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INVESTIGATION AND OPTIMIZATION OF NEEDLE ROLLER BEARING PERFORMANCE USING CAD & CAE

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Abstract

Needle roller bearings have high load carrying capacity although it have small cylindrical roller having low cross section, thus it used in application where space limitation is the important factor along with high dynamic loading capacity. So in any kind of machineries where space is limited for driving the mechanism a needle roller bearing having diameter of 15-20 mm is used in between connecting rod and head pin to give the relative motion between parts. As the continuous impacting of repetitive load on bearing, it fails with in shorter period of time if proper lubricant is not supplied within the period of 2 to 3 hours. While bearing are considered under observation it is found that bearing are fail due to brinelling. So here the approach is made for improve the life span of needle roller bearing by means of shape optimization. The stability of the existing design of needle roller bearing is checked computationally using ANSYS workbench and shape is optimize in the such way that the bearing should able to stand with same loading condition. The life span of the optimize needle roller bearing validate mathematically with existing loading condition for concluding the research work.

Key Words: *Brinelling, Connecting rod, Dynamic load capacity, head pin, life, Radial load.*

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1. INTRODUCTION

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The various important applications of bearings are as follows:

1. Two wheelers: A single motorcycle can consist of 20-30 bearings depending upon the type and structure. Bearing are preferred due to their reliability, low noise and vibration level, which enables a smooth ride for longer period of time.
2. Pulp and paper industry: In fast moving world, the paper industry has been improve itself through enhancing the pace and coverage width of paper making machine in order to boost their productivity level. Bearing is used in many sections of paper making machines.
3. Automotive Industries: The automotive industry is growing by leaps and bound in this competitive and fast-paced work. This requires orders in massive volume on a very short period for this bearing can use in automotive industries.
4. Gear drive and reducer: Gear drive and reducers are used in various industrial application enabling customers to operate with variable speeds, heavy torque and shock load, which required bearings with high quality material with longer life span.

In short, bearing is a mechanical device that is used to enable rotational or linear movement, while reducing friction and handling stress. Resembling wheels, bearings literally enable device to roll, which reduces the friction between the surface of the bearing and the surface it is rolling over.

1.1 Needle Roller Bearing

At Parvati Cotex Ginning and pressing factory, Yavatmal where 24 double roller ginning machine are working continuously for 24 hours, breakdown or stopping of machine is the major problem for production. Varieties of cotton purchase from farmers are sending to the ginning machine through conveyor system which is fully automatic. A quantity

of cotton to be feed is managed by auto feeder which is mounted on the top side of the ginning machine. Cotton which is supplied by auto feeder to the beater shaft assembly which is oscillating about 1179 rpm, calculated value from relative velocity method. This beater shaft assembly is drives by 5 HP motor, which gives power to the eccentric shaft. From eccentric shaft on one side power is transmitted to the gear train and on another side to the connecting rod, head block and beater shaft. Gear train are used to drive the leather chrome roller whose function is to adhere with lint and carried forward to the downside. Eccentric motion to the connecting rod then to head block in between this to have relative motion a needle roller bearing (RNA4911) are placed with gudgeon pin. After the discussion carried out at Parvati Cotex Ginning and Pressing factory related to performance of machine, it was found that bearings used in between connecting rod and head pin which is inserted in headlock is needle roller bearing having specification RNA 4911 get fails within 2 to 3 hours if lubricant not provided properly, even it having higher dynamic load capacity.

The oscillation of beater shaft assembly is for detaching the fiber from seed of the cotton. A moving knife which is attached with the assembly oscillates with 1179 rpm and time required for one oscillation is 0.0245 sec. and energy required for detaching fiber is around 2800 joule/kg of lint and it varies from condition and varieties of cotton. So this kinetic energy of rotating masses results in excessive load on bearing which causes plastic deformation of the cage called brinelling. The various parts of ginning machine of Parvati Cotex Ginning and Pressing factory are shown in Fig-1. In the present work failure analysis of Needle roller bearing having dynamic load capacity of 40 KN is done.

Fig-1: Double Roller Ginning Machine

2. WORK DONE

In ginning industry in present design, 21 bearings of different sizes and types are used which makes the maintenance complicated and costly. Also lubrication points are more i.e. 18 in number (Swing lever 8 points, hub 1 point, wrist pin 1 point, gear side pipe 2 points, weight lever 4 points, beater shaft 2 points). Uniform pressure between fixed knife and roller plays an important role in quality and output of the lint. In present design the roller is pressed against fixed knife with the help of hanging dead weights mounted on the weight lever of 495 mm in length. This method does not ensure uniform pressure between roller and fixed knife, occupies more space, and also makes it difficult to remove the roller for maintenance. Presently rollers are made of chrome composite leather washers and wear rate of roller is 0.02 mm/h of working (i.e. it has life of around 1200 working hours). Besides this in rainy season it has tendency to absorb water and get swelled to reduce the life of material further. Studies revealed that chromium particles generated during the process of ginning produce deleterious effect on the people working in the vicinity theoretically energy required to remove 1 kg lint (fibres) varies between 1075 to 2775 joules but actual energy consumed by present DR is about 118000 joules/kg lint. This is about 60 to 120 times more. This poor energy utilization efficiency is mainly due to improper design of gearbox, unscientific way of applying pressure etc. Machine noise level is reasonably high (93 dB) due to the reciprocating action of beater and gearbox. Noise levels of 85 dB and above have shown to cause hearing impairment.

5HP motor drives the hub of machine by using belt drives. An eccentric shaft is mounted inside of the hub which rotate with same speed of hub, on one side of eccentric shaft pinion gear is mounted which drives the gear train result in rotation of leather chrome roller. Also on another side eccentricity is provided on eccentric shaft which work like crank on which connecting rod is mounted at big end and at another side on small end head pin is attached with the help of needle roller bearing with gudgeon pin, result in oscillation of head block which drives the beater shaft assembly. Beater shaft assembly's function is to detach the fiber from cotton with the help of moving knife. The energy required for detaching the fiber from the seed, observed wide variation among the different varieties of cotton and relates to the strength of attachment of fiber from the seed. This is about 2800 j/kg of lint. Fig-2 shows the components of double roller ginning machine.

Fig-2: Components Driven by Needle Roller Bearing

3. FAILUER OF NEEDLE ROLLER BEARING

Needle roller bearings (of type RNA4911) are used in ginning machine because of higher dynamic load capacity. Fig-3 shows detailed terminology of bearings.

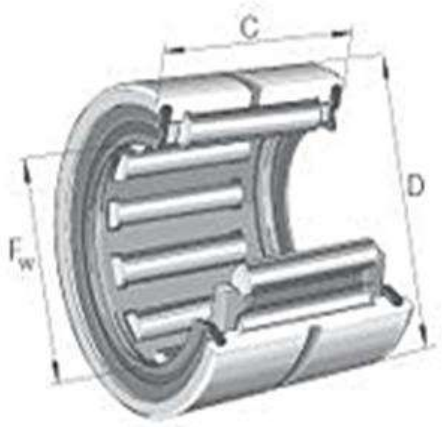

Fig-3: Needle Roller Bearing

Where,

C = Width of Bearing

D = Outside diameter of ring

Fw = Diameter under rollers

A Double roller ginning machine work on the principle of eccentric motion from eccentric shaft converted into oscillating motion of the beater shaft assembly, needed for continuous beating of cotton comes in between moving knife and fixed knife in order to detach fibre from the cotton. A Needle roller bearing is fixed in head pin with interference. A gudgeon pin is used to connect head pin with connecting rod and relative motion between them is done by this bearing.

Table-1: Needle roller bearing RNA4911 terminology

Principle Dimensions			Basic Load Rating		Fatigue load limit	Speed Rating		Mass	Designation
Fw	D	C	C	Co		Ref Speed	Lim Speed		
mm			KN		KN	r/min		Kg	
63	80	25	57.2	106	13.2	6300	7000	0.26	RNA 4911

A needle roller bearing (RNA4911) having dynamic capacity of 40KN taking reference from NSK bearing catalogue are subjected to a repetitive heavy load. As this is rolling element bearing it is subjected to radial load, according to company specification it is need to be lubricated after every 3 to 4 hours so the life of bearing is too small. So it becomes necessary to calculate the life of the bearing. Also need to find out the actual load to be imparted on the bearing which results in failure. Load acting on the bearing are calculated by taking into account all static load on bearing. Load acting by inertia masses which rotate with respect to bearing and force required to detach the fibre from seed. In order to find the load acting on the bearing we have data by prof. P. G. Patil and Prof P. M. Padole gives information about energy required for detaching the fibre from the seed, observed wide variation among the different varieties of cotton, and related it to the strength of attachment of fibre from the seed. The needle roller bearing investigated for failure of bearing. It is found that cage of the bearing are subjected to plastic deformation and also needle are sleep out from cage contact. This is due to high impact load acting on the bearing and such type failures are brinelling failure.

4. RESULT AND DISCUSSION

4.1 Structural Analysis (Static Analysis of Existing Bearing)

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools. Static Analysis used to determine displacements, stresses, etc. under static loading conditions. Both Linear and nonlinear static analyse. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces and creep.

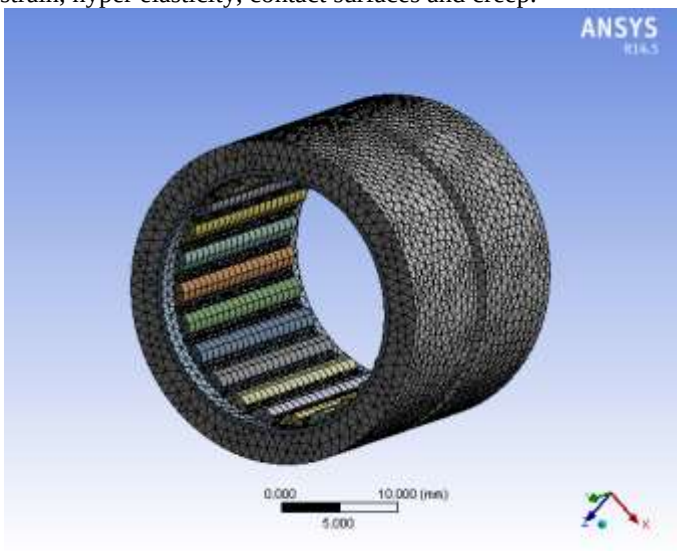

Fig-4.1: Meshing of Needle Roller Bearing Model

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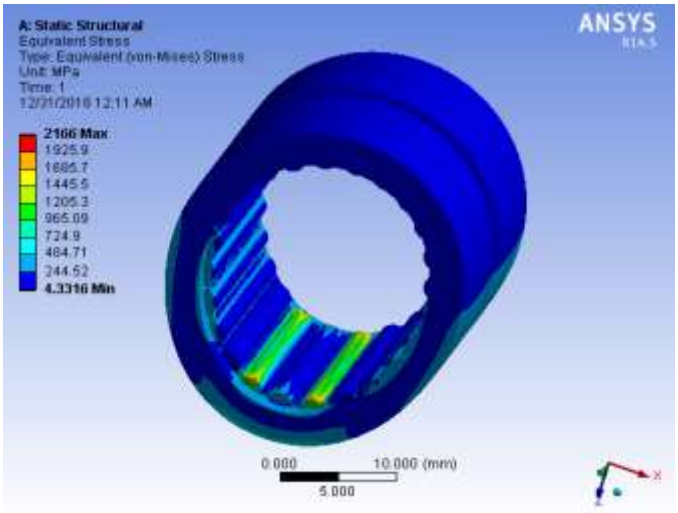

Fig-4.2: Equivalent Stress on the existing needle roller bearing

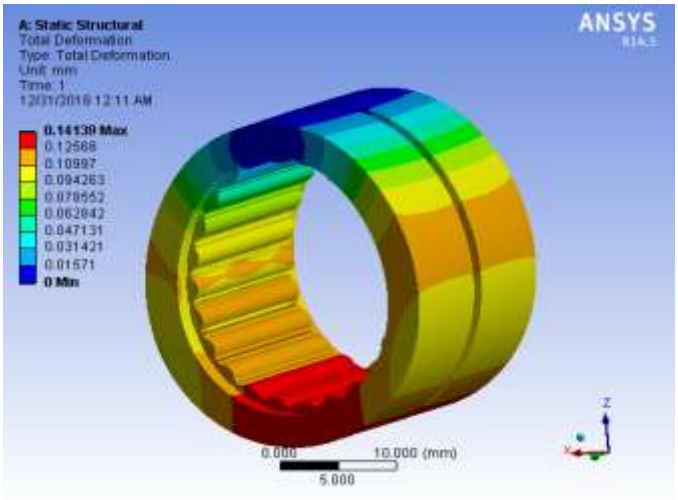

Fig-4.3: Total deformation on the existing needle roller bearing

The maximum stress for existing needle roller bearing is obtained 2166 MPa and the maximum deformation for needle roller bearing is found to be 0.14139 mm.

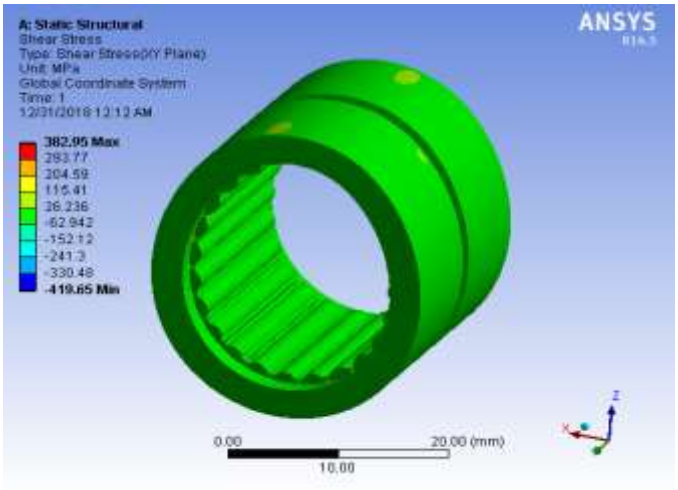

Fig-4.4: Maximum Shear Stress

The shape optimization is done in the existing design of the needle roller bearing as shown the fig. below. The red marked area described the removing of material for optimization of the shape of needle roller bearing. It is notify that the without change in the shape of needle roller bearing its weight will be try to reduced and improved its working life. In recent working operation the life of needle roller bearing is limited up to 5-6 hrs but the optimize design will enhance its operation life as explained with mathematical validation. The structural analysis does not shows large gap between the stability of existing and proposed design, but the overall the weight of the bearing will reduced with improving operational life.

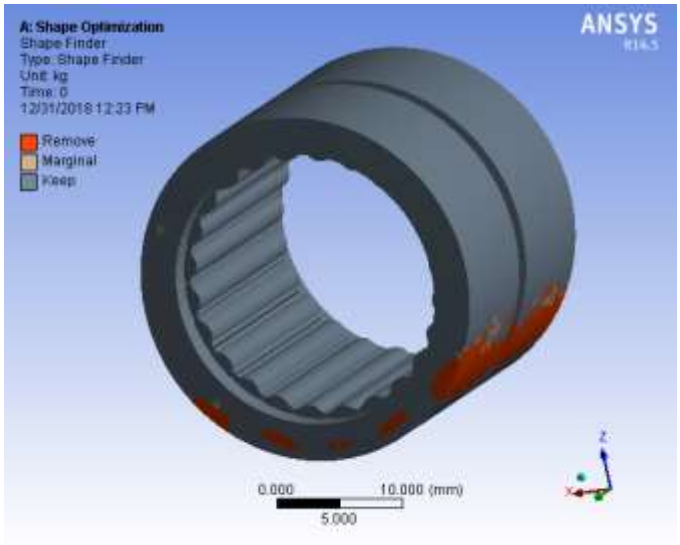

Fig-4.5: Shape Optimization of Existing Needle Roller Bearing

Table-2: Results Summary of Structural Analysis of Needle Roller Bearing

Parameters	Bearing
Total Equivalent Stress (Pa)	2166 max - 4.3316 min
Total Deformation (mm)	0.14139 max - 0 min

From the structural analysis of different available results, it is clear that the optimize shape does not affected the stability of needle roller bearing with great difference. The modified shape of needle roller bearing will improves the operational life with great extent.

4.2 Radial Load Calculation

For finding radial load on bearing which is fitted on head pin and it is mounted on head block, as head block oscillates it gives motion to the beater shaft assembly. This beater shaft assembly and head block along with head pin work as a fulcrum. So it becomes necessary to calculate torque on beater shaft which useful in calculating radial load on bearing.

Torque Transmitted by Beater Shaft

$T = I * \alpha$

Where,

T = Torque (N-m)

I = M. I. of rotating masses (Kg-m²)

α = Angular acceleration in (rad/sec²)

Radial Load (F_t)

$T = F_t * r$

Where,

T = Torque on beater shaft

F_t = Theoretical radial load on bearing

r = Radius of head pin from axis of beater shaft (m).

From the above calculation for calculating the radial load acting on the bearing, Torque on the beater shaft needs to be calculated which is undergoes various rotating and inertia masses. A head block which oscillates the beater shaft assembly considered as a fulcrum whose radial distance is 0.85 m from bearing. Radial load on the bearing is calculated as 7.05882 KN.

4.3 Bearing Life Calculation

Bearing Load (F_r)

The load applied on the bearing generally include the weight of the body to be supported by the bearing, the weight of the revolving element themselves, the transmission power of gears and belting, the load produced by the operation of the machine in which the bearing are used, etc. These load are theoretically calculated, but some of them difficult to estimate.

$F_r = L_f * F_t$

Where,

F_r = Load applied on bearing

F_t = Theoretically calculated load

L_f = Load factor (value from NSK bearing catalogue)

Equivalent Bearing Load (p in KN)

$p = (XF_r + YF_a) K_s . K_o . K_r$

Where,

F_r= Radial load (KN)

F_a= Axial load (KN)

X, Y = Bearing constant

K_s = Service factor

K_o= Oscillation factor

K_r = Rotational factor

(All values of factors are taken from design data book)

Life of Bearing

$$L = \left(\frac{c}{p}\right)^n * K_{ret} \quad \text{(Hrs)}$$

Where,

K_{ret} = Reliability factor

c = Dynamic load capacity (KN)

n = 3.33

From the above calculation the bearing life of Needle roller bearings it is found that 10.47 Hrs

5. CONCLUSION

In ginning machine the most of the problem which exhausted the working efficiency of machine is the life of needle roller bearing. The researcher working for finding out the solution to overcome the short life of needle roller bearing. The presented research work mainly focused on the improvement of life span of needle roller bearing with CAE approached. The following are the some conclusion remark is obtained from presented research work:

- Although the stresses comes is under the design stress which it can sustain but it can't live long in case of cyclic repetitive stresses which cause failure in the form of brinelling.
- The existing needle roller bearing shows the short life span which is found to be 07.65 hrs. The Structural stability of existing and optimized design of roller bearing is some equivalent but as far life span is concern the optimized design shows improvement in life span up to 10.47 hrs.
- The life of needle roller bearing can also enhanced with regular lubrication with span every two to three hours.
- Overall the problem of continuous failure needle roller bearing can be optimize to great extent due to uneven distributions working load and conditions but one can make periodic attention for proper loading and lubrication may enhance the life span.
- The results which are obtained computationally for checking out stress occurred on needle roller bearing for optimized and existing design does not great span of difference but removing the excess materials might be improves the life span for certain.

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