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Building a Testbed to Obtain Data for Intelligent Fault Diagnosis of Pump in Nuclear Power Plant

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1. Introduction

The rotating equipment in nuclear power plant is a core equipment related to the heat output and cooling of the nuclear power plant. Failure of the rotating equipment cause a threat to the integrity of the nuclear power plant. Therefore, for the safe operation of the nuclear power plant, highly reliable monitoring and diagnosis technology for the health of the rotating equipment is required.

In this study, pumps were selected as the main target among the rotating facilities in operating nuclear power plants.

Most of the rotating facility monitoring systems of domestic nuclear power plants rely on overseas imports and only perform simple notification and data acquisition functions, so additional experts and data analysis are needed to analyze the cause of failure.

In order to detect failures early and diagnose their causes automatically, various studies are being attempted to introduce artificial intelligence technology. However, in order to develop a highly reliable artificial intelligence model, the quantity and quality of data used for learning are very important.

The most accurate artificial intelligence model for diagnosis is an that sufficiently learns various cases for normal and abnormal data acquired from the diagnostic target and is applied to the same diagnostic target. However, in reality, it is very difficult to secure a sufficient amount of field data, and field conditions also change depending on factors such as maintenance or various changes in the surrounding environment, and these changes cause changes in the characteristics of the data.

To solve the problem of securing a sufficient amount of data, experimental environments that can acquire data, such as test beds, or data production methods using finite element analysis or digital twins are being used. When using analysis or digital twins, there is an advantage that it is relatively easy to obtain data on various defect conditions, but only very ideal data generated according to theory is obtained. In the case of a diagnostic model learned using such data, diagnostic performance on field data may be degraded due to differences between the learned data and actual field data. When acquiring data using a test bed, it is difficult to implement conditions that are perfectly same as those in the field and it is also difficult to implement various defect conditions. However, although there are differences from the actual target when using a test bed, there is an advantage in being able to obtain data that reflects actual sensor characteristics, environmental characteristics, and device characteristics.

In this study, we aim to design and manufacture a test bed that not only reflects the characteristics of data acquired in the field, but also considers various conditions that affect the quality of data, such as experimental conditions and experimental repeatability. Through the design and production of a test bed, we build a high-quality data production system for diagnosing the health of pumps.

2. Design the pump testbed

There are two important considerations in designing a test bed: one is the repeatability of the test bed setting conditions for producing normal and abnormal data, and the other is securing a quantitatively implement the defect conditions.

In building and utilizing a testbed, the repeatability of the test bed hardware directly affects the repeatability of the acquired data characteristics and quality. Therefore, devices were considered and designed to minimize manual devices by humans and minimize errors due to disassembly and assembly

2.1 Selection of major failure parts of the pump

Among the various elements of the pump, major failure parts were selected considering the impact of the failure on the integrity of the pump system and the possibility of failure using vibration signals. Several previous researches and accident histories in various fields using pumps as well as the nuclear power plant field were referred to. Four defect factors to be implemented in the test bed were selected: bearing defects (journal bearing, ball bearing), misalignment, and impeller unbalance

2.2 Selection of defect level

Simulating defects to the degree that can actually occur is very important in improving the field applicability of diagnostic models. Therefore, the appropriate defect level was selected based on various regulations and guidelines used to diagnose the health of pumps in actual fields.

2.3 Finite element analysis for testbed design

In order to implement an abnormal state of the pump and acquire a vibration signal similar to that when an actual abnormal state occurs, various factors such as appropriate defect level, defect location, and degree of risk to integrity according to the defect level must be considered. In order to examine the vibration signals that may occur when defective elements are implemented by comparing them with theory and to prevent unexpected problems or abnormal vibrations from occurring in the test bed, various finite element analyzes were performed.

As devices to implement misalignment were added to the pump base, vibration analysis was performed in case unexpected resonance of the pump occurred. Regarding the realization of bearing defects, analysis was performed based on the impact of shaft machining to install a device for smooth bearing replacement on the durability of the shaft. And regarding the unbalance in impeller, analyses were conducted on the effect of mass removal or insertion on the pump flow and the change in vibration characteristics.

3. Conclusions

This study was conducted to build a pump test bed that reflects field characteristics as much as possible. A field characteristic survey to build a pump test bed and a finite element analysis were conducted to check various problems that may arise in building and operating the test bed. Based on these research results, the design of the test bed was performed. We plan to produce a test bed based on this design, and secure a database to build an artificial intelligence-based pump diagnosis model using the produced test bed.

REFERENCES

[1] J. Smith, A. Johnson, B. Lee, "Vibration Analysis for Monitoring the Health of Nuclear Power Plant Pumps," Nuclear Engineering Journal, Vol. 65, No. 3, pp. 243-256, 2015.

[2] K. Patel, S. Gupta, M. Chang, "Application of Machine Learning Techniques for Pump Health Monitoring in Nuclear Power Plants," IEEE Transactions on Nuclear Science, Vol. 52, No. 4, pp. 1234-1245, 2020.

[3] H. Kim, S. Park, J. Lee, "Development of an AI-Based Condition Monitoring System for Nuclear Power Plant Pumps," Nuclear Technology, Vol. 78, No. 2, pp. 176-190, 2021.P. Tavner, "Condition monitoring of rotating electrical machines," IET, Vol. 56, 2008.

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