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Construction of a Vibration Monitoring System for HANARO's Rotating Machinery and Analysis of Pump Vibration Signals

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1. Introduction

HANARO is an open-tank-in-pool type research reactor with a thermal power of 30MW. In order to remove the heat generated by the reactor core and the reflector vessel, primary cooling pumps and reflector cooling pumps circulate coolant. These pumps are installed at the RCI(Reactor Concrete Island) which is covered by heavy concrete hatches. For the prevention of an abnormal operation of these pumps in the RCI, it is necessary to construct a vibration monitoring system that provides an alarm signal to the reactor control room when the rotating speed or the vibration level exceeds the allowable limit.

The first objective of this work is to construct a vibration monitoring system for HANARO's rotating machinery. The second objective is to verify the possibility of condition monitoring of the rotating machinery. To construct a vibration monitoring system, as a first step, the standards and references related to the vibration monitoring system were investigated[1~3]. In addition, to determine the number and the location of sensors that can effectively characterize the overall vibration of a pump, the vibration of the primary cooling pumps and the reflector cooling pumps were measured. Based on these results, detailed construction plans for the vibration monitoring system for HANARO were established[4]. Then, in accordance with the construction plans, the vibration monitoring system for HANARO's rotating machinery was manufactured and installed at HANARO. To achieve the second objective, FFT analysis and bearing fault detection of the measured vibration signals were performed. The analysis results demonstrate that the accelerometers mounted at the bearing locations of the pumps can effectively monitor the pump condition.

2. Vibration Monitoring System of HANARO

Figure 1 shows the schematic diagram of the designed vibration monitoring system. The vibration monitoring system consists of accelerometers, keyphasors, cables, signal conditioning amplifiers, a monitoring panel, and a computer. Considering the radiation environment, radiation resistant sensors and cables were used. It is designed to provide an alarm signal to the reactor control room as an early warning for an abnormal operation of the rotating machinery. In addition, the measured data can be displayed on the computer in the reactor control room and in the office via a LAN interface.

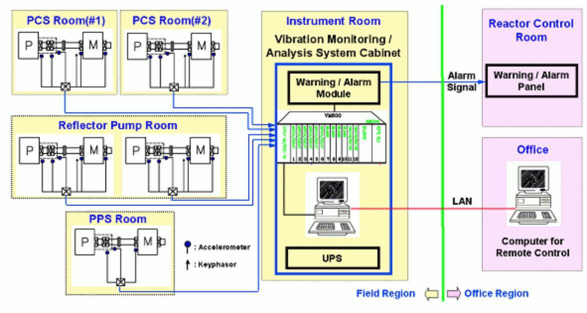


Figure 1. Configuration of HANARO's vibration monitoring system for rotating machinery

Figure 2 represents the real-time vibration monitoring panel installed at the reactor hall. Figure 3 shows the vibration sensors mounted on the primary cooling pump and reflector cooling pump. In order to measure the pump vibration and rotating speed, five accelerometers(4 horizontal and 1 axial directions) and one keyphasor were used for each pump.

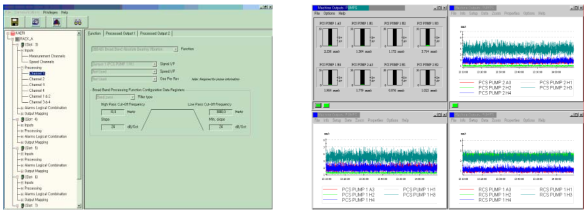
(a) Panel (b) Monitor screen

Figure 2. Vibration monitoring panel installed at the HANARO reactor hall

(a) Primary cooling pump (b) Reflector cooling pump

Figure 3. Configuration of HANARO vibration monitoring system for rotating machinery

Figure 4 represents the real-time vibration monitoring program installed at the monitoring panel. The program is designed to provide a user-friendly GUI environment. It is designed to offer rapid and precise information for a pump vibration obtained from the field sensors. It can provide an alarm signal to the reactor control room when the rotating speed or the vibration level exceeds the allowable limits.



(a) Monitoring condition setup (b) Vibration monitoring

Figure 4. Vibration monitoring program

3. Vibration Analysis of Pump Signal

To verify the possibility of condition monitoring, FFT analysis and bearing fault detection of the measured vibration signals were performed. Figure 5 shows the FFT analysis results of the vibration signal at the pump bearing locations. In Figure 5, one can observe the rotating frequency(f_r=19.87Hz) and its harmonic components such as 39.75Hz and 99.38Hz components that related to the unbalance and alignment status of the pump.

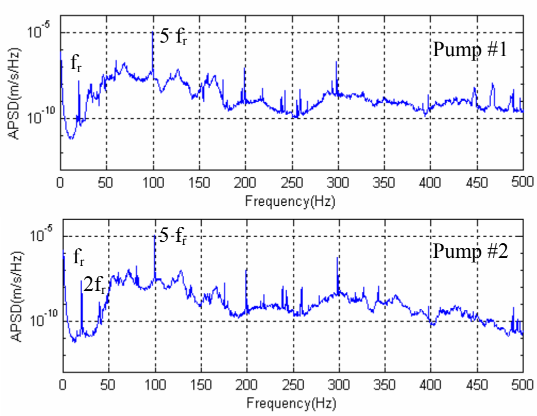


Figure 5. The FFT analysis result of vibration signal at the pump bearing locations.

Table 1 summarizes the bearing fault frequencies of the rolling bearings of the primary cooling pump. Figure 6 shows results of the bearing fault detection of the primary cooling pump. In Figure 6, one can observe small peaks that corresponding to harmonic components of the fault frequency of the bearing inner race.

Table 1 Bearing fault frequencies of the PCS pump

Bearing location	Pump(Unload)	Pump(Load)
Ball diameter(B_d)	30mm	38.33mm
Number of ball(N_b)	10	12
Pitch diameter(P_d)	155mm	157.5mm
Contact angle(θ)	0°	40°
Fault frequency of inner race $f_i=f_rN_b(1+B_d/P_d\cos\theta)/2$	80.2Hz	97.0Hz
Fault frequency of outer race $f_o=f_rN_b(1-B_d/P_d\cos\theta)/2$	118.6Hz	141.5Hz
Fault frequency of ball $f_b=f_rP_d(1-(B_d/P_d\cos\theta)^2)/(2B_d)$	49.4Hz	39.4Hz

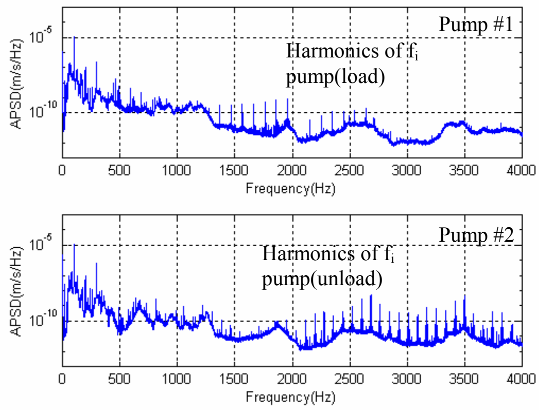


Figure 6. The analysis results of bearing fault detection

The vibration analysis results demonstrate that the accelerometers mounted on the bearing locations of the pumps can monitor the current status of the pump such as the unbalance, misalignment, and bearing condition. Based on the vibration analysis result, the hardware and software of vibration analysis system for HANARO's rotating machinery will be developed.

4. Conclusion

The vibration monitoring system for HANARO's rotating machinery has been constructed. The vibration monitoring system for HANARO's rotating machinery will be used as an advance warning system for the prevention of an abnormal operation of the rotating machinery. It is expected that the vibration monitoring system could be utilized for the realization of the preventive maintenance of HANARO's rotating machinery. To verify the possibility of condition monitoring for the rotating machinery, the measured vibration signals were analyzed. The results demonstrate that the accelerometers mounted at the horizontal direction on the bearing locations of the pumps can effectively monitor the pump condition such as unbalance, misalignment, and bearing condition, etc. Hereafter, the hardware and software of vibration analysis system for HANARO's rotating machinery will be developed for a condition diagnosis of the pumps.

REFERENCES

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