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미캐니컬 씰의 안전운용 감시를 위한 최적 계측인자

Optimum Monitoring Parameters for the Safety of Mechanical Seals

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ABSTRACT

The mechanical seals, which are installed in rotating machines like pump and compressor, are generally used as sealing devices in the many fields of industries. The failure of mechanical seals such as leakage, crack, breakage, fast and severe wear, excessive torque, and squeaking results in big problems.

To identify abnormal phenomena on mechanical seals and to propose the proper monitoring parameter for the failure of mechanical seals, sliding wear experiments were conducted. Acoustic emission, torque, and temperature were measured during experiments. Optical microstructure was observed for the wear processing after every 10 minute sliding at rotation speed of 1750 rpm and scanning electron microscopy was also observed. Except for the initial part of every experiment, the variation of acoustic emission was well coincided with torque variation during the experiments.

This study concludes that acoustic emission and torque are proper monitoring parameters for the failure of mechanical seals. The intensity of acoustic emission signals is measured in root mean square voltage. Temperature of sealing face will be used as a parallel parameter for increasing the reliability of monitoring system.

국 문 요 약

미캐니컬 씰은 회전축에 장착되는 밀봉장치의 하나로써 많은 산업 현장에서 사용되고 있다. 산업

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발전과 더불어 미캐니컬 씰의 고장 즉, 밀봉장치에서의 누설, 크랙, 파손, 과대마멸 등과 같은 이상상태는 대규모 공장의 생산라인을 정지시키거나 심각한 환경오염을 유발시키는 등 경제, 사회적 문제를 야기시키고 있다.

미캐니컬 씰 밀봉면의 미끄럼 운동상태를 인지하고, 미캐니컬 씰의 고장에 대한 감시인자를 도출하기 위하여 미끄럼 마멸실험을 수행하였다. 미캐니컬 씰의 회전속도를 1750 rpm 으로 하여, 매 10분 마다 미캐니컬 씰 밀봉면의 마멸상태를 광학현미경으로 관찰하였고, 실험동안에 미캐니컬 씰의 미끄럼 운동면에서의 음향방출(AE : Acoustic Emission), 토크, 온도, 등을 측정하였으며, 실시간으로 토크 신호의 주파수 분석을 실시하였다. 각 실험의 초기를 제외하고는 전 구간에서 음향방출 신호의 크기와 토크 값의 변화 경향이 대체로 유사한 경향을 보였다. 정상상태에서는 음향방출, 토크 및 온도가 안정된 상태를 유지하였으나, 이상상태에서는 음향방출의 크기와 토크값이 안정된 상태를 유지하지 못하였으며, 온도는 이상상태 때 급상승하는 경향을 보였다.

토크 값과 온도의 변화가 미캐니컬 씰의 고장에 대한 장기적 감시인자로 적절하다고 생각되며, 미캐니컬 씰의 순간적인 이상상태를 확인하거나 미캐니컬 씰의 운동상태를 인지하는 데는 실효치 전압 상태의 음향방출 신호가 적당하다고 생각된다. 온도는 이상상태 감시 시스템에서 시스템의 신뢰도를 증진시키는 병렬요소로써 활용될 수 있을 것이다.

1. INTRODUCTION

Mechanical seals are extensively used to seal rotating machinery such as pumps, mixers, and agitators in the many fields of industries. One of the particularly important fields is the chemical industry. More than 70 % of failures of this machinery occurred in the mechanical seal[1]. The necessity of on-line monitoring of the conditions of mechanical seals keeps growing in the many industrial fields. Because the failure of the mechanical seals which were installed in the chemical plants, for example, may result in the leakage of harmful chemicals, possibly causing the severe problems, namely, environmental pollution, damage or loss of life, and stop of production line.

Mechanical seals are essentially composed of two rings which provide a pair of flat sealing surfaces in mutual rubbing contact. The failures such as crack, breakage, severe wear, and weakening of contact pressure of two rings result in the leakage of sealing materials. The mechanisms of failure generation have been studied and various measures are investigated in order to suggest the appropriate solutions[1~3].

In this study, to identify abnormal phenomena on mechanical seals and to propose the proper monitoring parameter for failure of mechanical seals, sliding wear experiments were conducted.

2. EXPERIMENTAL PROCEDURES

To simplify the experiment conditions, the surface condition of seal rings was taken as variables with all other factors kept constant. As specimen, carbon ring was used for seat ring, and solid alumina(Al_2O_3) for seal ring as well. Before experiment was set off, carbon rings and alumina rings were degreased ultrasonically in acetone. Alumina rings were marked with none, one, two, and four diamond indentations on their sealing face, respectively. The indentation(s), as the defect on the seal ring, were made by Vicker's hardness tester to observe the crack propagation. Alumina rings were put in desiccator for 20 days after being indented. Specimens were isolated from the environments such as moisture and other contaminations using desiccator. Figure 1 shows the structure of mechanical seal.

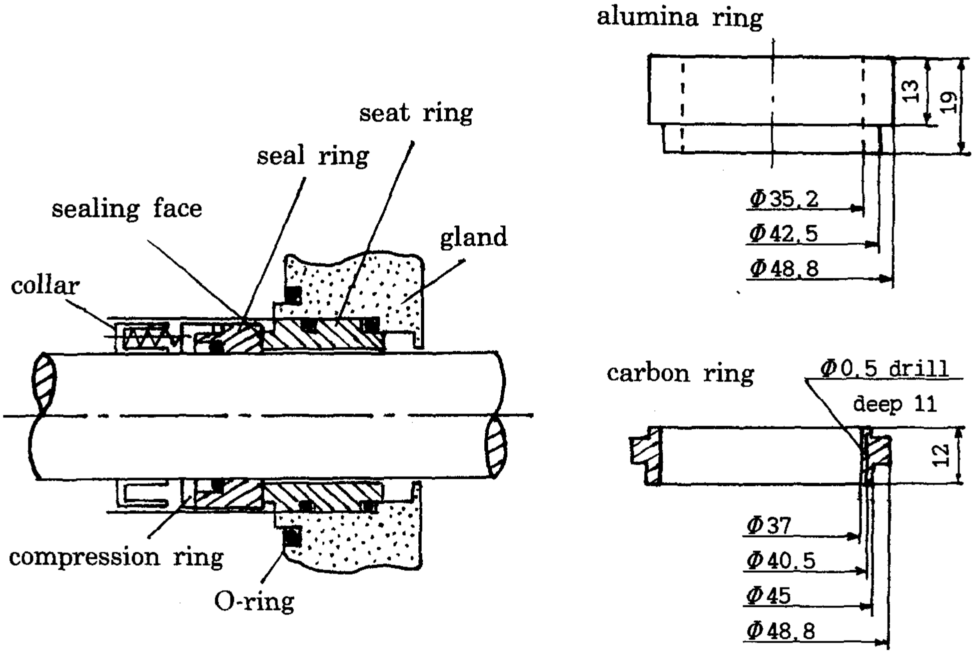

Fig. 1 General structure of mechanical seal (left) and demensions of specimen.

The sliding wear experiments were performed with the commercial wear tester employing a pair of adapter specially designed for installing mechanical seals. The sliding speed of 3.71 m/sec(1750 rpm) and the contact pressure of 13 kg_f/cm^2 were maintained. Each unlubricated experiment without cooling was conducted for 10 minutes and repeated 6 times on the same pair of mechanical seals. After every 10 minute experiment, the sealing faces of the both rings were observed by optical microscope. Scanning electron microscopy was used to examine the worn surfaces.

The torque, as frictional force, was measured by a load cell installed at the bottom of the seat ring. The load cell and the appropriate amplifier were built in the wear tester by manufacturer. The temperature of carbon ring was measured by K-type thermocouple at 1 mm beneath the sealing face of the seat ring. An AE sensor with 500 kHz resonant frequency (pico 1526, Physical Acoustics Corp.) was attached directly to the side of carbon rings using high temperature adhesive. Detected signals were amplified up to 40 dB by preamplifier with 400 ~ 600 kHz bandpass filtering for the amplification of the AE sensor signal and then amplified up to 32 dB by the main amplifier. The above three measuring signals and the output of rotation speed were fed into data recorder. The intensity of AE signals was recorded as a root mean square voltage. Figure 2 shows the experimental setup.

3. RESULTS AND DISCUSSION

Figure 3 shows a result of unlubricated sliding wear experiments. The typical curves illustrate the relation among torque, temperature, and AE intensity. Figure 4 is partial magnification of Figure 3. At the initial part (Upto 1.5 minutes after experiment starts off

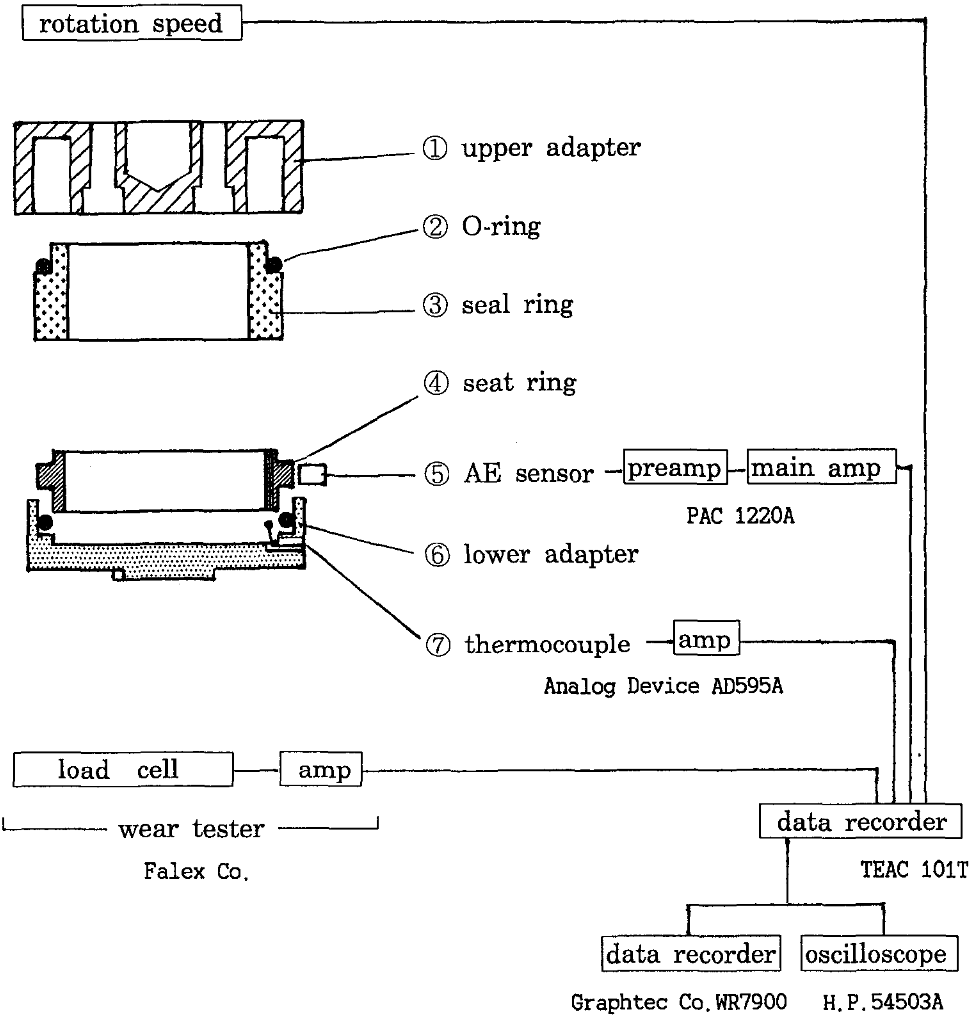

Fig. 2 Schemitic diagram of experimental setup.

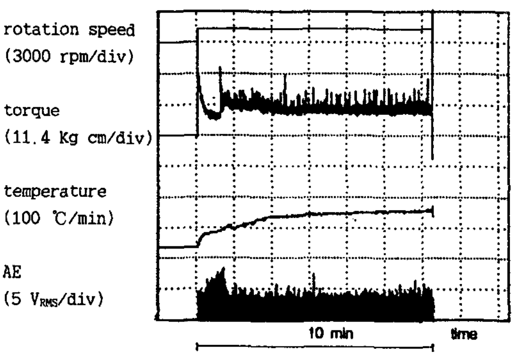

Fig. 3 Torque, temperature, and AE vs wear time.

in Figure 3) of each experiment, it appeared that torque value was reducing as AE intensity was increasing. This part is considered as the generation stage of adhesion layer between the sealing surfaces, which resulted from the wearing of carbon ring. After this initial part, the variation of acoustic emission was well coincided with torque variation during sliding wear. The measured temperature varied with the torque. It is considered that the heat generated by the friction of two rings

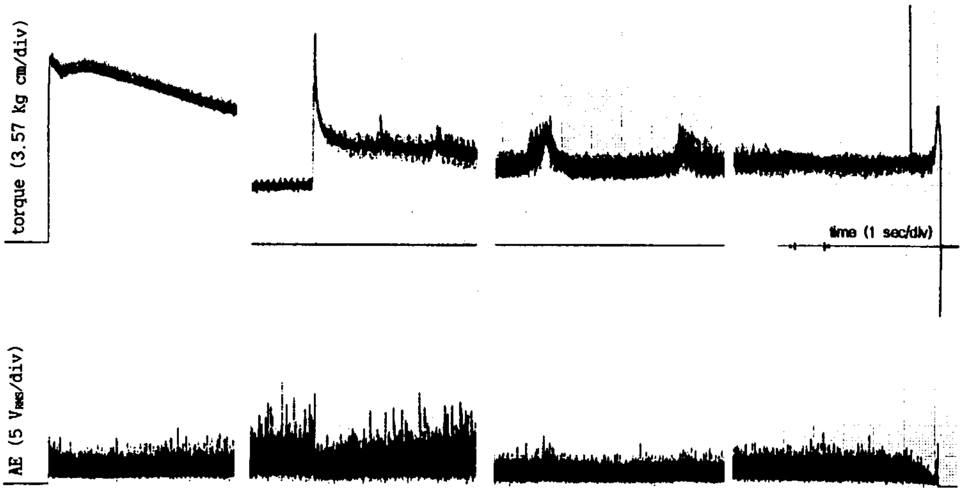

Fig. 4 Torque and AE vs. wear time.
(from left, initial part, single big peak, serial peaks, and ending part, respectively)

has rapidly accelerated the generation of adhesion layer, eventually causing slip phenomenon. As shown in the second part of Figure 4 which means a slip between the sealing surfaces, quick contact of two rings after a slip, which was acknowledged by means of rising of torque, results in severe wear including grain pull-out. Figure 5 shows the grain pull-out. In other words, the big peaks of the torque curve in Figure 3 are considered as quick contacts between two rings without the adhesion layer. It is also considered that slip occured due to the excessive generation of adhesion layer by frictional heat and the generation of debris. Similar curves about the sliding wear of silicon nitride were reported by others[5,6].

The overall fluctuation of torque and AE intensity is considered as the repeating of these wear processes. Figure 6 shows the appearance of worn sealing face. This illustrates coexistence of mild wear and severe wear. The SEM photomicrograph of alumina sealing face is similar to that of other report[4] which explained the severe wear of alumina.

Any differences between the alumina ring with diamond indentation(s) and that without indentation(s) were not found on AE intensity, torque, and temperature througout experiment. No crack growth occured during the experiment.

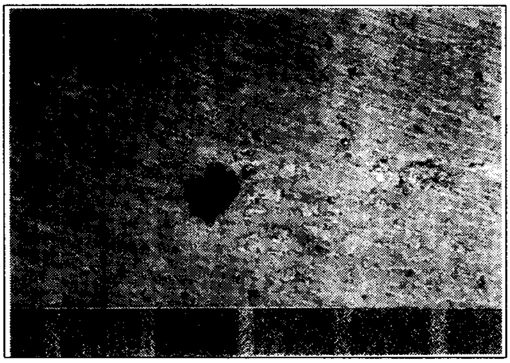

Fig. 5 Optical photograph of sealing face of alumina ring showing grain pull-out.(X500)

4. CONCLUSIONS

1) The AE intensity in root mean square voltage can be a monitoring parameter for the failure of mechanical seals.
2) Acoustic emission as well as torque and temperature can be used to identify the sl-

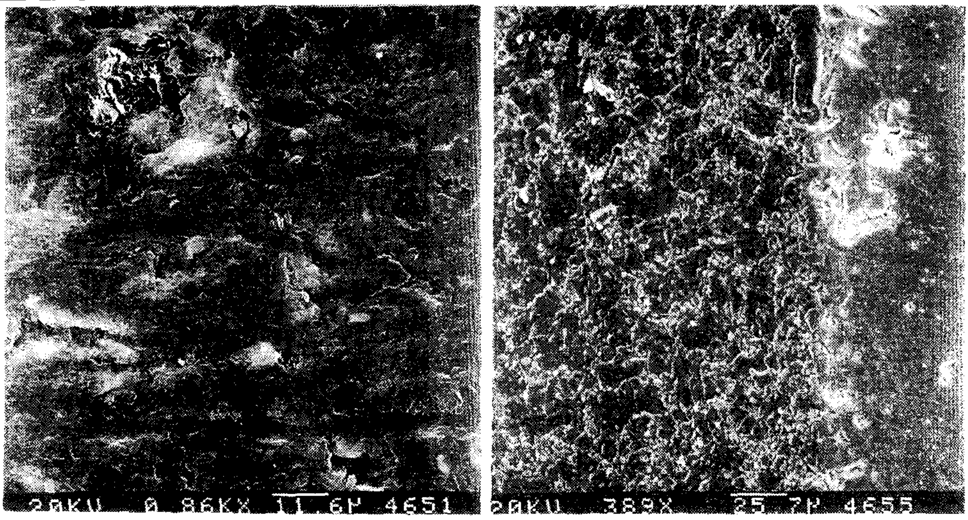

Fig. 6 SEM photomicrograph of sealing face
< carbon ring (left) and alumina ring (right) >

iding motion of mechanical seals.

3) Distinctive differences due to diamond indentation(s) on the sealing face of alumina ring was not found.

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