary condition applied to the sleeve is" Q" Heat Generated obtained through manual calculation, as shown in figure Fig 8 below:

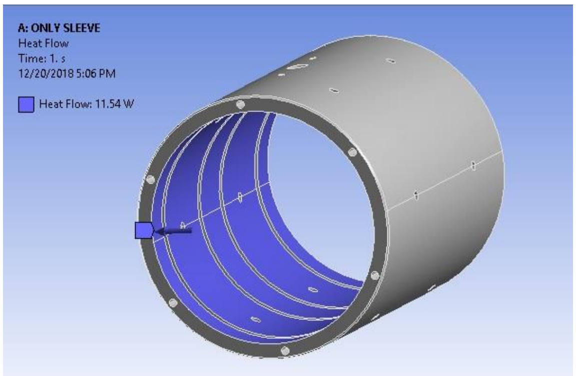


Fig 8 boundary condition applied to the sleeve "Q."

b) Another thermal boundary condition consists of Convection because of the flow of the air through the sleeve as shown in figure Fig 9 below:

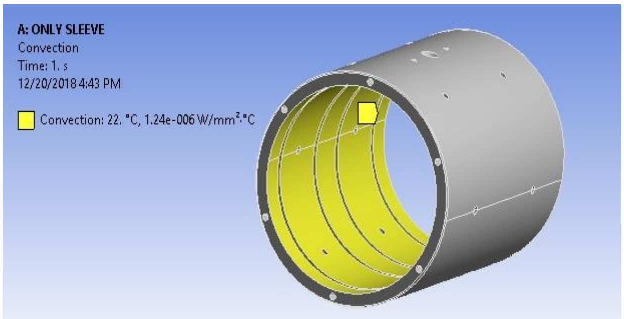


Fig 9 Boundary condition consists of Convection

3) Boundary Condition (Structural)

a) The outer periphery of the sleeve is press-fitted in an Aluminum body; hence a fixed boundary condition is applied on the same, as shown in figure Fig-10 below:

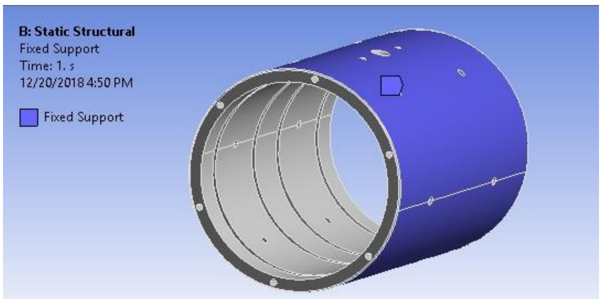


Fig. 10 Fixed boundary condition

4) **Meshing & Discretization;** The mathematical model is converted into a flexible model by meshing process. The digitized model is as shown in figure Fig-11 below:

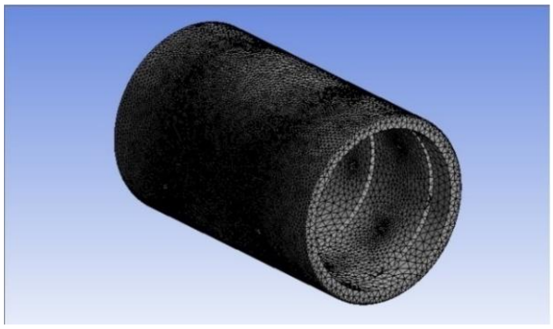
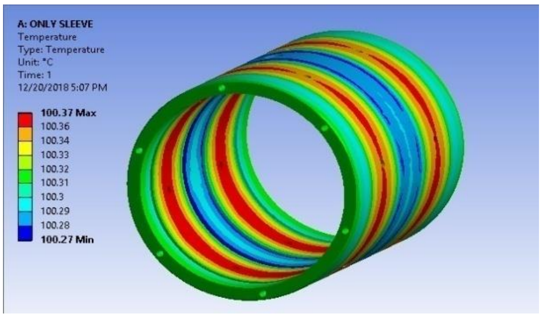


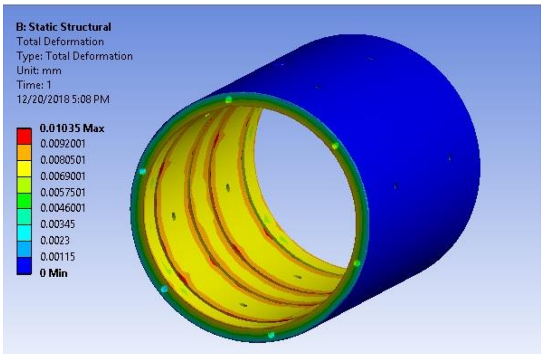
Fig. 11 Meshing & Discretization

5) Results:

a) Fig-12 Temperature Distribution



b) Fig-13 Total Deformation



From the above results, it is seen that the Continuous operation of the attachment generates much heat which in turn result in an expansion of the sleeve. As seen from the analysis result a total deformation of 10 microns shown in fig-13, which makes a jam between the piston and sleeve, as it needs around 5-micron gap for the free sliding of the Piston in the sleeve.

So research has been made to coat the inner of the sleeve with a material having very low thermal conductivity. So it is decided to coat to the inner with Ebonite which has following Mechanical properties which serve our requirement.

Ebonite: 1.15 to 1.68 g/cm^3

Young's modulus: 2000 to 3000MPA

Tensile Strength: 52-67 MN/m^2

Thermal Conductivity: 0.17 W/mK

Thermal Expansion: 42.8 micro inch / inch °F.

Poisson's Ratio: 0.39

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VIII. SURFACE COATINGS

Surface coatings can be applied over a wide range of thickness from a few micrometers to several millimeters. Coatings can be classified as soft coatings, with low or moderate-to-low friction and hard coatings, with high wear resistance and moderate friction.Many coatings deposition techniques are available, and these may be classified into three broad categories:

(a) Hard facing

(b) Vapor deposition and

(c) Miscellaneous deposition processes.

(a) Hard facing

Hard facing is used for depositing thick coatings (typically more than 50 μm) of hard wear-resistant materials.

(b) Vapor deposition

Vapour deposition techniques are used to deposit thin and reproducible coatings with excellent adhesion and significant flexibility.

(c) Miscellaneous deposition processes

Miscellaneous deposition processes are widely used for application of polymer coatings, non-metallic coatings and composite coatings for wear and corrosion resistance.

Using the Miscellaneous deposition Process, Ebonite is coated on the inner side of the sleeve and analysis is being performed and verified with physical testing.

IX. PINON DISK EXPERIMENT

To understand the friction behavior between OHNS and Ebonite coating an experiment was performed on DUCOM ROTARY TRIBOMETER. The details of the same are as given below.

X. DUCOM ROTARY TRIBOMETER:

Ducom Rotary Tribometer is a workhorse of several tribology labs for real-time measurement and analysis of friction and wears behavior of materials in the form of ball/pin and disk specimens. Pin and disk specimens can be tested irrespective of its roughness and hardness. Experiments can be conducted in dry or lubricated condition. In this tribometer, the load, speed, and motion are three critical variables.

The design allows a wide range of load: 2 N to 1000 N (manual/computer controlled profiles), speed: 0.3 rpm to 3000 rpm (computer controlled profiles) and three different types of wear profiles (i.e., rotation, spiral, and oscillation). Ducom Rotary Tribometer is a modular system comprised of environment control modules like heating (up to 1000 deg C), vacuum (up to 10-6 Torr) and humidity (up to 80 % RH). Ducom Rotary Tribometer complies with ASTM G99.

Figure -14 Ducom Rotary Tribometer with the heating chamber

For testing the tribometer, the following details are being calculated:

Pin: OHNS (Oil Hardened non-Shrinkable Steel)- Having 60 HRC

Disk: OHNS Coated with Ebonite Rubber- Having 92 BHN ρ = 1.15-1.68 g/cm3 , E = 2000-3000 mp Ϭt = 52-67 M Pa, (Thermal Conductivity) K = 0.17W/m k poison ratio – 0.39

Weight to be applied on pin = 5N (1kg/cm2)

Diameter of rotation = 100mm

Velocity = 0.1m/s = 0.1 = $\frac{\pi DN}{60} = \frac{\pi \text{ X } 0.1 \text{ X N}}{60}$

N = 19 turns / minute

Time = 45min

Total distance to be travelled

D = V.t = 0.1 x (45 x 60) = 270

The Tribometer directly gives the value of the temperature rise because of the friction between the pin and the disk. Here in the pin is of OHNS material and the disk is ebonite coated OHNS. The experiment is run for 45 minutes, and the temperature rise is recorded, and the same is being used in the FEA analysis and results are concluded.

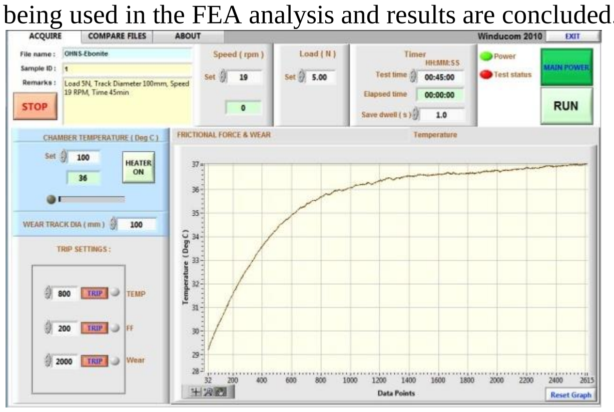

Fig -15 Temperature rise 37 ° C between OHNS Pin and ebonite coated disk.

The setup has the disk mounted on the rotor and the pin kept in contact with the disk under required pressure while the disk is rotating. The arrangement is as shown in the figure below.

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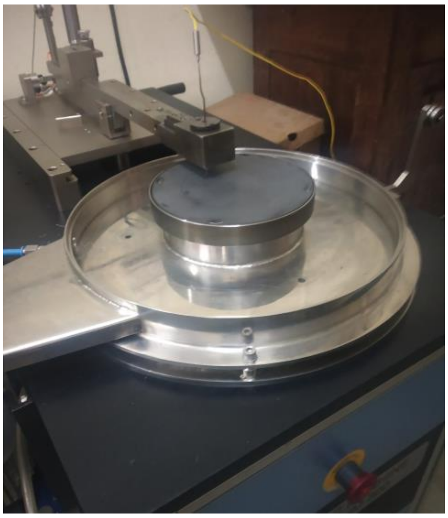
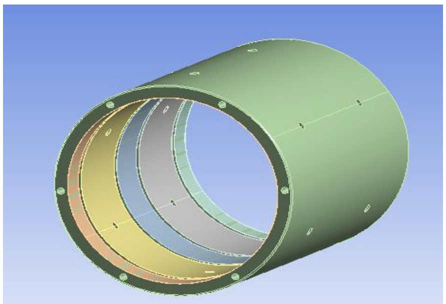


Figure 16 Pin on disk arrangement.

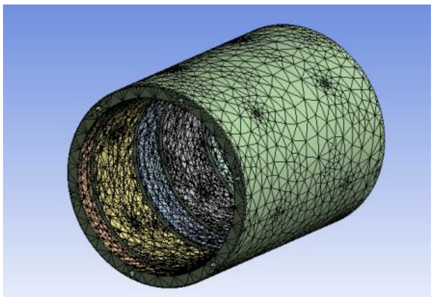
The value of the temperature rise is directly taken from the experiment performed on the tribometer with ebonite coated disk and OHNS Pin after rotating the disk continuously for 45 minutes. The temperature rise was 37^0 F

XI. ANALYSIS (EBONITE – OHNS)

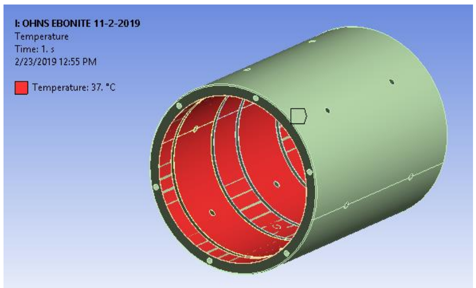
1) The 3D Geometry after ebonite coating is as seen in figure Fig -17 below.



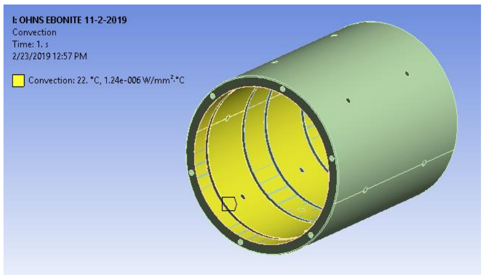
2) Meshed assembly of Ebonite coated OHNS Sleeve is as shown in figure-18 below.



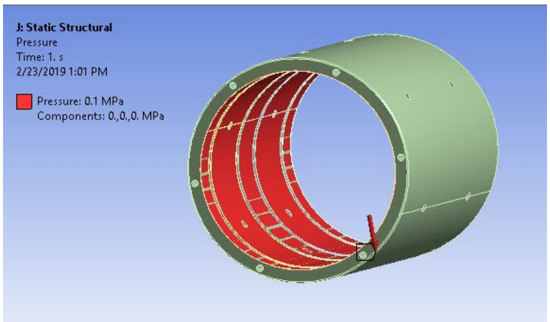
3) The thermal boundary condition applied to the sleeve, a temperature of 37 ºC, as shown in figure Fig -19 below:



4) The convection Boundary condition is as shown below in Fig-20

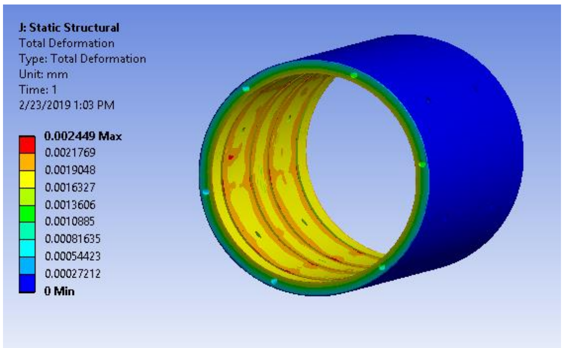


5) Internal Pressure is applied as shown in fig-21 below.



6) Results:

Total deformation is as shown in fig-22 below



XII. CONCLUSION :

1) As seen from the analysis above (Ebonite – OHNS) the total deformation is 2 micron which is less than 5 micron. The above results are needed for the free sliding of the piston in the sleeve.

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2) The experiments have been conducted with Ebonite coating, and running machine continuously gave excellent results both at high temperature and at places where the ambient in winter are very low. The above phenomena will avoid shrinkage of material. The above phenomena were possible because the Thermal conductivity of Ebonite is very low.

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