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A Study on the Ultrasonic Sensor and Accelerometer Installation and Signal Acquisition Method for Engine Condition Diagnosis on EDG in Nuclear Power Plant

Sang-Guk Lee*, Kwang-Hee Choi , You-Sung Choi
Plant Support Engineering Center, Korea Hydro & Nuclear Power Co., LTD Central Research Institute, 70 1312-Gil, Yusung-Daero, Yuseong-Gu, Daejeon, 305-343, Korea
**Corresponding author: sgklee@khnp.co.kr*

1. Introduction

As a plan for the improvement of the EDG (Emergency Diesel Generator) maintenance program, the research project is being done by changing from time to condition based maintenance. First of all, the condition of EDG was analyzed and CBM(Condition Based Maintenance) was applied. The diagnoses for EDG are mainly composed of combustion in cylinders, vibration and ultrasonic signal analysis. The combustion analysis provides information of the combustion performance on each cylinder of EDG. Vibration and ultrasonic analysis provide timing signal on each event and information on mechanical condition. These signals can be collected without trouble causing on the operation of EDG. In this paper, the optimum sensor installation and the signal acquisition method are described for monitoring and diagnosis of EDG.

2. Method of Installation for Sensors

2.1 Accelerometers

An accelerometer is an electromechanical transducer that gives an electrical output proportional to the acceleration to which it is subjected. Accelerometers are widely used as vibration sensors, partly due to their wide dynamic range and wide frequency band width. These wide ranges make accelerometers particularly attractive for diesel engine signal analysis due to the high frequency nature of combustion related vibrations.
Piezoelectric-type accelerometers are the most common. These consist of a spring-mass-damper system that places a piezoelectric element under strain when the mass moves. Under this arrangement, a force proportional to acceleration is applied to the piezoelectric element. The element is then strained in an amount proportional to the applied force. The piezoelectric element, by nature, emits an electric charge proportional to the applied strain.
Accelerometers have a natural frequency of vibration which is a function of their mass, geometry, and rigidity. In order to avoid gross distortion of the collected data, it should be used with caution below their natural frequency limit. The frequency band width of an accelerometer is the range of frequencies that can be measured without significant error in the vibration amplitude due to resonance of the accelerometer. The high end of the frequency response for an accelerometer is typically defined as the frequency at which the increase in vibration amplitude due to resonance of the accelerometer is 5%. Frequencies beyond this range be detected. However, the error in vibration amplitude must be considered when measuring signals with frequency components greater than the frequency response of the accelerometer [1, 2]. The frequency band width of an accelerometer is usually provided by the accelerometer manufacturer.
The method of mounting an accelerometer also affects its frequency response. Fig.1 summarizes the effect of mounting method on accelerometer response. Several different ways to mount accelerometers, along with their effect on frequency response, are described below [3]:

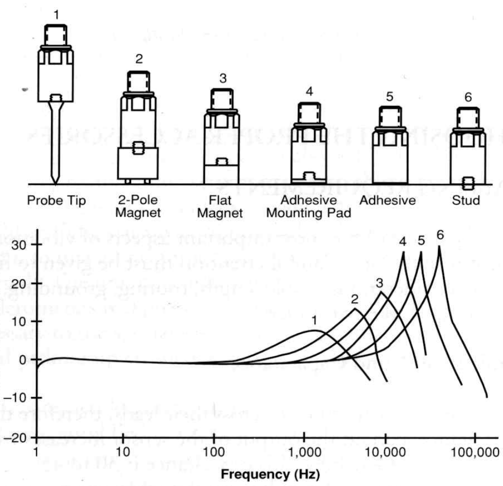

Fig.1. Effects of mounting technique on accelerometer sensitivity.

For most engines, an accelerometer with a magnetic mount has been found to produce acceptable vibration measurements because the frequency spectrum is not interesting data.

2.2 Ultrasonic Transducer

An ultrasonic transducer is an electromechanical transducer that detects sound waves that travel through air and originate from a vibrating surface. The ultrasonic transducer typically provides clearer signals than an accelerometer at the cost of having a significantly narrower usable frequency range. The ultrasonic transducer is essentially a microphone.

Sound waves are created at the vibrating surface with the same frequency and analogous amplitude as the original vibration. These sound waves are converted to a proportional electrical signal by the ultrasonic transmitter. A microphone consists of a diaphragm that moves with the varying pressures of the sound wave. A permanent magnet attached to the diaphragm induces an electric field in a coil. The electric field results in a voltage across the terminals of the coil. This voltage is the output of the ultrasonic transducer in unprocessed form. The ultrasonic transducers used with a rubber tip to eliminate background noise.

2.3 Sensor Location

The vibration and ultrasonic measurement outputs are came from the engine structural characteristics. Thus, locations of the sensors have significant effects on the measured signatures. In general, mounting the sensor closer to the source of vibration or noise will produce a stronger signal. Similarly, signals measured near cylinder head valves typically provide clear indications of valve closure events. However, it is usually not possible to measured all of the events of interest from a single location. As a result, it is typically necessary to record vibration and ultrasonic signals from more than one location on each cylinder.

When vibration and ultrasonic signals are first recorded on a particular engine or engine model, signals should be collected at various locations on the engine to identify the best locations for measuring clear signals. This is done by trial and error before the data is measured.

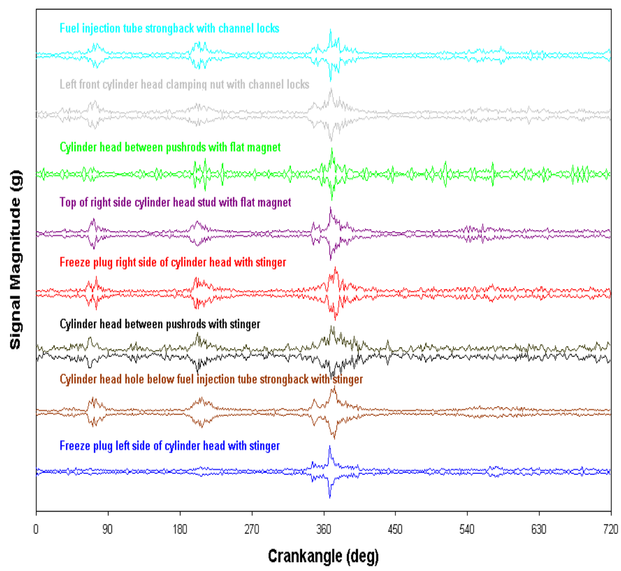

Fig.2. Vibration and ultrasonic signals for various locations

Engine analyzers allow the signals to be viewed in real time without recording the data. The vibration accelerometer and ultrasonic transducer are simply installed in different locations and the quality of the signatures judged relative to the events of interest.

Fig.2 shows vibration and ultrasonic signals measured at various locations on an EDG engine. The events of interest typically include exhaust valve closure, intake valve closure, delivery valve closure, fuel injection nozzle opening, fuel injection nozzle closure, and exhaust blowdown.

It is important to identify at least one vibration or ultrasonic signal in which each of the events of interest is clear enough to determine the timing and relative magnitude of the event. Locations which have been found to provide good signals include cylinder head studs, cylinder heads adjacent to cylinder head studs, cylinder heads close to the flame face, valve rocker supports, valve cage studs, fuel injection pump delivery valve nuts, fuel injection pump bodies and fuel injection line/nozzle hold down nuts. The accelerometer can be attached to the threaded studs on the pliers and the pliers clamped on to the engine in the region of interest. If difficulty is experienced obtaining a clear vibration signal with a magnetically-mounted accelerometer, the pliers may be used. Successive measurements on a cylinder should always be taken at the same location (with the same sensor and mounting) such that comparisons between the data are consistent. In addition, since it is useful to compare data from different cylinders, measurements should be taken at the same location on each cylinder.

3. Conclusions

The method of mounting an accelerometer affects its frequency response. The ultrasonic transducers should be installed with a rubber tip to eliminate background noise.

The locations of the sensors have significant effects on the measured signatures. In general, mounting the sensor closer to the source of vibration or noise produces a stronger signal. It is important to identify at least one vibration or ultrasonic signature which is clear enough to determine the timing and relative magnitude of the interested event.

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