Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2015

Characteristics of Acceleration and Acoustic Emission Signals from Mechanical Seals

Do Hwan Lee*, Che Woong Ha
KHNP Central Research Institute, 1312-70 Yuseongdae-Ro, Yuseong-Gu, Daejeon 305-343, Korea
**Corresponding author: dohwan.lee@khnp.co.kr*

1. Introduction

Mechanical seals are used for pumps to prevent excessive leakage that might be occurred between rotational and stationary parts. The mechanical seals account for the major pump component failures. In spite of its importance, there have been few studies on condition monitoring of the components. Recently, some researchers have paid attention to the application of acoustic emission (AE) sensors for the fault detection of seals [1, 2]. Based on these results, the applicability of acceleration signals for condition monitoring of mechanical seals is examined in the present study. In addition, the characteristics of acceleration and AE signals obtained from various defects are investigated.

2. Experimental Methods

2.1Experimental Facility

A closed-loop type facility for a mechanical seal experiment was constructed as shown in Fig. 1. The facility consists of a test section and RWSS (Recirculation Water Supply System). The cooling water of the RWSS flows into the test section and returns to a storage tank. The RWSS is equipped with a piston pump. By controlling the pump speed, the flow rate and pressure of cooling water are adjusted. The leakage from mechanical seals is collected in containers and the weight of leakage is measured.

Figure 2 shows sensors used in this study. Several sensors such as a pressure transducer, AE sensor, and accelerometer are installed on housing surface of mechanical seals. The signals from the sensors are transmitted to a data acquisition system. The principal sensors used in this study and their sampling rates are listed in Table 1.

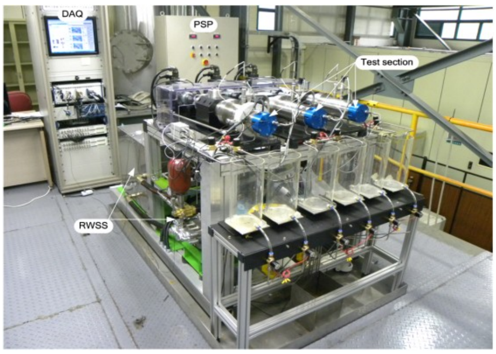

Fig. 1. Facility for mechanical seal experiment

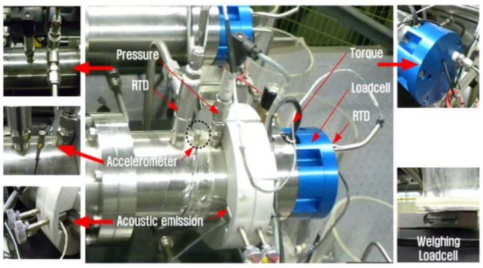

Fig. 2. Sensor locations on the mechanical seal housing

Table 1: Sensors and Sampling Rates

Sensor Type	Sampling Rate (kS/s)
Accelerometer (B&K 4397)	180
AE Sensor (PAC WD)	200
Pressure Transducer	10

A computer program for data storage and signal processing has been developed based on Labview software. Considering the high frequency nature of the signals from the seal interface, a high-pass filtering function has been included in the program.

One type of unbalance seals that are generally applied for low pressure conditions is selected as a test seal. The seal size is 55 mm in diameter. The materials for the stationary and rotational rings are carbon and silicon carbide, respectively.

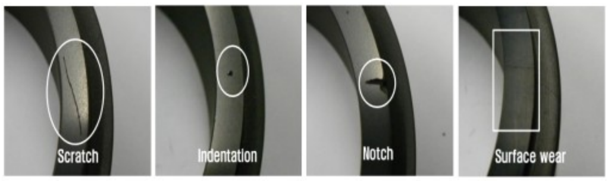

Fig. 3. Test specimens for defect tests

Table 2: Defect Size and Locations for Test Specimens

Defect Type	Defect Size and Location
Scratch	4 Locations (90 degree interval)
Indentation	4 Locations (90 degree interval)
Notch	4 Locations (90 degree interval)
Surface Wear	0.1 mm in depth
	2.0 mm in depth

Generally, four types of defects are most frequently found in mechanical seals failures. Those are the scratch, indentation, notch, and surface wear in stationary rings. To examine signal changes with different defect types, several test specimens are manufactured as shown in Fig. 3 and Table 2.

3. Experimental Results

The leakage greater than an acceptance range is the primary failure mode of mechanical seals. The leakage is induced mainly from an excessive asperity contact of the seal interface. This excessive asperity contact creates seal damage. As cooling water pressure increases, the film thickness of the seal interface decreases and lubrication condition of the seal interface is transferred from hydrodynamic into mixed state and eventually boundary mode. In the case of mixed lubrication condition, asperity contact does not widely occur. Thus, wear is a dominant failure mechanism of seals. On the other hand, if asperity contact covers whole area of seal faces, i.e., boundary lubrication mode, the seal might be distorted and destroyed by thermal stress. In this regard, condition monitoring of asperity contact strength is important to prevent seal failure.

If asperity contact occurs, the high frequency strain wave is released due to the deformation, fracture, and sticking of asperities. If elastic deformation is assumed for asperity contact, the elastic strain energy release rate $\dot{U}_E$ can be predicted as follows [1]:

$$\dot{U}_E = NWvF \tag{1}$$

where
N = Total number of asperity contacts between surfaces
W = Contact load
v = Speed of sliding surface
F = Function of asperity geometry

Since the total number of asperity contacts is proportional to the contact load, the energy release rate $\dot{U}_E$ increases with the square of the contact load.

Theoretically, the dynamic energy is equivalent to the square of RMS (Root Mean Square) of the signature. Therefore, we can deduce that the AE RMS has linear relationship with the contact load on sliding surface. From the statistical energy theory, it is noted the relation is also valid for the acceleration RMS and strain energy [3].

Figures 4~6 show the variation of the RMS values from acceleration and AE signals with different inlet pressure. The above relationship between RMS value and the contact load can be seen from these figures, considering that the contact load is proportional to inlet pressure. From Figs. 4 and 5, it is observed that the acceleration RMS values from normal and defect states can be more noticeable as the cut-off frequency for the high-pass filtering increases. Comparing 2.0mm wear conditions of Figs. 5 and 6, it seems that the acceleration is more effective than AE signal for wear monitoring. This is from the fact the probability of asperity contacts reduces with the severity of wear in seal face.

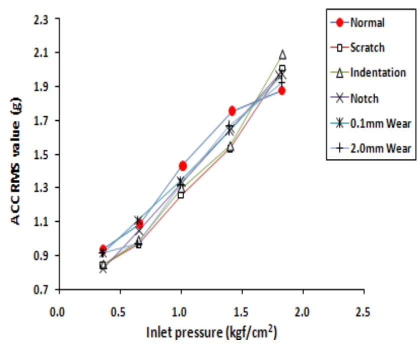

Fig. 4. RMS of acceleration with 10 kHz high-pass filtering

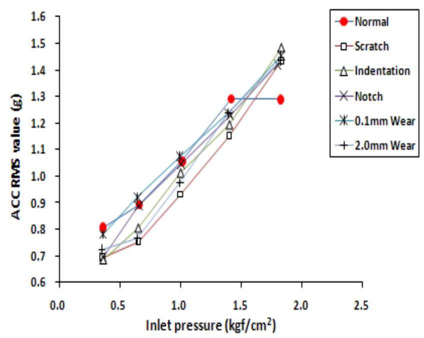

Fig. 5. RMS of acceleration with 50 kHz high-pass filtering

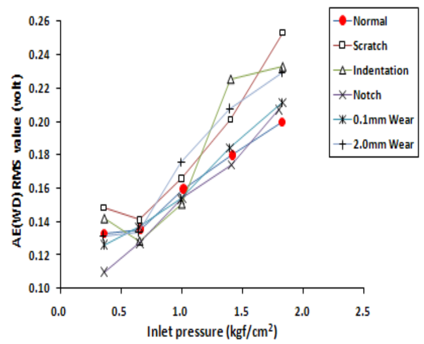

Fig. 6. RMS of AE signal with 50 kHz high-pass filtering

4. Conclusions

In order to prevent excessive leakage from mechanical seals, a condition monitoring technique is necessary. Based on the previous studies on AE techniques for seal monitoring, the signal characteristics from accelerometer and AE sensors are investigated in the present study.

REFERENCES

[1] Y. Fan, F. Gu, and A. Ball, Modelling Acoustic Emissions Generated by Sliding Friction, Wear, Vol. 268, pp. 811-815, 2010.
[2] H. Towsyfyan, O. Hassin, F. Gu, and A. Ball, Characterization of Acoustic Emissions from Mechanical Seals for Fault Detection, The 53rd Annual Conference of The British Institute of Non-Destructive Testing, September 2014.
[3] R. H. Lyon, Statistical Energy Analysis of Dynamic Systems: Theory and Applications, The MIT Press, 1975.