MEMS BASED ACOUSTIC PRESSURE MEASUREMENTS

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1. INTRODUCTION

Dynamic pressure measurements are a promising new approach to obtain diagnostic characteristics where pressure variations may be used to extract hardware performances. In this regard, pressure sensor designers agree that in-situ measurements would enable performance extractions currently unavailable with conventional pressure sensors. This paper proposes using Micro-Electro-Mechanical-Systems (MEMS) microphones as pressure sensors for monitoring dynamic pressure variations. Shown in Figure 1 is a cross-section of a Knowles acoustics SiSonic microphone [1]. It is a free-floating design with 36 support posts and one physical connection to the diaphragm. Shown in Figure 2 is an image of the SiSonic microphone diaphragm, support posts and connections.

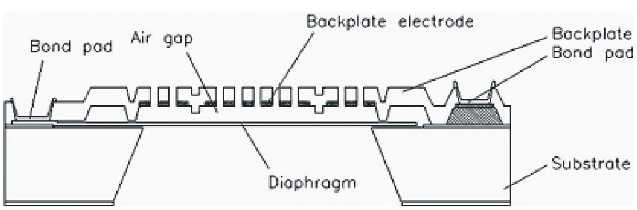

Fig. 1. Cross-section of SiSonic MEMS microphone [1].

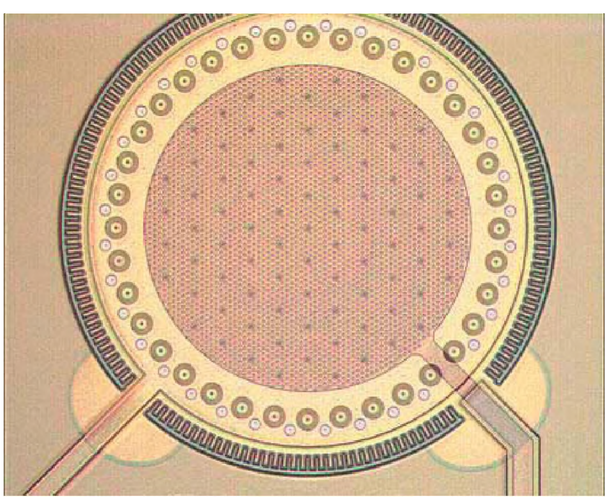

Fig. 2. SiSonic MEMS microphone diaphragm [1].

MEMS pressure sensors combine high sensitivity with small size/weight packaging that would enable in situ monitoring of pressure flows. Current pressure sensor technology for engine applications, for example, makes use of magnetic captors or torque sensors. While the sensitivity and selectivity of these types of sensors is satisfactory, problems are encountered with their reliability and the drift from the calibrated point. Packaging is to some extent heavy in part due to the sensor qualification requirements. In this capacity, MEMS pressure sensors satisfy several important criteria, namely, small size/weight, robustness, easily integrated with electronics, low power consumption and low cost. In this paper MEMS microphones are used to monitor the pressure variations of rotating axial fans.

2. EXPERIMENT

Described in this section is the experimental setup and equipment used for the MEMS based pressure sensor. The experiments consisted of measuring the pressure variation of several DC fans [2, 3] having maximum rotational frequencies ~4000Hz. Shown in Figure 3 is a 5 bladed DC axial fan used in the experiments. The white lines seen on the fan blades were used for stroboscopic measurements of the fan speed.

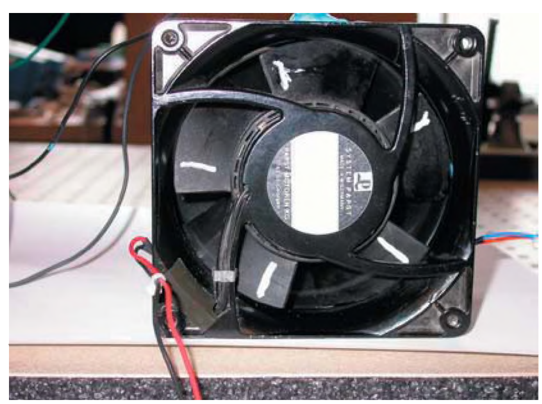

Fig. 3. Fan with 5 blades.

The pressure variations were measured using both an ultra-miniature electret microphone [3] and MEMS microphone

[1] for comparison. In the course of the experiments no differences were seen between these two technologies. In all of the experiments, pressure measurements were taken directly over the fan blades through a hole in the axial fan casing. Shown in Figure 4 is a Papst [2] technology fan with an electret [4] microphone mounted over the fan blades. A double fan configuration is also analyzed as shown in Figure 6 with a MEMS acoustic sensor mounted in between the two fans.

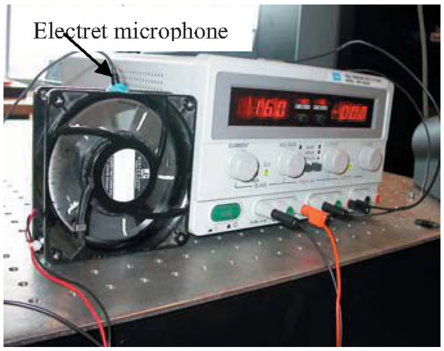

Fig. 4. Fan and power supply. White lines on the fan blades were used for stroboscopic measurement of the fan speed.

3. RESULTS

Shown in Figure 5 is an FFT [5] carpet plot of the fan speed and frequency (fundamental and harmonics). The frequency is a function of the blade passage across the plane of the sensor. These results were repeated for higher rotational velocities and frequencies (~4000Hz) with excellent signal-to-noise ratios obtained with the sensor.

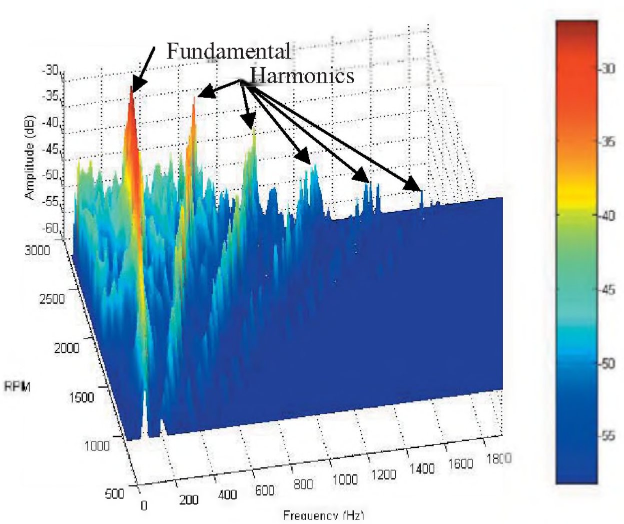

Fig. 5. FFT carpet plot of the fan rotation as a function of the pressure variation created by the fan blade passage. The fundamental mode and harmonics are visible.

The results obtained for the double fan scheme are given in Figure 7.

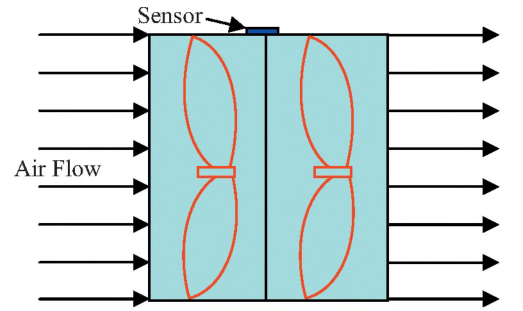

Fig. 6. Double fan configuration with an acoustic pressure sensor placed at the mid point of the two fans.

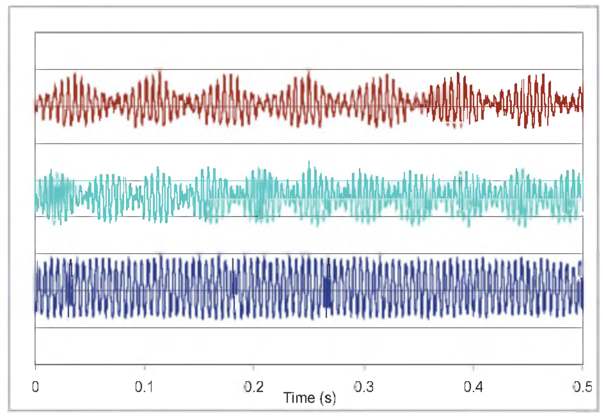

Fig. 7. Pressure plots for a two fan configuration taken at the midpoint of the two fans. Top: F1 speed> F2 Middle: F2 speed>F1. Bottom: F1 speed = F2.

5. CONCLUSION

The possibility of integrating MEMS based acoustic pressure sensors in rotating machinery such as fans has been presented. MEMS offer small size with great sensitivity and reliability at a reduced cost. In this regard, their suitability for in-situ measurements of active flow systems such as generated by rotating fans makes them an excellent diagnostic tool by virtue of the information extracted from the pressure signal obtained.

REFERENCES

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