Bearing life prediction on the basis of run-out using accelerated life testing coupled with numerical analysis

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ABSTRACT

Wear is one of the most important factors affecting roller bearing performance and in determining bearing life-time. Bearing life has traditionally been defined by the onset of spalling (ISO 281), but this definition does not always reflect operational conditions as bearing wear can also represent a failure criterion such as run-out. Therefore, bearing life is predicted according to the bearing run-out amount. Bearing wear was modeled based on Archard wear model and Cockroft-Latham damage model which were incorporated as part of an FE wear and run-out simulation. The wear models were modified in order to increased reliability of the bearing life prediction. Also, accelerated life testing was used for testing in a short time, and the amount of bearing run-out was measured in the testing. Experimental testing was also performed to confirm the integrity of the methodology and validate the simulation results and showed good correlation with the simulation results. The simulation model was also used to predict the bearing life under spalling and was compared to test data obtained using ISO 281 and was also found to provide good agreement.

Keywords: bearing life, run-out, wear depth, spalling, accelerated life test

1 INTRODUCTION

Generally, bearing life is caluated by using ISO 281. This standard has been determined that the spalling initiation is failure of the bearing. However, the bearing wear and run-out is also defined as bearing failure depending on the actual conditions. Currently, users measure the bearing run-out by themselves in order to judge the bearing failure in case of the large bearings used in the machine tools and wind power plants in which bearing precision is important. Because there is no standard of bearing life prediction based on run-out. If repalcement timing is accurately predicted by using bearing run-out prediction method, users are able to save the time and cost. Therefore, relable bearing life predcition method is really importatn.

In this paper, bearing life prediction method on the basis of run-out is proposed. And accelerated life testing and numerical analysis applying wear model were conducted in order to progress test in a short time and obtain quantitative life data [1] [2] [3].

2 BACKGROUND

When using the bearing, in roller and race clearance more and more increases by bearing surface defect such as wear, spalling and pitting. With this bearing, vibration occurs and precision decreases. The bearing vibration is defined as a axial and radial direction run-out which is measured by using a dial gage.

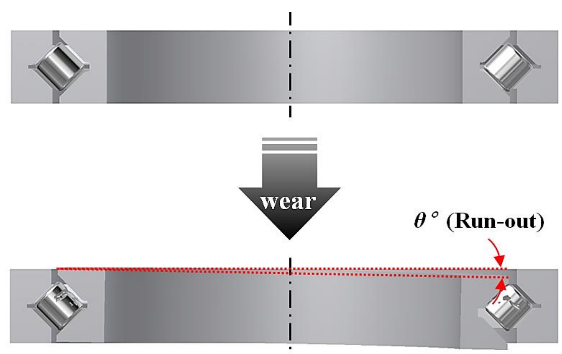

Figure 1: Bearing run-out occurance

In this paper, bearing defects was clasified as linear wear and non-linear wear. The linear wear is progrssed by roller and race surface contact. And non-linear wear is progressed according to the voulume flaking such as spalling and pitting which is resulted from repeated tensile stress. Through experiment, bearing wear is represented as shown in Figure 2.

Figure 2: Bearing wear occurance in rollers

In order to simulate linear and non-linear wear, Archard wear model and Cockroft latham-damage model were used resepectively [4]. Archard wear model was modified as the model to consider the state of the surface as shown in Eq 1. And Cockroft-latham damage model was also modifid as nonlinearity model by adding exponential terms as shown in Eq 2. [5]

$$W = \int k\left(1 + C_w W^{i_w}\right)\frac{P^a V^b}{H^c}\,dt \qquad (1)$$

W and k are wear depth and wear coefficient. P , V and H are nomal pressure, sliding velocity and hardness. a , b , c are constants [6]. C_w and i_w are surface roughness constants.

$$C = \int^{\bar{\varepsilon}_f} \left(\frac{\sigma^*}{\bar{\sigma}}\right)^{\alpha} d\bar{\varepsilon} \qquad (2)$$

C is critical value and α is constants for nonlinearity. σ^* and $\bar{\sigma}$ are maximum principal stress and effective stress. $\bar{\varepsilon}_f$ and $\bar{\varepsilon}$ are damage effective strain and total strain.

k	Cw	iw	a	b	c
1.0e-07	1	0.15	1.3	1.2	2.5

Table 1: Constants in linear wear model

C	α
0.63	2.30

Table 2: Constants in non-linear wear model

Linear wear parameters were obtained by using pin-on-disc test. It is defined as ASTM G99. [7] Non-linear wear parameters were obtained by using Taguchi method. The reponse was selected as initial run-out data between experiment and simulation. Obtatined parameters are as shown in Table 1. and 2. [4]

3 BEARING LIFE PREDICTION

In this paper, bearing life was predicted in short time efficiently and quantitatively by using accelerated life testing coupled with numerical analysis in place of the conventional method using only experiment. There 5 steps for the bearing life prediction method as shown in Figure 3.

First , bearing linear and non-linear wear model is selected. And the model parameter are obtained through pin-on-disc test and Taguchi method. Second, test response is selected as run-out. Considering accelerated conditions and cycle, graph is derived by experiments results. Third, through simulation results, graph is also derived. The wear model is applied to simulation. And then life prediction curve is obtatined. At the result, the bearing life can be predict by using the life prediction curve.

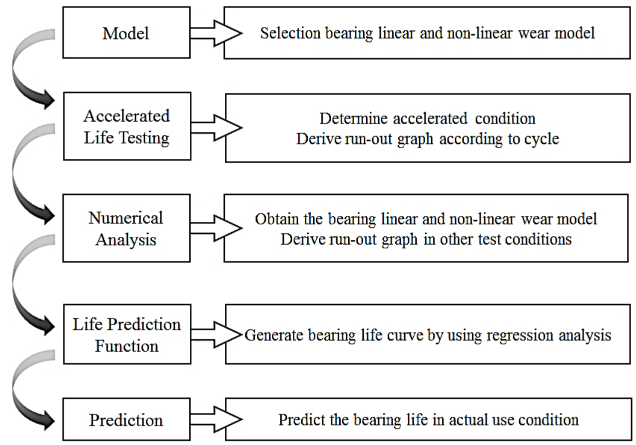

Figure 3: Bearing life prediction method procedure

3.1 Accelerated life testing

Bearing simple wear tester was designed as shown in Figure 4. Bearing is loaded by hydraulic cylinder and rotated by motor. The test bearing is a crossed roller bearing of 50mm inner diameter in THK.

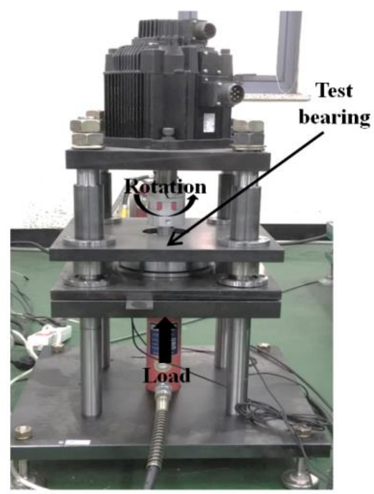

Figure 4: Bearing simple wear tester

The accelerated testing were perfomed as shown Table 3. It is 200, 175, 150 and 125 percetage of the dynamic rating load.

NO.	1	2	3	4
Load [kgf]	1020	893	765	638
Velocity [RPM]	400			

Table 3: Accelerated life test conditions

3.2 Numerical analysis

Numerical analysis was performed by applying modified linear and non-linear wear model. And finite element analysys program was used as DEFORM-3D. In numerical analysis, amount of wear was accumulated as shown in Figure 5. And wear gemetry was represented by delete element and change node position according to the wear as shown in Figure 6. Through wear update in simulation geometry, stress concentration and accelerated wear can be calculated. Also, incresement of clearance between roller and race can be simulated. According to the clearance, bearing run-out is measured as axial and radial direction displacement results. [4]

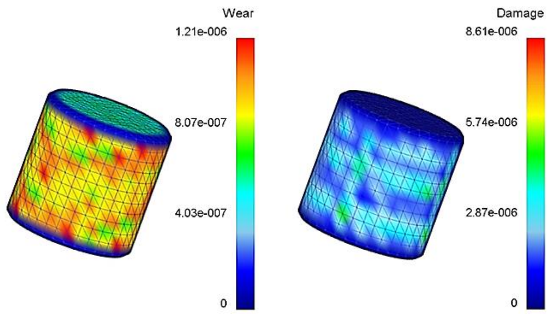

Figure 5: Distribution of wear in simulation

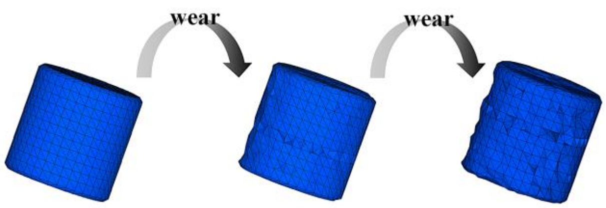

Figure 6: Simulation examples on the roller surface

As Figure 7, the run-out parabolically increases both experiment and simulation results. As a result, it is possible to simulate the actual test results by using wear model at less than 8.08% difference. If the wear model is formulated reliably, run-out results can be derived only by the simulation.

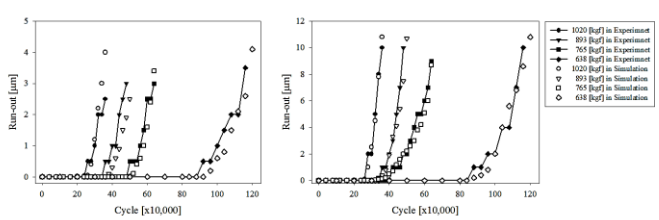

Figure 7: Experiment and simulation results

The slower bearing run-out initiation was, the lower load is. And run-out increase ment rate was lower, too. The axial run-out was more larger than the radial run-out.

3.3 Life prediction curve

Bearing life prediction curve was formulated by using rotation number to reach the life criteria for each test load. Bearing life criteria is selected as $2.5\mu m$, because the amoun of allowance run-out in this bearing is $2.5\mu m$.

The bearing life in the nonpregressed conditions both experiment and simulation can be predicted by using regression curve. For example, the bearing can be used about 2,530,000 rotations when using te bearing at 420kgf .

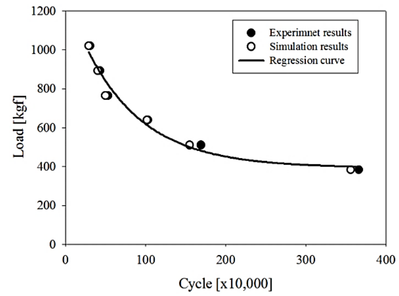

Figure 8: Experiment and simulation results

4 APPLICATIONS

In order to verify the bearing life prediction method, it was applied to other size and type bearings life prediction. The crossed roller bearings of inner diameter 70 and 100mm were performed for size effect. And the taper roller bearing of inner diameter 35mm was performe for type effect. All materials of the bearings is quenching a JIS SUJ2. [8]

NO.	1	2	3
Load [kgf]	897	747	598
Velocity [RPM]	400		

Table 4: Accelerated life test conditions for 70mm

NO.	1	2	3
Load [kgf]	1073	894	715
Velocity [RPM]	400		

Table 5: Accelerated life test conditions for 100mm

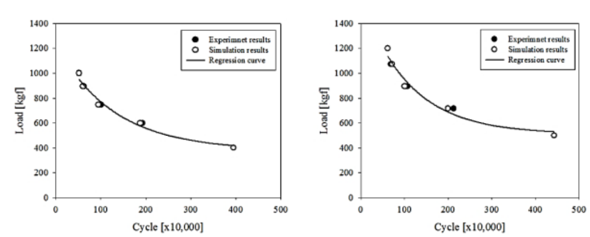

Figure 9: Life prediction curver of crossed roller bearing

Each baering parmeter was derived, and the difference was within 2%. In the same material and heat treatment, the wear model parameters were same. At a result, life prediction curves were obtained as shown in Figure 9. and 10. for other size and type bearigng. As a result, it is possible to simulate the actual test results by using wear model at less than 15% difference.

NO.	1	2	3
Load [kgf]	4,185	3,488	2,790
Velocity [RPM]	400		

Table 6: Accelerated life test conditions for taperd bearing

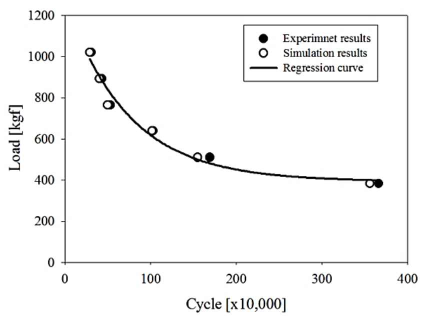

Figure 10: Life prediction curver of taperd roller bearing

5 RESULTS

In this paper, bearing life prediction method on the basis of run-out was developed. By using accelerated life testing and numerical analysis, quitative life prediction was possible in a short time. In particular, the difference between the testing and simulation results is about 15%. Therefore, numerical caculation applying reliable wear model can simulate the results without experment data. Ii is said that wear model is significantly imporat.

Also, bearing life predcition method was validated by performing other size and type bearings life predciton.In case of same material and heat treatment, The wear model and parameter is same.

When predicting the large bearing used in machine tools and wind power plants, user can be reduce the time and cost . Therfore, the user can be use the large bearing effectively.

ACKNOWLEDGEMENT

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