Analysis of End Profiling of Needle Roller on Modified Centre Less Grinding Machine

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Abstract— Needle roller bearings are designed to carry heavy radial loads but due to misalignment and edge loading it is affecting the life of the bearing. So in the design of needle roller bearings, the profile of the roller plays important role. Roller with crowning lead to reduce the edge stress concentration, so as to improve the service life of roller bearings. In this paper, the design of processing equipment for crowning rollers is developed and experimentation is performed, from which suitable radius of curvature of the wheels of modified centreless grinding machine is determined.

Key words: Needle roller, crowning (end relieving), centreless grinding machine

I. Introduction

In the process of needle roller bearing operation, stress concentration occurs at the ends of the needle roller, which affect on the bearing capacity and bearing fatigue life adversely. The flat profile of the needle roller element results in the edge loading as shown in figure 1. [1]. Crowned profile of the rollers eliminates stress concentration at the edges, also distributes the contact stresses uniformly along the roller length which in turn, reduces, the end stress concentration [2].

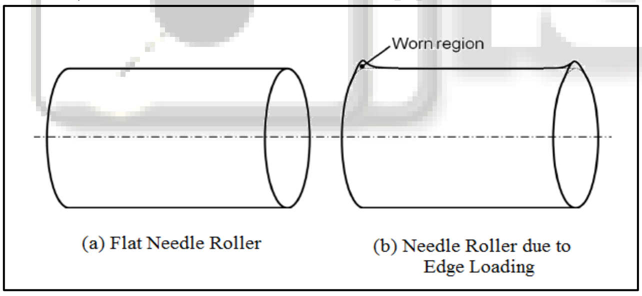

Fig. 1: Needle Roller due to Edge Loading

A logarithmic profile is essentially optimal crowning geometry for rolling machine elements such as bearing rollers and raceways [6]. When a needle roller bearing is subjected to a load, the rollers of finite length contact the mating raceways of greater length, and compressive stresses at the roller ends tend to be substantially higher than those at the centre of the contact. This phenomenon of stress concentration is referred to as “edge loading” [4] [7]. In needle roller bearings, the radii of the rollers and/or the raceways are reduced on the order of micrometers to avoid edge loading. This modified geometry is called “crowning”. Typical crowning profiles include a single straight line, circular curve, their combination, and so on. In some cases, crowning extends over the full length of the rollers and/or raceways (full crowning), while in other cases crowning is processed only near both ends (partial crowning) [8].

Currently, the conventional centreless grinding machine is used to manufacture the workpieces having straight generatrix and crowning operation takes place as a mass finishing process.

As the literature, crowning is necessary for needle roller bearing operation, so to perform the crowning operation, the centreless grinding machine should be modified to obtain the minimum edge loading [4][7]. Development of such machine will enable batch production by reducing the cycle time of needle rollers and will improve the quality of needle rollers and productivity as well. The author of this paper introduces the research on arc modification of the wheels of modified centreless grinding machine, and experimentation of the required parameters.

In a conventional grinding machine, needle roller is constrained by the grinding wheel, regulating wheel and the work rest blade. The regulating wheel drives the roller as well as feeds it towards the grinding wheel while work rest blade positions the roller in the grinding zone [3][5].

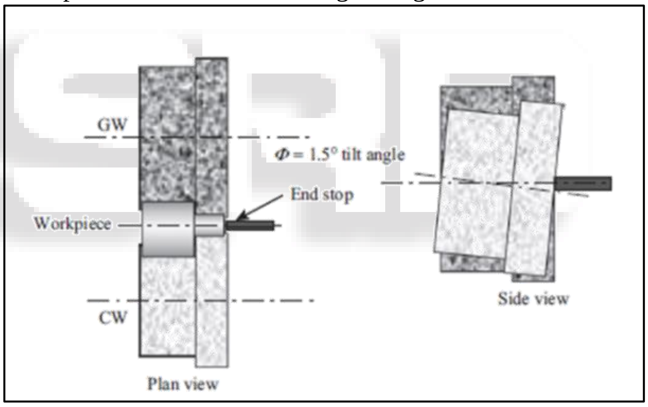

Fig. 2: Conventional Centreless Grinding Machine

In the conventional centreless grinding machine, both the wheels i.e. grinding wheel and regulating wheel are having flat profile, and the work rest blade is straight, shown in the figure 2. So, the end product is having same flat profile as that of wheels.

The author suggests that in modified centreless grinding machine, the grinding wheel will be dressed into inner concave surface and the regulating wheel will be dressed into outer convex surface and the work rest blade will have the same curvature as that of the wheels, instead of being straight plate. The 3D model of modified centreless grinding machine is shown in figure 3. The main objective is to evaluate the radius of curvature of the both wheels and of the path.

Fig. 3: 3D Model of Modified Centreless Grinding Machine

II. DESIGN DESCRIPTION

The objective of current research is to find out the radius of curvature of wheels through which the needle roller will pass out, and of the roller path. This radius is dependent on roller dimensions and specifications. They are shown in figure 4, and table 1.

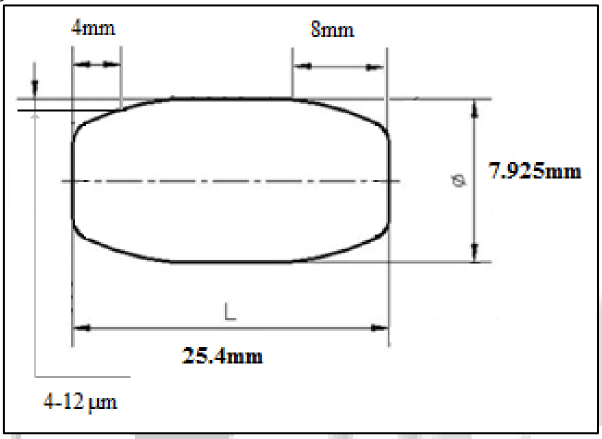

Fig. 4: Needle Roller

Sr. No.	Needle Roller	Specification
1.	Material	SAE52100
2.	Size	7.925mm×25.4mm
3.	End Drop Desired	4-12 µm at the pivot point

Table 1: Needle Roller Specification

To find out the radius of curvature of the wheels, it is necessary to evaluate the needle roller end drop arc.

Sample calculation:

From figure 5,

$Let, OB = OD = OE = R$

$AC = h = End\ Drop = 4\mu m = 0.004mm$

E is imaginary point on extended arc.

$Let\ EC = h_1$

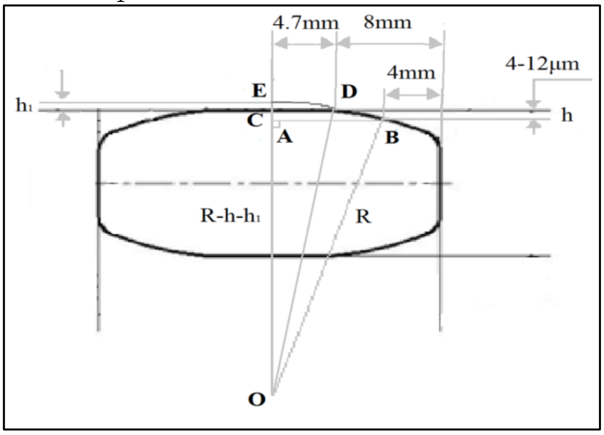

Fig. 5: Evaluation of the End Drop Arc R.

$In\ \Delta\ OCD,$

$According\ to\ Pythagoras\ Theorem,$

$OD^2 = OC^2 + CD^2$

$R^2 = (R - h_1)^2 + 4.7^2$

$R^2 = R^2 - 2Rh_1 + {h_1}^2 + 4.7^2$

${h_1}^2 - 2Rh_1 + 4.7^2 = 0$ …. (1)

In $\Delta OAB,$

According to Pythagoras Theorem,

$OB^2 = OA^2 + AB^2$

$R^2 = (R - h - h_1)^2 + 8.7^2$

$R^2 = R^2 + h^2 + {h_1}^2 - 2Rh - 2Rh_1 + 2hh_1 + 8.7^2$

$Here, h = 0.004mm$

$(0.004)^2 + h_1^2 - 2 \times 0.004R - 2Rh_1 + 2 \times 0.004h_1 + 8.7^2 = 0$

$h_1^2 - 2Rh_1 - 0.008(R - h_1) + 75.690016 = 0$ …. (2)

From equations (1) and (2),

R = 6700.00165mm

$h_1 = 0.0016485mm$

As this is the crowning radius of needle roller, this radius must be same as radius of curvature of the grinding wheel, regulating wheel and the work rest blade on which roller will be fed, to get the desired end drop on roller.

Required end drop ranges from 4-12µm. Therefore, experimentation can be done to find best possible outcome.

From this, different radii of curvature can be obtained, which is shown in Table 2.

Sr. No.	End Drop (µm)	Radius of Curvature(mm)
1.	4	6700.00165
2.	6	4466.66914
3.	8	3350.00329
4.	10	2680.00412
5.	12	2233.33838

Table 2: Radius of Curvatures from Required End Drops

For the experimentation on modified centreless grinding, these radii are to be used. The radii are rounded off to nearest decimals.

III. EXPERIMENTATION

After performing the experimentation, following values are obtained.

Sr. No.	R (mm)	Experimental Output		
		Avg. End Drop (µm)	% of Error	Surface Roughness (µm)
1.	2230	11.3	5.85	0.42
2.	2680	9.4	6.00	0.38
3.	3350	7.3	8.75	0.38
4.	4470	5.2	13.33	0.35
5.	6700	3.3	17.50	0.32

Table 3: Experimental Output Variables

IV. RESULTS AND DISCUSSION

From the experiments, it is observed that, more the radius of curvature, more will be the error in the resulting end drop. And it is also observed that due to curvature provided to the wheels, the rate of deterioration of the template is directly proportional to radius of curvature. Hence, the dressing frequency is less for less radius of curvature and it gets increased as the radius of curvature increases. Surface finish is also improved as compared with that of mass finishing process. This means, to obtain the desire end drop (4-12 µm), radius of curvature should be kept as low as possible ($R_{min} = 2230mm$).

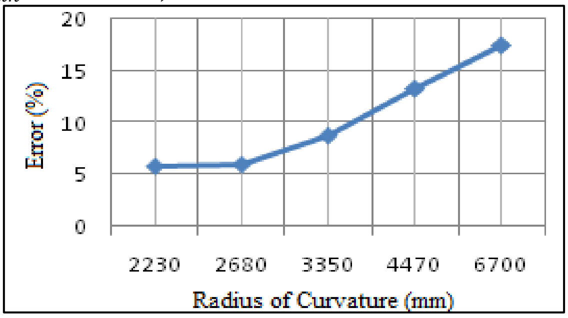

Fig. 6: Graph of Radius of Curvature vs. Percentage Error

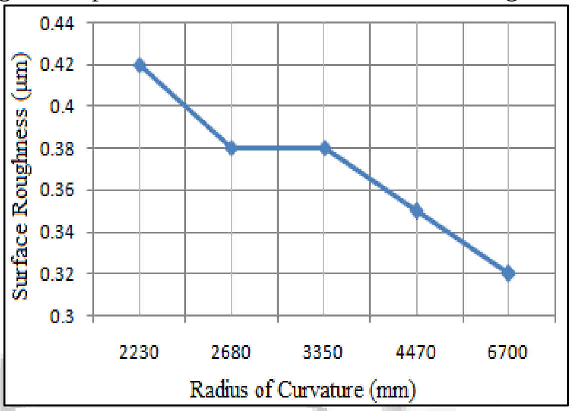

Fig. 7: Graph of Radius of Curvature and Surface Roughness

By using this method, cycle time reduces considerably, in comparison with mass finishing process.

Cycle time of needle rollers in mass finishing can be calculated as follows,

$Volume = (\pi/4) \times D^2 \times l$

$= 0.785 \times (7.925)^2 \times 25.4$

$= 1252.281 mm^3$

$Specific\ gravity = 7.8 gm/cm^3$..[1]

$\boldsymbol{Unit\ weight = Specific\ gravity \times Volume}$

$= 7.8 \times 1252.281 \times 0.001$

$= 9.78\ gm$

$\boldsymbol{Numbers\ of\ needles\ in\ barrel (70\ kg)}$

$= 70/0.00978$

$= 7157.46\ needles$

$\boldsymbol{Cycle\ time\ in\ mass\ finishing\ process},$

$10\ hours = 7200\ needles$

$1 needle = 60/12 = \mathbf{5\ sec}$

So, to operate 1 needle roller, approximately 5 second time is required.

Cycle time of needle rollers operated in modified centreless grinding machine is as follows,

$\boldsymbol{Feed\ rate}:$

$\boldsymbol{f = \pi \times D \times N \times \sin\alpha}$

$Where,$

$D = Diameter\ of\ Regulating\ Wheel = 275mm$

$N = Rotational\ speed = 200rpm$

$\alpha = Inclined\ Angle = 1.5°$

$f = \pi \times 275 \times 200 \times \sin 1.5°$

$f = 4523.05\ mm/min$

$\boldsymbol{Number\ of\ needles\ per\ minute}$

$= feed\ rate/\ length\ of\ needle$

$= 4523.05/\ 25.4$

$= 178.05\ needles$

$\boldsymbol{Cycle\ time\ of\ needle\ rollers\ in\ modified\ centreless\ grinding},$

$1 minute = 178\ needles$

$1 needle = 60/\ 178 = \mathbf{0.338\ sec}$

So, to operate 1 needle roller in modified centreless grinding machine, approximately 0.338 second time is there.

V. CONCLUSION

The flat profile of roller element results in the edge stress concentration. Crown roller reduces the edge stress concentration when acted under the loads. This paper analyzed crown roller and centreless grinding principle, the equipment was designed. The optimum radius of curvature of both grinding wheel and regulating wheel is determined and the working path is also designed for given input conditions.

In comparison with mass finishing process, this process reduces the crowning operation cycle time of needle rollers considerably, which in turn improves the productivity. As the process is controlled, the dimensional accuracy also improved.

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