Case Study of Signature Analysis on Engine Condition of Emergency Diesel Generators

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1. Introduction

The effort has been done to effectively improve the maintenance method of emergency diesel generator (EDG) by changing from time based maintenance to condition based maintenance (CBM) in nuclear power plant. Technologies of engine signature analysis to evaluate the diesel generator condition have been applied to CBM for EDG in domestic and foreign nuclear power plants.

Engine signature analysis includes both combustion analysis and vibration and ultrasonic analysis. Combustion analysis provides information on the combustion performance of the individual cylinders of the diesel engine. Vibration and ultrasonic analysis provides information on event timing and mechanical condition within the diesel engine. These signatures are collected non-intrusively during a normal loaded engine run. The primary impetus for the use of engine signature analysis has been as part of a program to replace the traditional time based open and inspection maintenance program imposed on plants by the original equipment manufacturers. Condition-based maintenance programs based largely on the use of engine signature analysis have increased the reliability and availability of diesel engine [1]. The results of signature analysis on various cases in EDG of KHNP and overseas nuclear power plants are described in this paper.

2. Signature analysis of Diesel Engine Condition

The different parameters gathered in both combustion analysis and vibration and ultrasonic analysis are used to determine if the diesel engine manufacturer's design limits have been exceeded and if the engine shows any signs of problems. There are several engine signature analysis system such as RT 9260 manufactured by Dynalco, DCDS (diesel engine condition diagnosis system) by KHNP, and Win 6320 by Windrock. The figure 1, 2 and 4 shows a composite graph generated by a Dynalco RT 9260.

2.1 Normal Engine Signatures

Figure 1 shows engine signal of normal form absent of unusual events for pielstick PC2.5 type EDG.

All traces show normal events for a four-stroke engine. Vibration signal shows early exhaust valve and intake valve closure. The figure 1 shows a composite graph. Early valves closure are noteworthy, but not necessarily a problem.

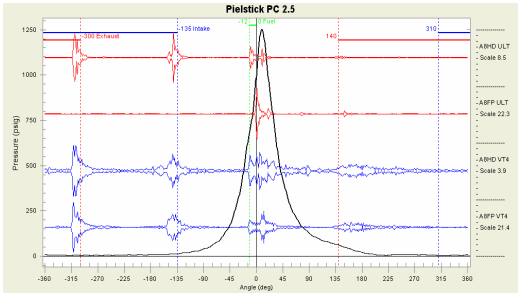


Fig. 1 Fig. 1 Composite graph of combustion (P-θ), ultrasonic and vibration signatures for a single cylinder

2.1 Abnormal Engine Signatures

The first case is about a bouncing fuel cam roller in a four-stroke engine in nuclear standby service. Figure 2 shows multiple regularly spaced impact spikes on ultrasonic signals of fuel injection pump. Severalinspection identified spalling on leading edge of fuel cam lobe as shown in Fig. 3. Roller bouncing damaged cam lobe. This damage was not apparent during initial inspection.

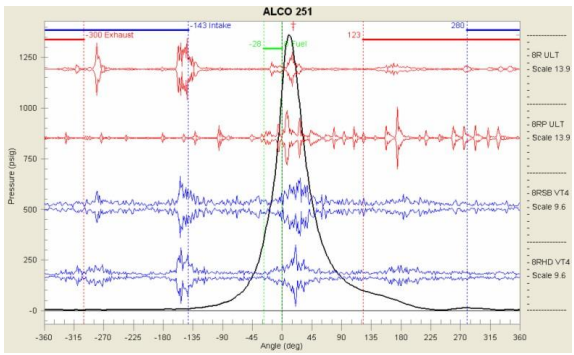


Fig. Fig. 2 Engine signatures for cylinder with bouncing cam roller

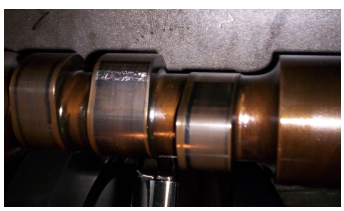
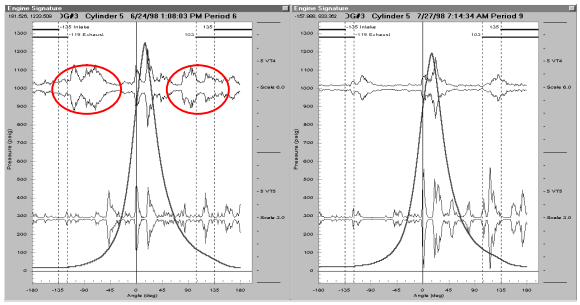


Fig. 3 Damaged fuel cam lobe

The second abnormal engine signature is liner scuffing/scoring and resulting blow-by in an EMD 645

engine. As shown in Fig. 4, abnormal large amplitude of vibration events was occurred during the compression and power strokes. The cylinder liner was worn in the location where the compression rings are during the compression and power strokes. This liner wear allowed blow-by gases to escape past the rings during the compression and power strokes. The vibration events are a result of the blow-by. The traces on the right hand side were taken after replacement of the liner and show no signs of blow-by [2].



(a) (b)

Fig. 4 Vibration traces showing liner scuffing/scoring and resulting blow-by (a) before and (b) after linear replacement

The third case is about sealing malfunction between a piston and a cylinder wall in a diesel engine

. In the case of sealing malfunction, blow-by phenomenon (fuel, air, and exhaust gas leaking between the cylinder liner and piston ring during period of high cylinder pressure) can occur. The blow-by phenomena can be confirmed from the vibration and ultrasonic signals. As shown in Fig. 5, high-amplitude rounded vibration and ultrasonic signal occurring simultaneous to period of high cylinder pressure [1]. The absence of an oil film on the cylinder wall due to a loss of lubrication or ring wear is sufficient to allow cylinder gases to escape.

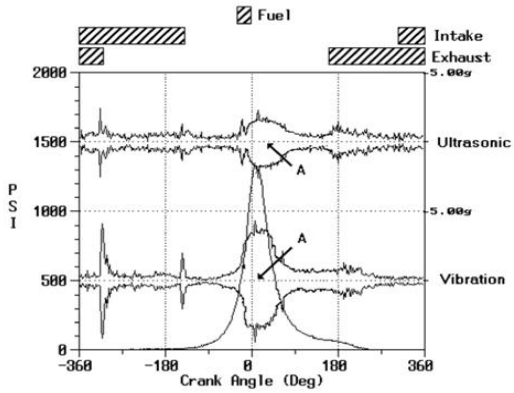
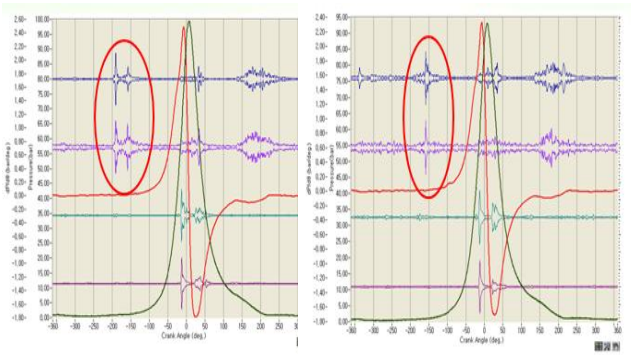


Fig. 5 E Signal of engine status signal for blow-by

Signals acquired from the EDG engine before power plant overhaul were compared with signals acquired after power plant overhaul. These EDG engine condition data could be applicable as important reference values.

As shown in Fig. 6, it was founded that a valve double contact signal appeared from the intake valve before maintenance, and such a signal was disappeared after maintenance.

It was concluded that the double contact signal of the valve resulted from inappropriate adjustment of a tappet. This figure was generated by DCDS which was developed by KHNP Central Research Institute [3].



(a) (b)

Fig. Fig.6 Improvement of double contact valve (a) before Before and (b) after overhaul maintenance

3. Conclusion

The technologies of engine signature analysis, both combustion analysis and vibration and ultrasonic analysis, were used for evaluating the diesel engine condition. These different signals can be used to determine if the diesel engine manufacturer's design limits have been exceeded and if the engine shows any signs of problems. Abnormal engine conditions such as cam roller bouncing, blow-by between piston ring and piston liner, and abnormal adjustment of exhaust/intake valve can be detected by using the technologies of engine signature analysis. Therefore, the technologies of engine signature analysis can be used usefully to apply CBM to EDG.

REFERENCES

[1] KEPRI, July 2008, MPR-3171, Rev1 Chap 3,4 "KEPRI Engine Signature Analysis Training Manual".

[2] Christian L. Haller and Mark J. O'Connell "Condition-Based Maintenance and On-Line Monitoring of Plant Safety Equipment - Methods and Case Histories For EDGs" Paper 5326, Proceedings of ICAPP 2005.

[3] Kwang-Hee Choi, Sang-Guk Lee, You-Sung Choi, and Byoung-Oh Lee "Application and Development of Technologies for Engine-Condition-Based Maintenance of Emergency Diesel Generators" Paper 12393, Proceedings of ICAPP 2012.