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A NEW TECHNIQUE TO MEASURE EXPERIMENTAL PRESSURE DIAGRAMS OF RECIPROCATING COMPRESSORS

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ABSTRACT

An experimentally obtained pressure-volume (P-V) diagram is of special significance to compressor engineers. In such experiments, the measurement of valve opening instants are used as reference signals to set the absolute level of the cylinder pressure signal. These valve signal measurements have typically been measured using proximity sensors. However, the original valve system often has to be modified significantly to accommodate the installation of the proximity probes in small fractional horsepower compressors. This modification deteriorates the accuracy of the measurement. In this work, a new measurement technique is applied to detect the valve opening instances accurately. A very small device is developed so that the valve opening instance causes a sudden change of the electric voltage output in its circuit. Experimental pressure diagrams obtained by the new procedure are shown. Advantages of the new method are discussed.

INTRODUCTION

One of the primary purposes of measuring valve motions is to use the results as reference signals to set the absolute level of the dynamic pressure of the cylinder. For example, at the opening instant of the suction valve, the cylinder pressure can be thought of having the same pressure level as the pulsating pressure of the suction cavity [1] . Traditionally, proximity probes have been used to measure the valve lift for use in this purpose. However, these probes have some significant disadvantages when used in small hermetic compressors because of their large size relative to the port system. Often some modification of the prototype is necessary, which may produce significant measurement errors. Also, it has been found that the instant of valve opening is rather hard to determine from the probe signal because of the gradual motion of the valve when it opens [2]. Therefore judgment and experience must be used in interpreting this data to find the opening instant.

The purpose of this paper is to report a new measuring scheme which can replace the proximity probe to find valve opening instants. The device can pick up the valve opening instants much more accurately compared to the proximity probe methods. Related modifications of the valve system becomes much smaller, which also helps to obtain accurate results. Furthermore, the associated cost is only a fraction of the proximity probe device.

VALVE MOTION MEASUREMENT

Contact Sensor

The contact sensor consists of a copper bondable terminal attached to the valve with adhesive as shown in Figure 1, and a dc battery to provide a voltage. The principle behind this measurement method is elementary electric circuit theory. Since most of the elements of the compressor are metal, an electrical circuit can be completed when the valve makes contact with the "contact sensor" as seen in Figure 2. The valve acts like a switch. When the valve is closed, the circuit is closed and a voltage is measured across the resistance as shown. When the valve is opened, the circuit is open and the voltage across the resistance becomes zero. Because the circuit has no element with a sizable electric inertia, the response time becomes very fast, which makes it possible to pickup the opening instant very accurately.

Valve Plate Modifications

To install the contact sensors, modification of the valve plate is necessary. Channels are machined in the valve plate from the plate edge to both suction and discharge ports. These channels are used to locate insulated wires which are soldered to the contact sensors. The disruption of the original system is much smaller compared to using the proximity probe, because of the compact size of the whole device.

EXPERIMENTAL SETUP

A fractional horsepower compressor was modified for this experiment. Holes for the attachment of pressure transducers were needed, as was the machining of channels in the valve plate for the contact sensors. Crank angle was measured with respect to the TDC position by using a magnetic pickup. A bolted shell with a cable feedthough for the instrumentation was used because of the frequent need to open the shell. Three pressure transducers were installed, one each at the cylinder, discharge cavity and suction cavity.

Six signals; three pressure, two valve motions, and one magnetic pickup signal were simultaneously monitored using two, four channel HP35670A digital signal analyzers (DSA). The time window used was 32 milliseconds with 1024 time samples. The power supplies for the pressure transducers were provided by the DSA. The magnetic pickup's power supply was provided by an external amplifier. The power supplies for the two contact sensors were 9 Vdc batteries.

The operation of the compressor was facilitated through the use of a hot gas load stand. This stand provides several adjustments to set the compressor at specific operating conditions. It consists of a water cooled condenser and evaporator, a hot gas by-pass, and an adjustable superheat expansion valve.

RESULTS

Figure 3 shows valve lift as a function of crank angle, measured from the top dead center (TDC) position. Note that in Figure 3 the valve is in the closed position when the indicated voltage is approximately -8 Vdc. The valve is open when the indicated voltage suddenly jumps to 0 Vdc indicated voltage. In Figure 4 the valve signal is magnified around the opening instant. Compared to proximity probe signals reported in [2], the figure shows that the signal identifies the opening instant within one or two time intervals. Figure 5 shows the pressure as a function of crank angle, which can be converted to a P-V diagram without much difficulty.

Perhaps due to leakage in the prototype or in the test stand, the test was not able to be conducted in a typical operating condition of a refrigeration compressor. Also, we failed to obtain the signal from the suction pressure transducer, therefore the suction pressure was taken as constant in this work. The work necessary to remedy these problems is currently on-going.

Dynamic signals from the pressure transducers can be converted into absolute pressure levels in the following manner.

1) Multiply the dynamic pressure signals of the discharge and suction transducers by their gains. This provides the dynamic components of their pressures.
2) Add the average suction line pressure and the average discharge line pressure to the dynamic pressures which will provide the total suction and discharge pressures.
3) Scale and move the cylinder pressure signal so that it has the same pressure as the suction and discharge pressures at their respective valve opening instances.

In the process, the gain of the cylinder pressure transducer is calculated from the difference between the suction and discharge pressures, while the calibrated gains are used for the suction and discharge transducers. The final error in pressure diagrams caused by the transducer calibration can be minimized in this way [2].

CONCLUSION

Experimental pressure diagrams were obtained utilizing a new technique identifying valve opening instances more accurately. The device was designed as an electrical switch which makes a completed circuit only when the valve closes. The new approach showed several advantages, especially the following:

- Minimal disruption of valve system.
- Accurate identification of the valve opening instants.
- Very small size allows the cavity pressures and valve opening instants to be measured simultaneously.
- Reduced cost compared to proximity probe methods.

Actual valve motion time histories cannot be measured by this device since it captures only opening instances. Therefore, valve motion must be measured using proximity probes in addition to the P-V measurement if it is necessary. However, in small hermetic compressors, the valve motions and pressures usually have to be measured using separate compressors. This is because the typical small compressor does not have enough space for both sets of instrumentation. In such a case, the valve motion measurement may be done only for the purpose to study valve dynamics.

ACKNOWLEDGMENTS

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REFERENCES

[1] Werner Soedel, "Introduction to Computer Simulation of Positive Displacement Type Compressors," Ray W. Herrick Laboratories, School of Mechanical Engineering, Purdue University.

[2] J. Kim, W. Soedel, "On Experimental Errors in P-V Diagrams," Proceedings of 1986 Purdue Compressor Technology Conference, pp. 698-713.

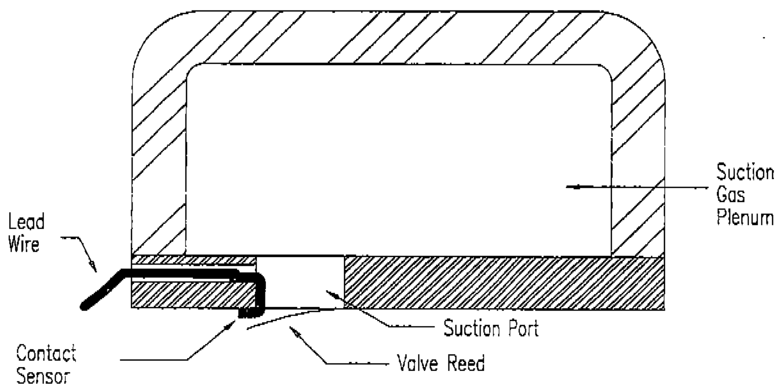

Figure 1: Contact Sensor Setup.

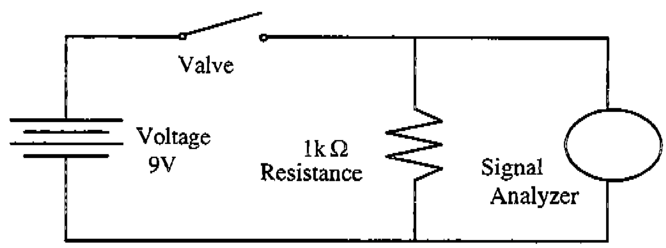

Figure 2: Contact Sensor Electical Circuit Setup

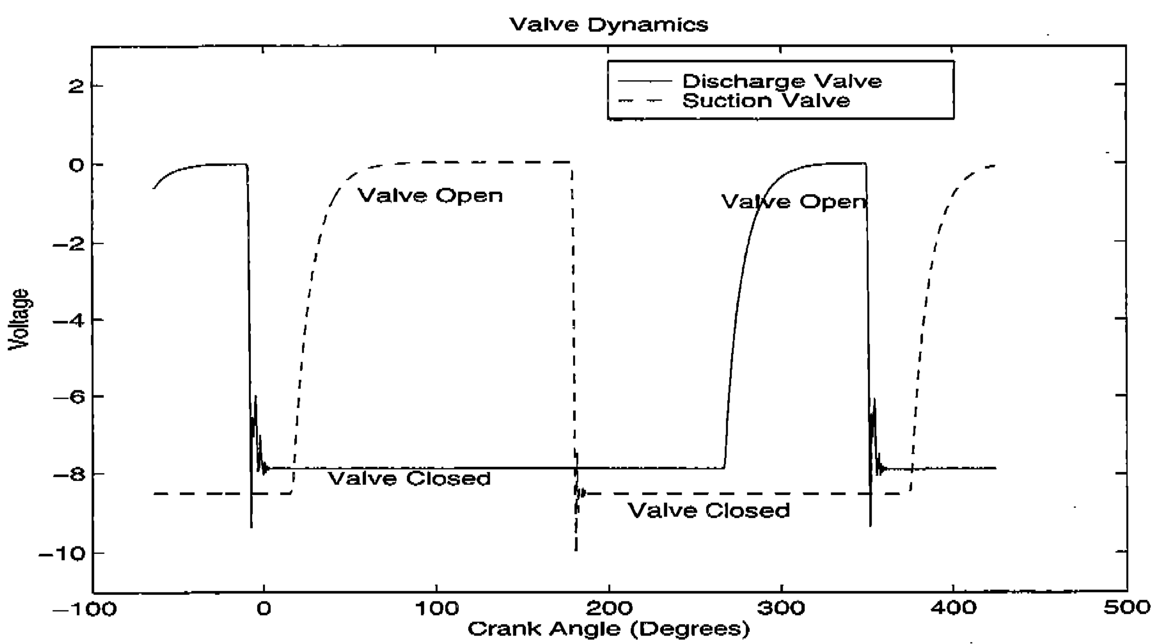

Figure 3: Measurement of Valve Lift

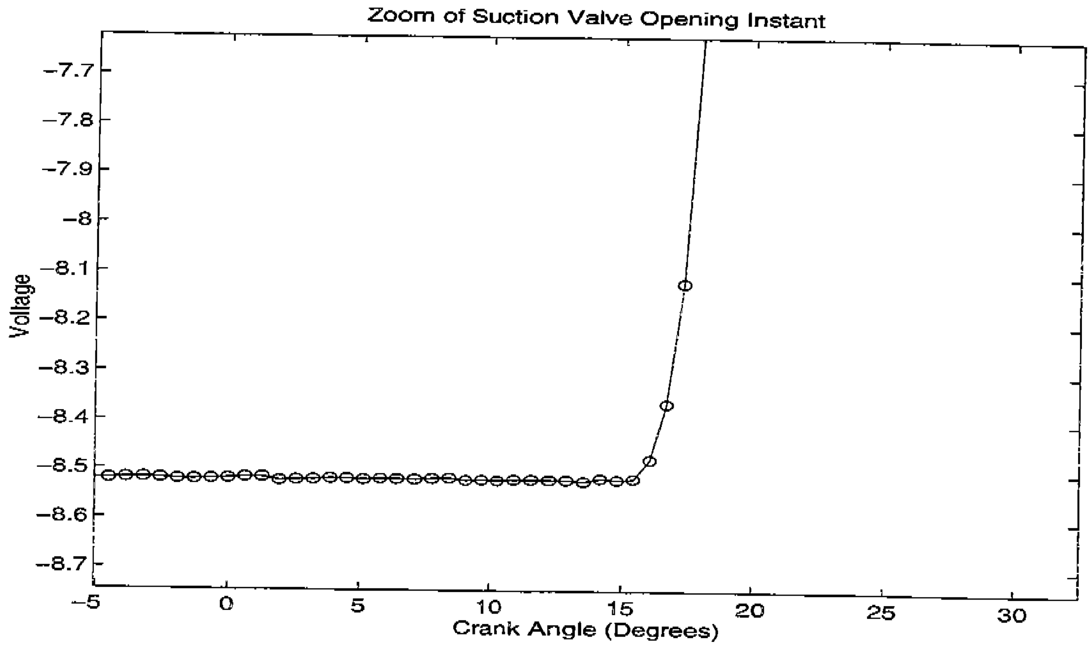

Figure 4: Zoom of Suction Valve Data at Instant of Valve Opening

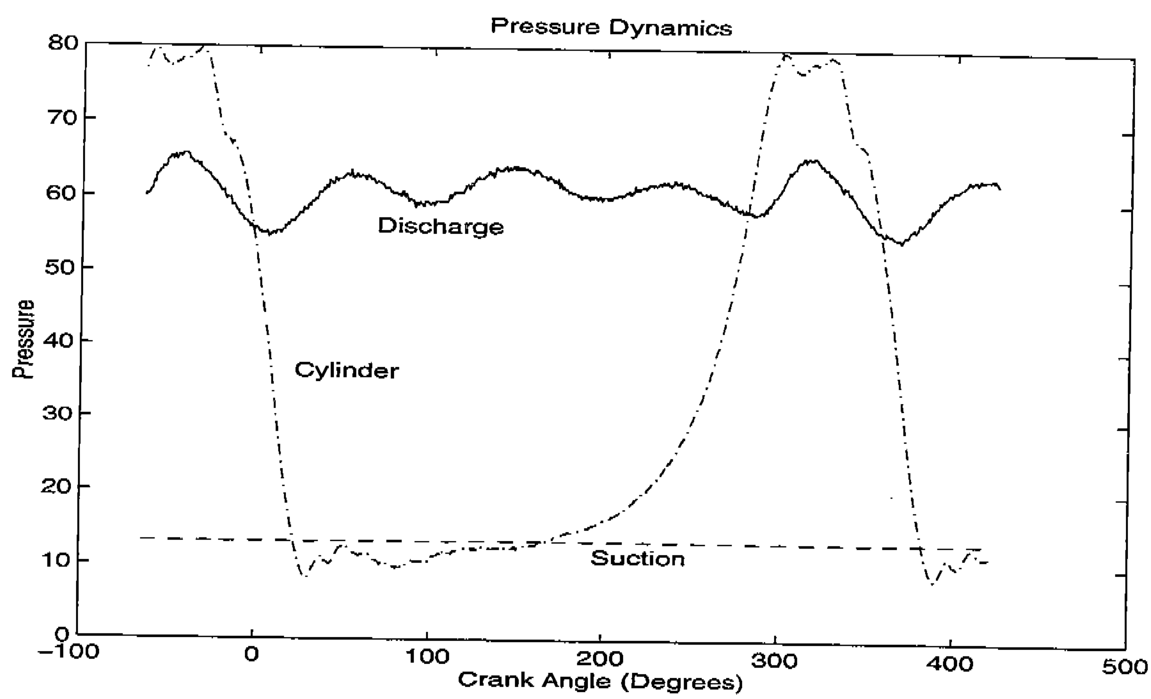

Figure 5: Compressor Pressure Data