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MEASUREMENT OF ORBITING SCROLL MOTION

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ABSTRACT

In a scroll compressor, the orbit path of the moving scroll is important to ensure an efficient product. Any deviation from a circle during running indicates a flank separation causing leakage and a loss of efficiency.

During compressor shutdown, the motion is also important as it is an indication of radial unloading and the pressure equalization time across the compressor. At startup, the motion indicates the relative speed of compressor loading and can increase or decrease starting torque requirements for the compressor.

Unfortunately, the orbit measurement can be difficult to make. This paper describes a method to measure the orbit using four cantilever beams. By fixing two beams to the bearing housing and two others to the oldham ring, with proper calibration the orbit can be referenced to the bearing housing.

INTRODUCTION

During the development of a new scroll compressor, it is vital to understand the motion of the orbiting scroll. Radial compliance is designed into the compressor to aid starting and debris management but is undesirable during normal running. A good understanding of the timing and amount of inward radial compliance after power interruption is desirable to ensure complete unloading of the scroll set.

Trapping a pressure difference across the scrolls, or the failure to relieve axial pressure loads, can easily lead to problems. The scroll set is designed to radially unload inward separating the flanks during a reverse rotation. The rotation is caused when the pressure trapped in discharge plenum by a ball check-valve equalizes with the lower shell pressure in the compressor. During this time interval the axial load is relieved when an intermediate cavity seal releases clamping pressure. An assembly cross-section is included as Figure 1.

During a recent development program, the question arose as to the exact behavior of the orbiting scroll during several operating conditions. Testing indicated the compressor was not responding as expected leading to slow pressure equalization and increased noise. An understanding of the scroll behavior was required to assist in the solution to the dilemma.

APPROACH

Several instrumentation approaches were available to measure the orbit path. Initially proximity probes were seriously considered. One major problem with these types of sensors is the motion of the orbiting scroll relative to a sensor mounted on the shell. The tangential velocity of the scroll past the sensor makes accurate measurements difficult.
The approach chosen utilized thin steel cantilever beams in contact with the moving parts. Each beam initially had four strain gages, wired in a full bridge configuration, attached near the fixed end. As the beam tip bent, the strain gages responded to the bending moment. By calibrating each bridge based upon tip motion, the displacement of the tip can be determined. After several tests, a single strain gage was found adequate for the measurement.

The beams were designed such that strain signals would give satisfactory movement resolution. Special care was taken to ensure the natural vibration frequency of the beam was above the running frequency of the compressor. No oscillation problems were encountered with the beams during testing. As a further precaution the scroll and oldham ring surfaces on which the beams rode were machined smooth.

The oldham ring moves in a linear path with respect to the main bearing housing. By attaching motion beams to the bearing housing, the position of the oldham ring is determined. The beams must be in continuous contact with the oldham ring to measure the position. Two were used to balance the small pre-load necessary for contact in an attempt to minimize interference with natural motion.

Next, two beams were attached to small, light blocks mounted on the oldham ring. These were in continuous contact with the orbiting scroll. The orbiting scroll translates linearly with respect to the oldham ring. Thus by allowing these two beams to move with the oldham ring the orbit was determined. Figure 2 is a photograph of one such beam affixed to the oldham ring, contacting the orbiting scroll, with the mating scroll removed for clarity. Figure 3 shows the same beam in place as tested. Note these two photographs do not show the bearing housing beams.

The main bearing beams were calibrated by pushing the oldham ring through the entire range of motion and recording linear position and strain. Similarly the beams on the oldham ring were calibrated moving the orbiting scroll. A quadratic relation between position and strain yielded optimum results for both beam sets. By using the oldham ring displacement as the abscissa and the orbiting scroll displacement as the ordinate, a plot of the orbit can easily be visualized.

**RESULTS**

The orbit path, when plotted, is circular with any deviation easily discernible. Figure 4 shows one test run where the orbiting scroll, after an initial stop, gently reverses direction and halts with the flanks unloaded. These test results occurred at a compression ratio of 2.32. The orbit track is comparatively smooth and reproducible with minor aberrations near the extreme limits of the orbit. These are attributed to beam end effects.

Figure 5 shows another example of radial unloading. In this case, with a compression ratio of 3.86, the orbiting scroll made almost a complete reverse rotation prior to a final stop. It is noteworthy that the flanks came close to reloading during the reverse rotation. Other tests, not included, showed results where the orbiting scroll first unloaded, reloaded and ran several revolutions in the reverse direction. Reverse rotation can be up to one and one-half times the forward speed.

The sixth figure is an example of little to no radial unloading at a compression ratio of 2.56. Obviously this stop occurred with the flanks in contact that may delay pressure equalization.

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CONCLUSIONS

The technique has proven effective when questions arise as to the scroll set orbit. Unloading and other phenomena are easily seen as a first step to understanding of hardware revisions. Alternate uses include the measurement of scroll tracking as well as unpowered speed measurements.

Figure 1. Cross Sectional Drawing of Scroll Compressor
Figure 2. Orbiting Scroll Motion Beams

Figure 3. Orbiting Scroll Motion Beams in Position
Figure 4. Scroll Orbit and Stop for 2.32 Compression Ratio

Figure 5. Scroll Orbit and Stop for 3.86 Compression Ratio
Figure 6. Scroll Orbit and Stop for 2.56 Compression Ratio