

# Vibration analysis of Kartini reactor secondary cooling pump using FFT analyzer

*by Risse Rachmanita*

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## <sup>2</sup>Vibration analysis of Kartini reactor secondary cooling pump using FFT analyzer

H Ahmadi<sup>1</sup>, M Subchan<sup>2</sup>, R E Rachmanita<sup>3</sup>, R D Audora<sup>1</sup> and A Wibuna<sup>1</sup>

<sup>1</sup>Polytechnic Institute of Nuclear Technology, National Nuclear Energy Agency of Indonesia (BATAN)

<sup>2</sup>Center for Accelerator Science and Technology, National Nuclear Energy Agency of Indonesia (BATAN)

<sup>3</sup>Renewable Energy Engineering, Politeknik Negeri Jember, Jember 164, Indonesia

E-mail: haerul.ahmadi@sttn-batan.ac.id

**Abstract.** The vibration of the secondary cooling system the Kartini reactor works to remove heat from the primary cooling system so that the heating element stays below the safety limit of the specified operating temperature. One component that is supported is a pump that is needed one of them by the vibration analysis method. By using vibration analysis, the type of cause of damage to the pump can be detected without dismantling the pump, so that it can provide predictability of maintenance time, scheduling repairs, picking up damaged equipment before hazardous needs. Vibration measurement with vibration meter (Lutron VB 8202) is carried out on the bearing housing of the secondary cooling pump motor housing in the direction: vertical, horizontal and axial. The value of the vibration compared with the vibration pump standard (ISO 10816-3). From the results of pump vibration measurements, there are several pump parts whose conditions are classified as vibrations that can cause damage to these components, namely the pump motor section. The average vibration on the pump motor is 5.74 mm / s greater than 4.5 mm / s that is classified as a vibration velocity value which can cause damage to other pump components. The results of the symptom analysis of variations in the vibration of abnormal values in the pump motor are caused by looseness of rotation and damage to roller bearings.

### 1. Introduction

The reactor cooling system functions to move the heat generated by <sup>1</sup> fuel elements so that it can prevent damage due to overheating. One component <sup>2</sup> of the reactor <sup>3</sup> cooling system is a secondary cooling system that functions to take heat from the primary cooling system, to be subsequently discharged <sup>4</sup> into the environment/air outside the reactor building. The heat recovery process takes place inside a heat exchanger where the hotter primary cooling water will transfer its heat to the cooler secondary cooling water. Kartini reactor, in its operation, uses various types of pumps that are used to move fluid from a component to other components. Therefore, the need for secondary cooling pump performance is vital in the operation of the Kartini reactor.

One method that can be used to determine the condition or performance of equipment is by performing predictive maintenance. Predictive maintenance is maintenance as a precautionary measure based on the condition of an engine. This predictive <sup>1</sup> maintenance observes mechanical conditions, maintenance efficiency and other parameters [1]. By using vibration analysis, the type of <sup>2</sup> cause of pump damage can be detected without pump <sup>3</sup> disassembly, so that it can provide predictability of time



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3 maintenance, scheduling repairs, picking up damaged equipment before hazardous conditions occur [2]. All these defects are categorized by the frequency characteristics in terms of vibration spectrum. And the spectrum obtained has variation in the amplitude with respect to the energy levels [3].

The working principle of the pump is based on the centrifugal force that is the flow of water in the pump will rotate following the rotating impeller. The vibration will occur on all machines that are operating. Vibration can also occur on machines that are not operating, and it is caused by environmental factors [4], [5]. Parameters that can be taken from vibration measurements include frequency and amplitude. Amplitude parameters include displacement, velocity, and acceleration. The causes of vibration in the pump are due to unbalance, misalignment, mechanical looseness, roller bearings, roller bearing damage: stage three outer race, roller bearing damage: stage three inner race, blades, vanes, impellers, bent shafts, cavitation, and cocked bearings. The cause of the vibration has a characteristic pattern (symptom) each based on the FFT (Fast Fourier Transform) spectrum of the vibration. So by knowing the characteristics, the types of vibrational causes will also be known.

The secondary cooling system serves to take heat from the primary cooling system, to be further discharged into the environment/air outside the reactor building. The heat recovery process takes place inside a heat exchanger where the hotter primary cooling water will transfer its heat to the cooler secondary cooling water. Next, the cold water is pumped back to the heat exchanger. The water pressure in the secondary cooling system is made greater than the water pressure in the primary cooling system. This is intended to prevent the possible entry of water in the primary cooling system into the secondary cooling system.

Secondary cooling water is prepared from shallow well water which quality is controlled to minimise the process of corrosion and scaling on heat exchanger components, secondary pumps, or piping systems. The secondary cooling system has two pumps connected to a heat exchanger tube, and one pump connected to a heat exchanger plate and two cooling towers. When using a heat exchanger tube, the secondary system is served by two pumps which are operated alternately. Likewise, the cooling tower is operated alternately [6].

2. Research methods

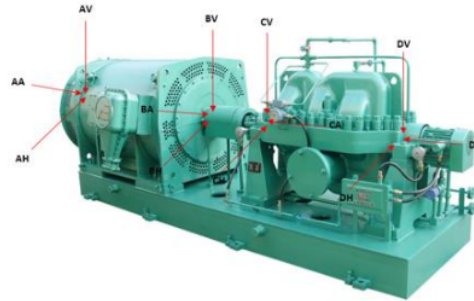
In this study, there are two main variables to determine the vibration conditions of the Kartini reactor secondary cooling pump motor, namely vibration velocity data and vibration spectrum frequency. The velocity vibration data will be used as a parameter of the operating conditions of the pump. The intensity level of vibrations and noise characterize the perfection of pump operation, its construction and pump condition during exploitation period, as well as cavitation phenomenon in the pump [7], [8]. Meanwhile, the vibrational spectrum frequency is used to analyse the types of causes of vibrations in the pump motor.

Table 1. Pump data sheet.

<b>Volts</b>	380	
<b>Kw</b>	25 HP	18,5 KW
<b>RPM</b>	2930	
<b>Hertz</b>	49	
<b>Bearing Number</b>	6307	

This study uses a piezoelectric accelerometer sensor to measure pump vibrations. The accelerometer can measure acceleration, detect and measure vibration, deflection of construction. In this study, the accelerometer is used to measure the amount of vibration (acceleration) that occurs in centrifugal pumps. The working principle of the piezoelectric accelerometer is that when the accelerometer part is aimed at a form of vibration, the mass placed on the crystal will maintain its position due to the influence of the force of inertia so that it will compress or loosen the piezoelectric crystal. This force will cause a charge, and according to Newton's first law, this force is proportional to the acceleration. The outgoing charge is converted to a low impedance voltage with an integral electronic device [9].

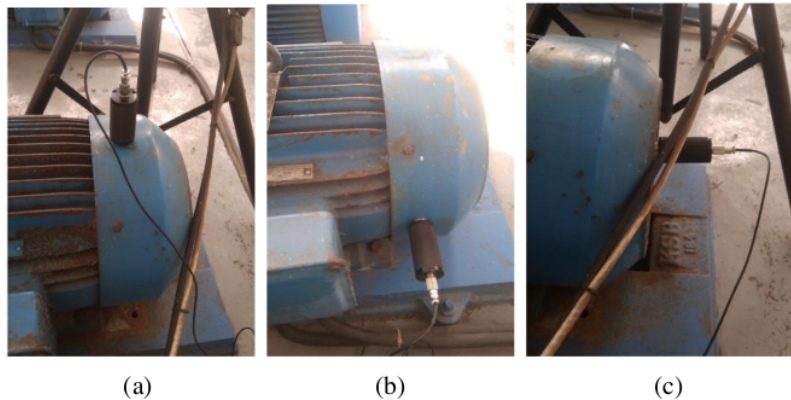
Data collection at the secondary coolant pump is carried out at 12 (twelve) points spread over 4 (four) pump parts: bearing motor housing, coupling, pump inboard and pump outboard. Each pump section will place 3 data collection positions, namely vertical, horizontal, and axial positions.



AV = Motor Outboard Vertikal	CV = Pump Inboard Vertikal
AA = Motor Outboard Aksial	CA = Pump Inboard Aksial
AH = Motor Outboard Horizontal	CH = Pump Inboard Horizontal
BV = Coupling Vertikal	DV = Pump Outboard Vertikal
BA = Coupling Aksial	DA = Pump Outboard Aksial
BH = Coupling Horizontal	DH = Pump Outboard Horizontal

**Figure 1.** Pump vibration measurement point.

Data signal processing becomes a spectrum to address the frequency of each peak of the vibrational spectrum using the FFT (Fast Fourier Transform) method [10]. The accelerometer is connected to the USB port, which in real time measures the vibration signal. FFT spectrum calculates for various ranges of data forms with minimum to maximum frequency ranges. The vibration sensor can measure in the vibration range of 10 Hz up to 1 kHz. The speed range of the motor is 0-2930 rpm.



**Figure 2.** Position of motor vibration data retrieval point (a) vertical, (b) horizontal, (c) axial.

The vibration velocity data of the pump will be compared with the ISO 10816-3 vibration standard as a parameter of the operational feasibility conditions of the pump. Vibration spectrum frequency can

be used to analyse the types of causes of vibrations in the pump because each type of vibration causes has a different frequency curve.



Figure 3. Vibration severity of pump [11].

3. Results and discussion

In this study, measuring the vibration velocity of the secondary coolant pump on the pump uses the Vibration Meter (Lutron VB-8202) and piezoelectric accelerometer. Measurements were made to analyse the vibration signal to determine the condition of the Kartini reactor secondary cooling pump. The existence of a secondary cooling pump is very much needed in the operation of the Kartini reactor. Therefore, monitoring and predictive maintenance are important. During each experimental test for the vibration signal sampling process, the pump rotation speed is kept constant at different flow rates. In this experimental measurement, each experimental test has been repeated at least three times at each data collection point. This is done to determine the repeatability of data retrieval by the sensor. The results show the highest repeatability in the horizontal direction of the three measurement directions.

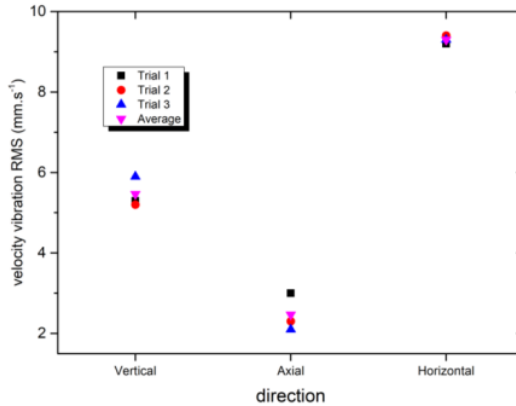


Figure 4. Repeatability of data retrieval by sensor.

Pump maintenance predictive is analysed by checking the condition of the equipment in operation. One of the common methods for monitoring pump conditions is by checking the vibration conditions and compared with the referenced standard using ISO 10816-3 vibration severity. The Kartini reactor secondary cooling system pump is a pump that has a construction design that is embedded in its foundation. Based on the ISO 10816-3 vibration standard, the pump is classified as a rigid construction pump with a group two category (medium-sized machines). The pump class is as the basis for determining pump conditions at each measurement point. RMS velocity vibration measurement results of pumps in the bearing housing motor, coupling, pump inboard and pump outboard are shown in Figure 5.

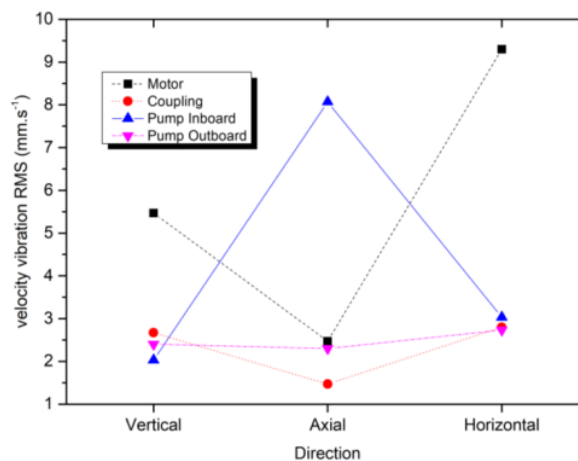


Figure 5. RMS velocity vibration measurement results of pump.

The results show that the bearing housing motor portion in the vertical and horizontal directions has the highest RMS vibration value compared to other measurement directions. The highest RMS velocity vibration value in the pump motor comes from the horizontal direction which is 9.30 mm/s. Meanwhile, the vertical vibration value is 5.47 mm / s, and the axial vibration value is 2.47 mm/s. So that the mean vibration value of the velocity RMS of the pump motor is 5.74 mm/s. Based on the ISO 10816-3[11] vibration standard (4.5 mm/s), the pump is categorised as a vibration that causes damage because the average vibration value of the RMS velocity of the pump motor has exceeded the standard limit. The condition of the pump inboard is categorised in vibration conditions which can cause damage to other pump components, and this is due to large vibrations in the axial direction (8.07 mm/s) according to Figure 5.

High vibration is a characteristic of damage to the pump. Analysis of the signal amplitude in the time and frequency domains carried out in the pump has been presented to predict and diagnose cavitation [12]. If left unchecked, this vibration will cause damage to the main components of the pump. One method to determine the damage to the pump is to understand the pattern (symptom) of the vibration FFT (fast fourier transform) spectrum. The pump has a part that has an RMS vibration above the ISO 10816-3 vibration standard, and it is necessary to do a more detailed analysis to determine the cause of the condition. Therefore, damage analysis of the vibration spectrum symptom was performed to obtain the causes of vibrations that exceeded the standard. Evaluation of experimental measurements based on normal operation and condition detection has been carried out using MATLAB code.

The initial step of identification is to look for the value of Pump Rotational Frequency based on the specifications of the pump. The following is the equation for obtaining the rotational frequency BPI (Ball Pass Inner Race) and BPO (Ball Pass Outer Race) value on bearing type: 6307 [13].

$$Defect\ on\ Outer\ Race\ (BPO) = \frac{1}{2}n \left(1 - \frac{d}{D} \cos\alpha\right) \times Pump\ Freq \tag{1}$$

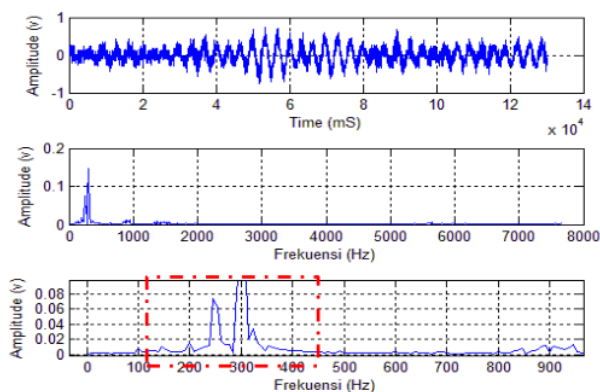
$$Defect\ on\ Inner\ Race\ (BPI) = \frac{1}{2}n \left(1 + \frac{d}{D} \cos\alpha\right) \times Pump\ Freq \tag{2}$$

The following results are obtained:

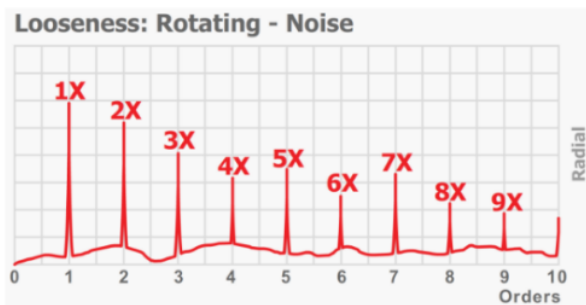
**Table 2.** Pump rotational frequency.

	n X Rotational Frekuensi (Hz)			
	1X	2X	3X	4X
BPO	148,69 (149)	297,38 (297)	446,07 (446)	594,76 (595)
BPI	243,31 (243)	486,62 (487)	729,93 (730)	973,24 (973)

Analysis of RMS velocity AV (Vertical Outboard Motor) Point 5.47 mm/s seen in Figure 6 shows that a harmonic peak appears at the nX frequency of motor frequency, starting from 2X (98 Hz) frequency, 3X (147 Hz) frequency up to 6X ( 294 Hz) motor rotation frequency. This is a characteristic of rotating looseness, where there is a high peak starting from 2X rotation of the motor in the radial direction (vertical and horizontal) to 6X rotation of the motor and followed by an increase in the noise floor.



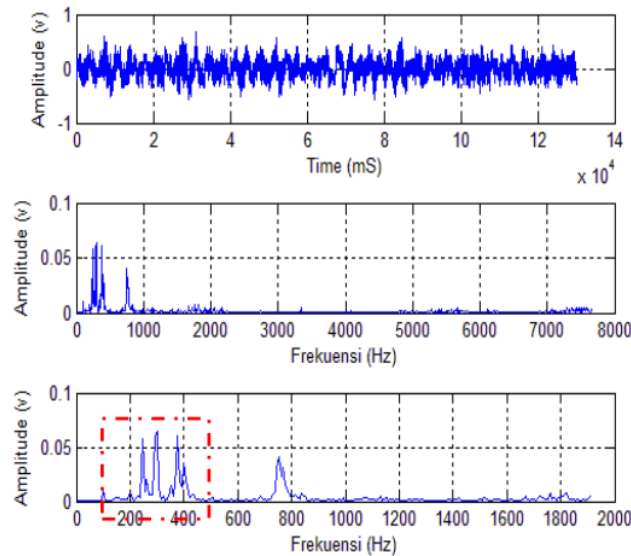
**Figure 6.** AV point vibration spectrum.



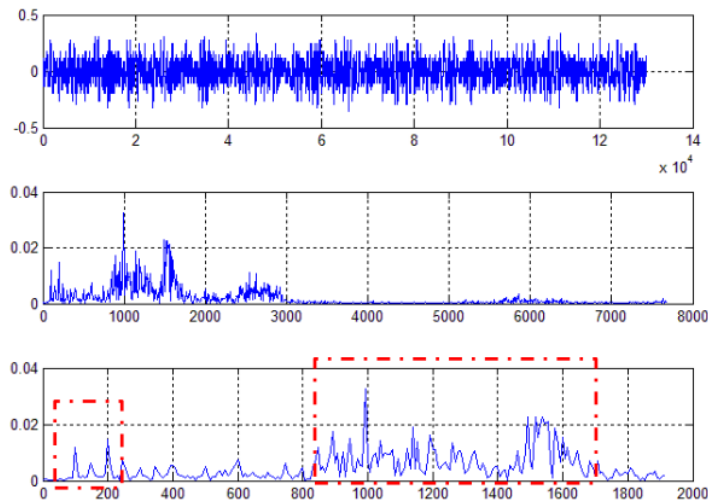


**Figure 7.** Vibration pattern caused by rotating looseness [14].

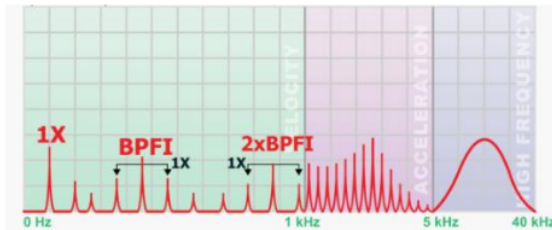
Horizontal pumps have a significant role in water transportation. Electro motors of horizontal pumps are extremely burdened from the aspect of continuous exploitation for maintaining the permanent operation/[15]. Analysis of RMS velocity AH (Motor Outboard Horizontal) point 9.3 mm/s shows that the point has vibrational peaks which frequency is harmonic at the motor frequency  $nX$  as well as at AV Point. Vibration at this point is also caused by rotating looseness with the characteristics of harmonic vibration peaks appearing from a frequency of  $2X$  in the radial direction (vertical and horizontal) up to  $6X$  the rotation of the motor. But what distinguishes the AV point is greater amplitude value and is followed by an increase in the noise floor.



**Figure 8.** Motor outboard horizontal point vibration spectrum.



**Figure 9.** Axial inboard pump point vibration spectrum.



**Figure 10.** Rolling element bearings: stage three fault: inner race [14].

Vibration can affect pumping segments of different aggregate [16]. The FFT spectrum in the picture shows that vibrations peak appear at frequencies of 1X (49 Hz) of motor rotation, 2X (98 Hz) and 3X (147 Hz) of motor rotation and are followed by vibrations at high frequencies (0.8 kHz to 1.6 kHz). These results are an indication of damage to the roller bearing. The analysis results present pump bearing malfunction but also a high frequency range, which is appearing as a result of hydrodynamic processes in a motor. From the observations and analysis of the RMS velocity of the pump vibration and the FFT (Fast Fourier Transform) spectrum, the advice that can be given is that the pump bearings must be replaced and accompanied by an inspection of the components around the damaged bearings to avoid adverse effects resulting from roller bearing damage and rotating looseness.

#### 4. Conclusion

Measurement of velocity vibration of the Kartini reactor secondary coolant pump by using a piezoelectric accelerometer sensor. After comparing with the ISO 10816-3 vibration severity, the average RMS velocity vibration of the motor and inboard pump parts is categorised as a vibration that can cause damage condition. Based on FFT (Fast Fourier Transform) spectrum analysis, vibrations at the pump are dominated by fault rotating looseness at the Vertical Outboard Motor and Horizontal Outboard Motor points and roller bearing damage at the outer race at the pump inboard. The presented results in the study points out that in motor, it is possible to determine a bearing malfunction as well as other mechanical defects from spectrum analysis. For future research directions it is necessary to analyze other parts of the system that can have harmful effects on bearings malfunction. Need to complete with motor temperature analysis as part of comparison with vibration analysis. Due to the importance of damage prediction on the secondary coolant pump in the reactor, this result is part of the safety and operational standards of the reactor.

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