設備余寿命予測に関する研究
—遺伝的アルゴリズムによる最適予測法—

Life Prediction of Rolling Bearing Using Genetic Algorithm

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Rolling bearing is the most part used in rotating machinery of industrial plant. The condition diagnosis technology of rolling bearing is very important and indispensable for the plant safety and operation stability. The purpose of this study is to improve the accuracy of the life prediction for a rolling bearing. The paper proposes a searching method for the optimum mathematic function for the high accurate prediction by using the genetic algorithms (GA).

Keywords: Rolling bearing, Rotating machine, Life prediction, Genetic Algorithms.

1. Introduction

Rolling bearing is the most part used in rotating machinery of industrial plant. The condition diagnosis technology of rolling bearing is very important and indispensable for the plant safety and operation stability. The purpose of this study is to improve the accuracy of the life prediction for a rolling bearing.

The paper proposes a searching method for the optimum mathematic function for the high accurate prediction by using the genetic algorithms (GA). Firstly, for deciding the starting point of the prediction function, 10 initial genes expressed by $\mu_0(X_0, Y_0)$ are made, and the regression analysis of the inspection data for the life prediction is carried out from the starting point μ_0. The exponential functions from one to five orders are used for the prediction function.

The fitness is calculated by residual between measurements and predicted data. The exponential functions with high fitness are superior genes, and next generation's genes are generated based on them. The operation selection, crossover and mutation are done until the finishing condition is satisfied.

The weights are added in the predicted data when regression analysis for dealing with the rapid change in state tendency of the machine. Optimum weights are also searched by GA. We will show the prediction results obtained by this method to verify the efficiency.

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2. Tendency Prediction of Rotating Machinery

2.1 Vibration property of rotation machine equipment

In general, the machine condition can be divided into five stages, namely normal stage, early abnormal stage, middle abnormal stage, terminal abnormal stage and breakdown[1]. The purpose of tendency control of rotating machinery is judging these stages quantitatively. The values of some symptom parameters calculated from vibration signal for diagnosing state of a rotation machine has the tendency where the values rise with the abnormality level. An example of the relation between the abnormality level and the value of symptom parameter is shown in figure 1.

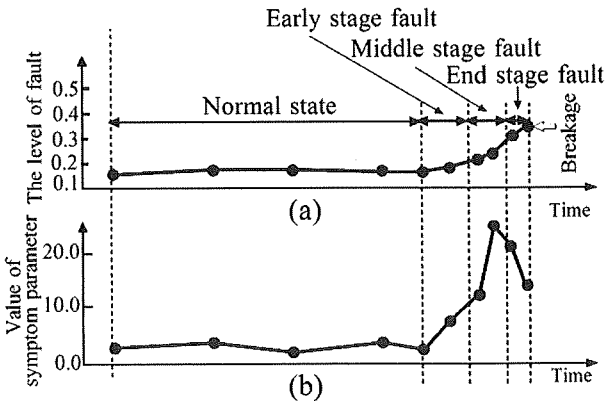

Fig.1 Relation between fault level and symptom parameter

The value of a symptom parameter conforms to the normal

probability distribution or weibull probability distribution when the vibration signal measured more than five times at same point continuously. Conceptive graph of the tendency control for rotating machinery is shown in figure 2.

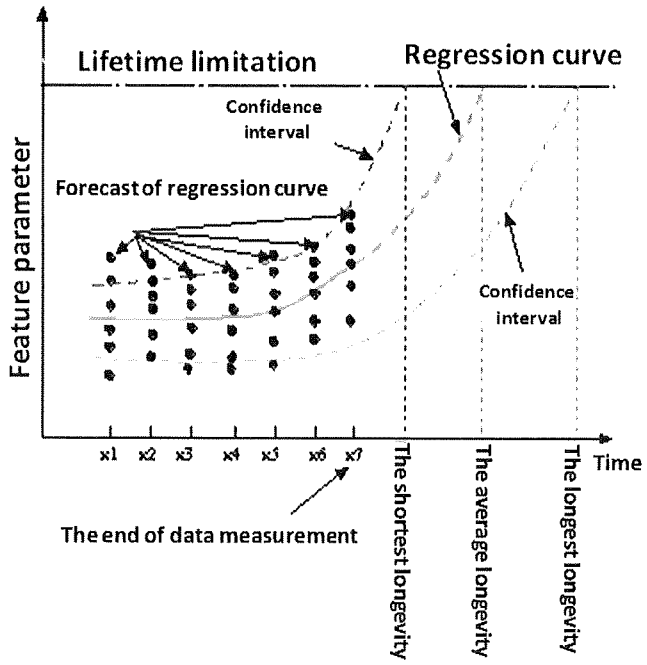

Fig.2 Tendency control for rotating machinery

2.2. Decision of optimum starting position of the regression curve

The life prediction is started from the point that the early abnormal stage. Or, the life prediction is started from the point at which the state is judged to be a slight fault by absolute judgment standard. However, the detection of an early abnormal stage by watching the graph of inspection data is difficult. Moreover, the value of symptom parameter changes with the operating conditions even if the same type of rolling bearing in a rotating machine.

This study deals with the problem of the life prediction for a rolling bearing in a rotating machine by statistical test method. Time when significant difference in the value of a symptom parameter against normal state existed is judged as abnormal occurring time. The life prediction is started from the point of the abnormal occurring time. The equation used to judge the significant difference (m) of the value of the symptom parameter is shown as follows.

$$\text{significant difference(m)} = (\overline{x_2} - \overline{x_1})\sqrt{\frac{N_1 N_2 \phi}{(N_1+N_2)(N_1 S_1^2 + N_2 S_2^2)}} \quad (1)$$

Here,

$N_1 \cdots$ Number of samples from $T_0 to T_{n-1}$;

$N_2 \cdots$ Number of samples T_n;

$\overline{x_1} \cdots$ Average of specimen of N_1

$\overline{x_2} \cdots$ Average of specimen of N_2;

$S_1 \cdots$ Average of standard deviation N_1;

$S_2 \cdots$ Average of standard deviation N_2

2.3 Tendency prediction simulation method

Procedure of tendency prediction simulation is shown in Figure 3. Firstly, for deciding the starting point of the prediction function, 10 initial μ0(X0, Y0) expressed by genes[2] are made, and the regression analyses of the inspection data for the tendency prediction are carried out from the starting point μ0. The exponential functions from one to five orders are used for the prediction function. The fitness[2] is calculated by residual between measured and predicted data. The calculation of the fitness (I) is shown by equation (2). The exponential functions with high fitness are excellent genes, and next generation's genes are generated based on them. The operation selection, crossover and mutation are done until the finishing condition is satisfied.

$$Fitness(I) = \frac{\sum_{i=N_0}^{N}(y_i - y_i')}{N - N_0} \quad (2)$$

Here,

$N-N_0$: Number of data for pridiction;

y : Vibration value of inspection data;

y' : Vibration value of regression curve.

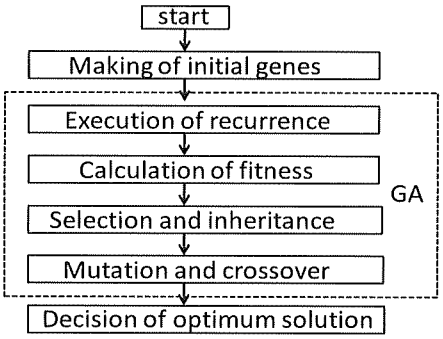

Fig. 3 Processing procedure of genetic algorithm

3. Simulation and experiment results

Examples of results of life prediction simulation are shown Figure 4 and Figure 5. These simulations were carried out by using 95 points from starting point, and the simulation results were verified by last 5 points. Figure 4 shows the rapid change pattern of the state tendency of a rolling bearing after abnormal stage, and figure 5 shows the gradual change pattern. The index recurrence curve is the optimum curve for the lift prediction found out by the GA.

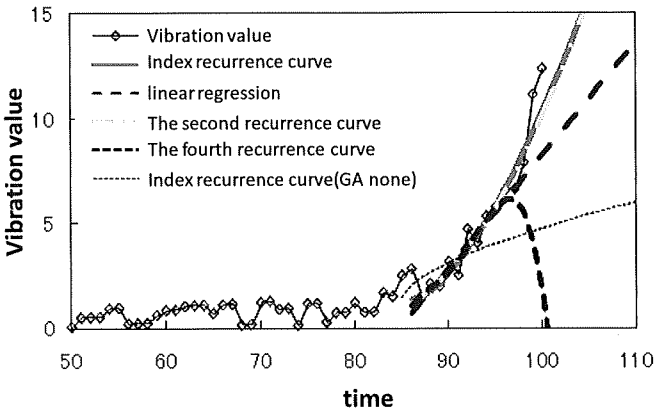

Figure 4 The case of rapid change pattern of the state tendency

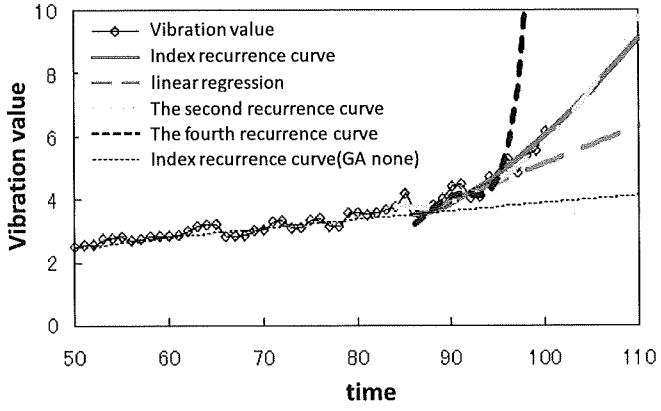

Fig. 5 The case of gradual change pattern of the state tendency

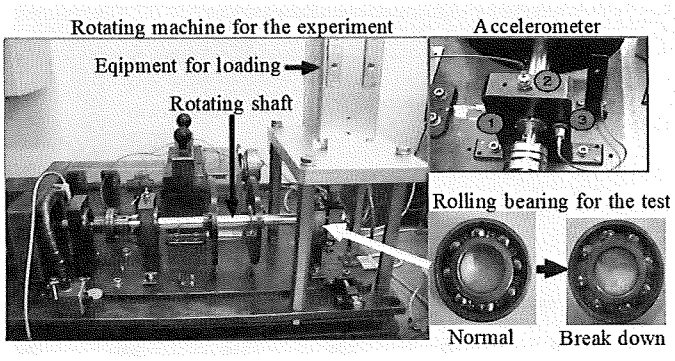

Fig. 6 Rotating machine for the prediction tests

In order to verify the efficiency of the method proposed here, we did accelerating fatigue test using a rolling bearing shown in fig. 6. The test conditions are follows :

Rotating speed : 800rpm;

Type of signal : vibration acceleration;

Sampling frequency : 100kHz;

Sampling time : 5sec.;

Time interval of signal measurement : 2 min.;

Type of bearing : NTN (6204LLUCM/5K);

Load : 1800kg.

Fig. 7 shows the change of values of symptom parameters (rms and γ) with time while the test, which are calculated by time signal of vibration acceleration.

Fig. 8 shows the prediction result for the tested bearing. The data in the abnormal area are used for prediction, and the data in the prediction area are used for verification. The optimum prediction curve found out by using the method proposed in this paper is well fitting the data for verification.

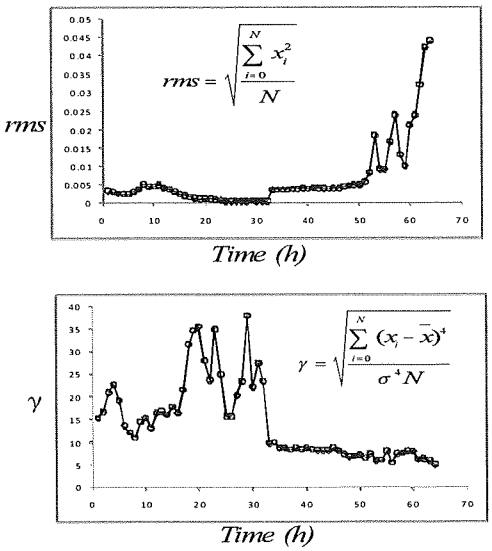

Fig.7 Values of symptom parameters while the life test

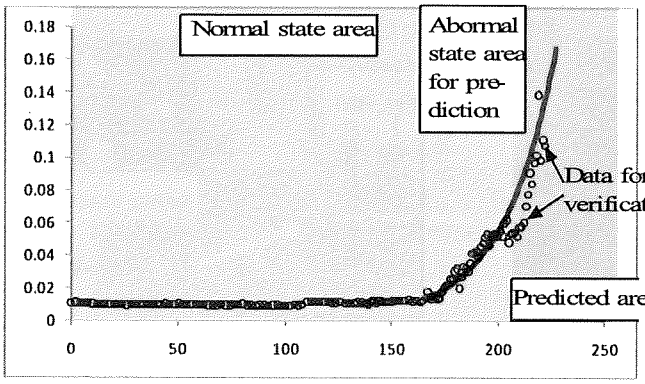

Fig. 8 Life prediction for the tested bearing

4. Conclusions

This paper has proposed a searching method of the optimum mathematic function for the high accurate life prediction of a rolling bearing in a rotating machine by using the genetic algorithms (GA).

The following results were obtained in this study.

Tendency prediction using genetic algorithm has been improved more than traditional methods.

The optimum prediction starting position can be specified by statistical tests and GA.

Optimum regression curve for the life prediction is index recurrence curve and the second recurrence curve.

The method proposed in this paper has been verified by the experiment of accelerating fatigue test for a rolling bearing.

References

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