RESEARCH INVENTY: International Journal of Engineering and Science
ISSN: 2278-4721, Vol. 1, Issue 1 (Aug 2012), PP 8-13
www.researchinventy.com

Study of Interval of Arc Modification Length of Cylindrical Roller Using ANSYS

Xintao Xia, Shichao Zhu, Chenhui Jia, Rongjun Niu
College of Mechatronical Engineering, Henan University of Science and Technology, Luoyang, 471003 China

ABSTRACT - *Taking a cylindrical roller bearing as a research object, the contact stress between the roller and the raceway is studied by means of ANSYS in order to obtain an optimum interval of the arc modification length. The results show that the given load corresponds to the suitable interval of the arc modification length to avoid edge stresses. However, when the loads exceed the normal range, edge stresses still exists. Therefore, the arc modification length of the roller should be chosen according to the actual work condition so as to realize the uniform distribution of the contact stresses between the roller and the raceway. This can increase the service life of the cylindrical roller bearing.*
Keywords - *cylindrical roller bearing, cylindrical roller, finite element analysis, arc-line modification generatrix*

I. INTRODUCTION

It is important to design and manufacture the cylindrical roller for the working performance and service life of a cylindrical bearing. The early stage of contact fatigue often occurs in the ends of the raceways and of the roller with the general straight generatrix because the cylindrical bearing with the straight generatrix roller loaded inevitably is influenced by edge stresses, viz., stress concentration, at the ends of the roller. This greatly reduces the working performance and service life of the cylindrical bearing.

To avoid edge stresses, the generatrix of the roller is generally manufactured into a slightly crowned shape [1-4], which is called the modification generatrix. So far, there are many types of crowned cylindrical rollers, such as, the roller with convex generatrix (called the entire convex generatrix type), the roller with a slightly crowned transition zone between the central straight line and the corner (called the arc-line modification type), and the roller with logarithmic curve generatrix (called the logarithmic curve type).

For the modification generatrix mentioned above, logarithmic curve generatrix has more advantages [1-4]. It can not only reduce greatly edge stresses, but also make the surface stress distribution better, which is useful to improve the capacity of the bearing. However, the logarithmic curve roller is difficult to be manufactured and its precision is difficult to be obtained. Thus, the rollers with the arc-line modification generatrix are widely used in many engineering practices due to their easy manufacturing and lower cost.

Because the machining error of the arc modification length of the arc-line modification generatrix directly affects the distribution of the stress [5], it is very significant to determine a reasonable interval of the arc modification length under the given work condition to enhance the performance of the bearings. Therefore, taking a cylindrical roller bearing N1015 as a research object, the contact stress between the roller and the raceway is studied by means of ANSYS in order to obtain an optimum interval of the arc modification length.

II. FINITE ELEMENT MODEL OF CYLINDRICAL ROLLER BEARING

2.1 Structure and parameters of bearing

The technical parameters of the cylindrical roller bearing N1015 are shown in Table 1 and Figure 1.

2.2 Meshing

In order to reduce computing time, on one hand, the model of one quarter roller at the bottom of the bearing that bears the maximum load is created; on the other hand, the chamfers of the inner and outer rings and the effect of radial clearance are ignored. The Solid 45 is adopted to mesh the model. The meshes of the contact part of the roller and the inner and outer rings are refined to enhance the computing accuracy. The length of the grid along the axial direction is 0.07 mm. Because the side length of the finite element model mesh is, particularly, less than half of the size of the minor semi-axis, the calculation results are precise enough. The half-width size of the contact area is 0.15 mm and the size of the finite element model is suitable, as shown in Figure 2.

Table 1. Technical parameter

Parameter	Parameter value
Inner diameter of bearing, *d*/mm	75
Outer diameter of bearing, *D*/mm	115
Thickness of ring, *T*/mm	5
Width of ring, *W*/mm	20
Diameter of roller, *Φ*/mm	10
Length of roller, *L*/mm	11
Radius of modification generatrix of roller, *R*/mm	1000
Length of modification generatrix of roller, *l*/mm	1.8
Number of roller, *N*	22
Elastic modulus of bearing element material, *E*/GPa	208
Poisson ratio of bearing element material, *v*	0.3

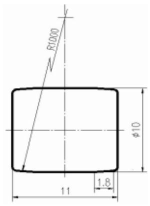


Figure 1. Diagram of the roller

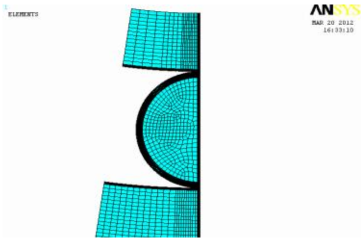


Figure 2. Finite element model

2.3 Creation of contact pair

The creation of the contact pair and the setting of the contact parameters are crucial issues on contact analysis [6-9]. Considering the inner and outer rings whose surfaces are bigger and stiffness is higher than the roller, the inner and outer rings are set as target surfaces and the roller is set as a contact surface. Then, the contact pairs are created respectively. Both the contact stiffness coefficient and the tolerance of penetration are key contact parameters. The smaller contact stiffness coefficient is favorable to be convergent. However, the bigger contact stiffness coefficient is favorable to improve the precision. By many times of calculation, the contact stiffness coefficient is set to 1.5 and the tolerance of penetration is set by a default value.

2.4 Loading

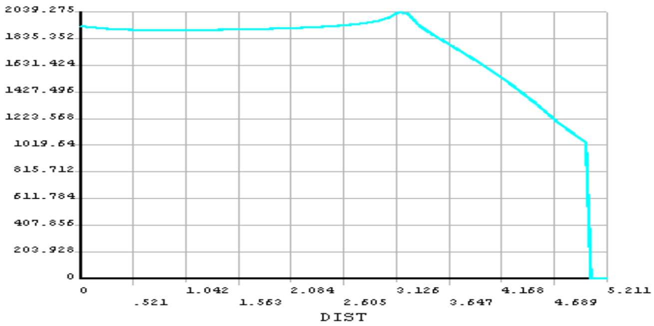
Before the load and the constraint are applied, the nodal coordinate systems belonging to the middle plane of the roller are all converted to the cylindrical coordinates and the displacement of nodes of the middle plane of the roller along the circumferential direction are all constrained. Furthermore, a symmetry constraint is applied to the cross-section of the roller and all the degrees of freedoms of the outer surface of the outer ring nodes are constrained. The load is applied to the finite element model after the radial freedom of the inner surface of the inner ring is coupled.

III. ANALYSIS OF RESULTS

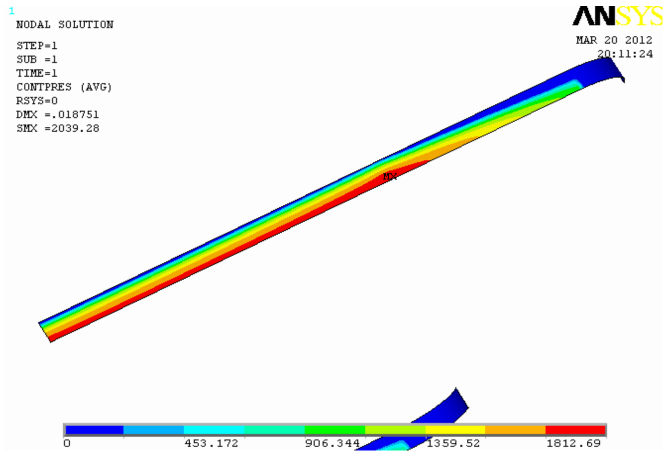
Through modeling, meshing, constraining, loading, and solving, the results of the contact stress of the roller are obtained by finite element analysis. The normal direction contact stress produced by the roller and the inner ring is used to analyze the effect of the arc-line modification generatrix of the roller.

The normal roller loaded 1/5 of the dynamic load rating is analysed, as shown in Figure 3. When the abscissa DIST, viz., the roller axes whose geometrical center locates at the origin of the coordinate, takes values in [0, 3] mm, the approximately uniform contact stress appears within the contact zone between the inner ring and the roller. When the abscissa DIST takes the value 3.15 mm, the contact stress takes the largest value 2039 MPa. When the value of the abscissa DIST is greater than 3.15 mm, the contact stress gradually decreases. When the value of the abscissa DIST is equal to 5.5 mm corresponding to the end of the roller generatrix, the contact stress takes the smallest value 1937 MPa. Obviously, the stress is distributed uniformly at the middle of the roller generatrix.

The trend of contact stress between the outer and the roller is the same as that between the inner and the roller.



(a)



(b)

Figure 3. Contact stress curve and stress contour of surface of roller with 1.8 mm modification length along axial; (a) Contact stress curve; (b) Stress contour

According to the approximate value of the crown, finite element models with different arc-line modification generatrices are recreated. The length of the arc modification is from 1.1 mm to 2.5 mm and their contact stresses are given in Table 2 and Figures 3-5. It shows that the distribution of contact stress is uniform when the length of arc modification generatrix is 1.8 mm under the same load. But the maximum stress and the stress of the middle of the roller changes with the arc modification generatrix along the axial direction. If the length of the arc modification generatrix exceeds 0.5 mm, the value of the maximum stress increases sharply. The stress of the middle of the rollers with the arc modification lengths like 1.1 mm, 1.2 mm, 2.4 mm, and 2.5 mm is lower than the maximum stress, but the larger stress value occurs at the joint of the arc and the line. If the lengths of arc modification of rollers are 1.3 mm, 1.6 mm, 1.7 mm, 1.8 mm, 1.9 mm, 2.0 mm, and 2.3 mm, respectively, the curve of the contact stress rises smoothly along the axial direction from the end to the middle and the larger stress value does not occur. Therefore, these values are more ideal. If the length of arc modification is more than 2.3 mm or is less than 1.3 mm, the larger contact stress occurs, which is adverse to the bearing life.

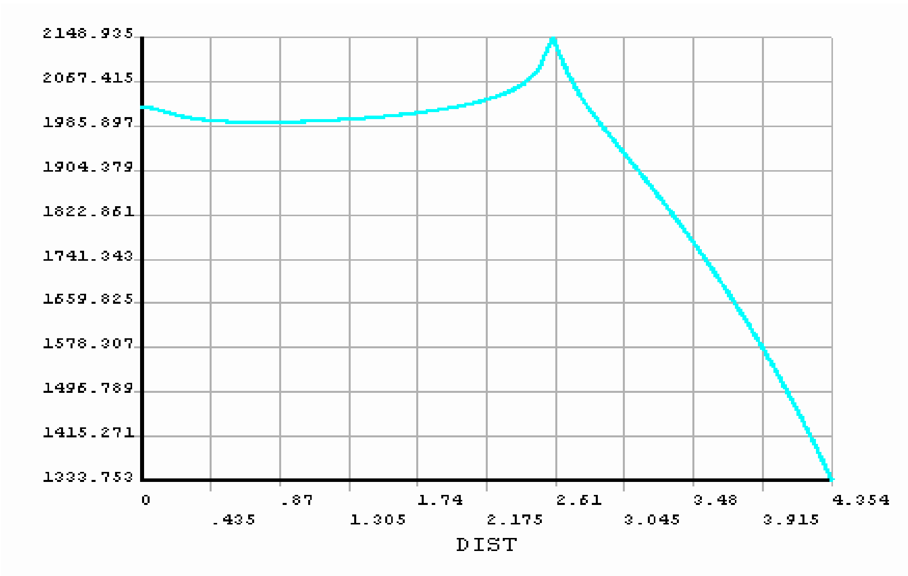
As a result, the difference between the maximum contact stress and the contact stress of the middle of the roller can be employed to evaluate the uniformity of the contact stress, providing a reference for choosing the length of the arc modification, as shown in Table 2 where A stands for the contact stress of the middle of the roller and B for the maximum contact stress.

The suitable length of arc modification should be determined according to the uniform distribution of the contact stress and no stress-concentration appearing at the joint of the line and the arc of the roller generatrix.

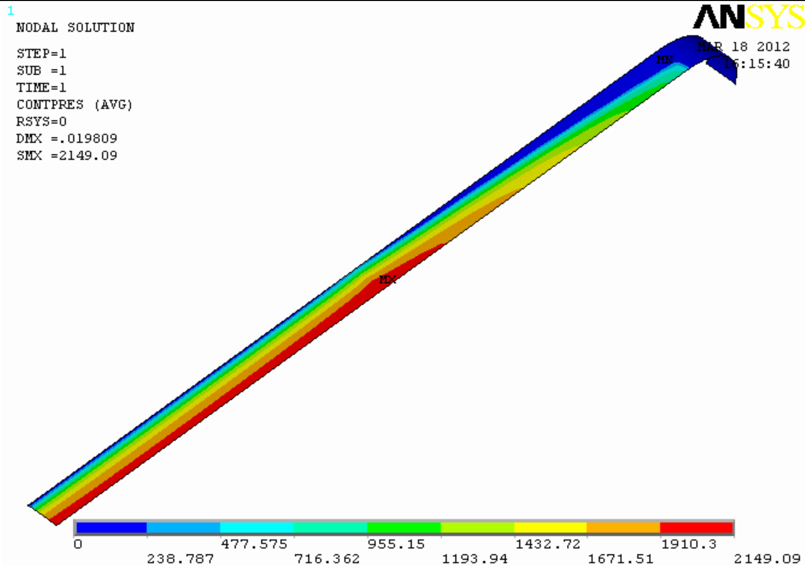
Table 2 also indicates that the maximum contact stress value and the stress difference value change with the increasing or decreasing length of the arc modification. The length of the arc modification should be determined according to the actual load, that is, the length of arc modification is not the longer the better, so-called suitable is the best.

Table 2. Computed result of contact stress

Length of arc modification, l/mm	Contact stress of middle of roller, *A*/MPa	Maximum contact stress, *B*/MPa	((*A*-*B*)/*A*)/%
1.1	1938	2170	-11.9
1.2	1945	2151	-10.6
1.3	1858	2065	-11.4
1.6	1905	2050	-7.6
1.7	1900	2052	-8
1.8	1937	2039	-5.3
1.9	1940	2056	-6.0
2.0	1960	2065	-5.4
2.3	1927	2057	-6.7
2.4	1934	2148	-11.1
2.5	1945	2162	-11.2

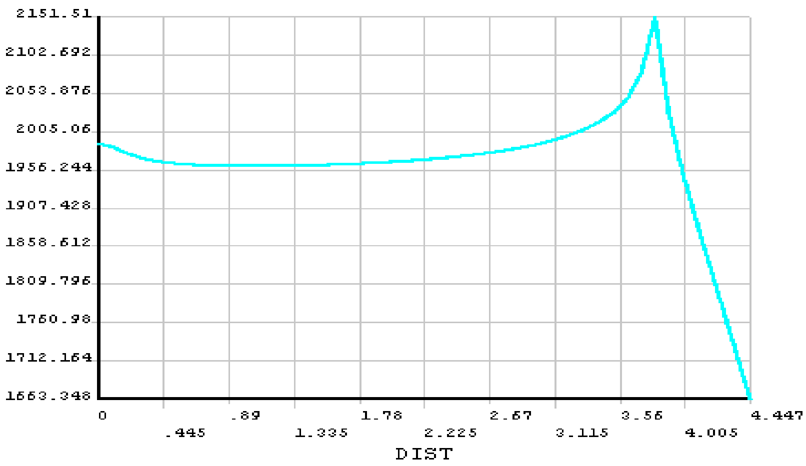


(a)

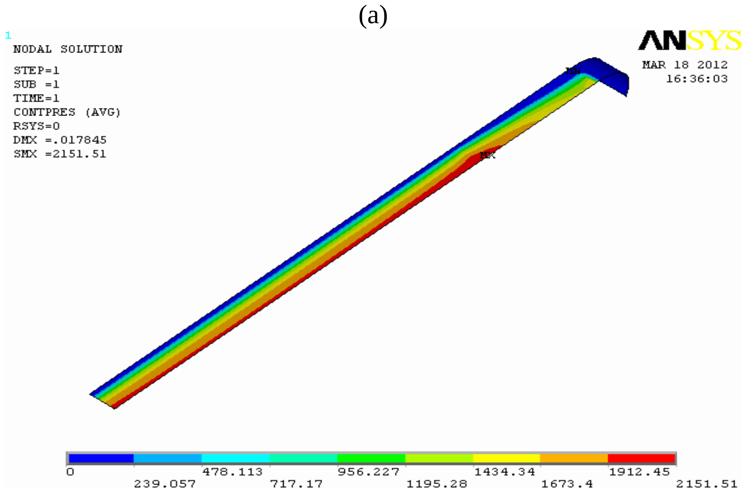


(b)

Figure 4. Contact stress curve and stress contour of surface of roller with 2.4 mm modification length along axial; (a) Contact stress curve; (b) Stress contour



(a)



(b)

Figure 5. Contact stress curve and stress contour of surface of roller with 1.2 mm modification length along axial; a) Contact stress curve; b) Stress contour

IV. CONCLUSIONS

The range of values the length of the arc modification takes is connected with the actual load the roller bears. Under the condition of the given load, if the range is too large or too small, the stress peak appears at the joint of the line and the arc of the roller generatrix.

The length of the arc modification should be determined according to the actual load, that is, the length of arc modification is not the longer the better, so-called suitable is the best.

ACKNOWLEDGEMENTS

The research is financed by the National Natural Science Foundation of China (Grant No. 51075123) and the Doctoral Scientific Research Initiation Fund of Henan University of Science and Technology (Grant No. 09001318).

REFERENCES

[1] T. A. Harris, *Rolling Bearing Analysis* (Third Edition)(New York, US: John Wiley & Sons, 1991).
[2] L. Q. Wang, Z. H. Ye, and L. Gu, The effect of roller profile modification on roller bearing performance, *Advanced Materials Research*, *230-232*, 2011, 1210-1215. http://dx.doi.org/10.4028/www.scientific.net/AMR.230-232.1210
[3] H. Y. Sun, X. Y. Chen, C. H. Liu, and P. R. Yang, Study on thermal EHL performance of Lundberg profile rollers and the modification of its crowning value, *Tribology*, *28*, 2008, 68-72. (in Chinese)
[4] H. Y. Sun, X. Y. Chen, and H. X. Zhang, Crowning design for the logarithmic profile roller according to a thermal elastohydrodynamic lubrication (EHL) theory, *Tribology*, *30*, 2010, 567-571. (in Chinese)
[5] N. Demirhan and B. Kanber, Stress and displacement distribution on cylindrical roller bearing rings using FEM, *Mechanics Based Design of Structures and Machines*, *36*, 2008, 86-102. http://dx.doi.org/10.1080/15397730701842537
[6] T. Slack and F. Sadeghi, Explicit finite element modeling of subsurface initiated spalling in rolling contacts, *Tribology International*, *43*, 2010, 1693-1702. http://dx.doi.org/10.1016/j.triboint.2010.03.019
[7] Y. P. Chiu and M. J. Hartnett, A numerical solution for the contact problem involving bodies with cylindrical surface considering cylinder effect, *Journal of Tribology-Transactions of the ASME*, *109*, 1987, 479-486. http://dx.doi.org/10.1115/1.3261478
[8] M. T. Hanson and L. M. Keer, Mechanics of edge effects on frictionless contacts, *International Journal of Solids and Structures*, *32*, 1995, 391-405. http://dx.doi.org/10.1016/0020-7683(94)00153-N
[9] M. C. S. Chandrasekara and R. A. Ramamohana, Mechanics and behaviour of hollow cylindrical members in rolling contact, *Wear*, *87*, 1983, 287-296. http://dx.doi.org/10.1016/0043-1648(83)90132-1

BIOGRAPHY

Xintao Xia is a professor at College of Mechatronical Engineering, Henan University of Science and Technology. He received his PhD degree in Mechanical Science Engineering from Shanghai University in 2008. His main research areas include information processing, information poor system, vibration and noise. He has published more than 170 journal papers and 11 technical monographs since 1985. E-mail: xiaxt1957@163.com, xiaxt@mail.haust.edu.cn.