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The Rotary Screw Compressor

By Todd Duncan

urprisingly enough, the rotary screw compressor was invented in 1878. However, commercial application developed slowly because of its inability to match tight tolerances with existing manufacturing equipment of the time. Over the past 10 years, several manufacturers have introduced chillers with rotary screw compressors and have moved away from older reciprocating technology. Rotary screw compressor technology offers many benefits over reciprocating types, including higher reliability and improved performance. In addition to these benefits, some noteworthy characteristics make the rotary screw compressor the compressor of choice for future chiller developments and designs.

Basic Operation

There are two different rotary screw compressor designs. One is a twin rotary screw design, in which there is a male and a female rotor that mesh together (see *Figure 1*). The other is a single rotary screw design, in which two gate rotors are placed on both sides of the main compressor rotor (see *Figure 2*).

The twin rotary screw design works in the following fashion. As the male and female rotor unmesh, refrigerant gas is drawn into the void. Compression begins when the male rotor meshes with the female rotor, trapping the suction refrigerant gas. The occupied volume of the trapped gas is reduced, thus increasing the pressure. The discharge port is uncovered, and the compressed gas is discharged into the high pressure side of the system.



The single rotary screw design compresses gas somewhat differently. Intake begins with refrigerant gas filling the flute of the rotor. The gate rotors act as aspirating pistons and trap the refrigerant gas. The rotor continues to turn and the occupied volume of gas is reduced, thus increasing pressure. Compression ceases when the edge of the rotary screw and the edge of the discharge port coincide. At this point, the compressed gas is released into the high pressure side of the system.

Fewer moving parts on rotary screw compressors have produced increased reliability over their reciprocating predecessors. Connecting rods and valves, integral components to the reciprocating compressor design, can be easily damaged or broken with a slug of liquid refrigerant. Most rotary screw compressors can handle limited amounts of liquid slugging without damaging the compressor. A larger degree of superheat is required to prevent liquid slugging on reciprocating compressors. On the contrary, rotary screw compressors can run with only 4°F to 10°F (2°C to 6°C) of superheat. This correlates into savings in heat exchanger size and energy efficiency improvements.

Installation

Rotary screw compressor machines are different than reciprocating compressor machines of the past. Their inherently smaller size leads to easier retrofit applications. However, there are a few important installation differences to address. The rotary screw compressor discharges refrigerant gas at different pulsations than does a reciprocating compressor. This equates to different frequencies of sound and vibration from the unit. Placement of the compressor should be next to noncritical areas, such as mechanical rooms, copy rooms, storage rooms or any other nonoccupied areas.

If these installation criteria cannot be met, take precautions such as installing the chiller on neoprene or elastomeric isolators. These provide better attenuation of vibration transmission to the building structure than do spring isolators. Adding elastomeric pipe vibration eliminators rather than metal braided ones also attenuates high frequency vibration from traveling down the water piping.

Troubleshooting

Troubleshooting a chiller with a rotary screw compressor is different from standard troubleshooting practices for reciprocating compressors. All manufacturers have different control models. The following tips can be used regardless of

About the Author

Todd Duncan is a marketing engineer for the Water Chiller Systems Business Unit of The Trane Company. Duncan is a graduate of the University of Wisconsin-Madison with a bachelor of science degree in mechanical engineering. manufacturer type. If an equipment room operator is unfamiliar with troubleshooting chillers with rotary screw compressors, most OEMs provide training courses on servicing their specific chiller.

Typically, most rotary screw chillers have state-of-the-art microprocessor controls. With these advanced controls, additional safeties are built into the chiller to protect it from adverse conditions. In addition, the control logic will lead an operator to the problem by producing a diagnostic code or characters on a display. Electro-mechanical controls typically had components in series that led many operators astray in determining a problem. Time to discover the problem was doubled or tripled if a component failed on the older electromechanical controls.

Oil protection is one such example. On reciprocating chillers, a relay coupled with a timing function constituted the oil protection function. If either the relay or timer failed, the source of the problem was probably an oil loss, a relay/timer failure or any other component upstream. Today, most manufacturers use a switch or temperature/ pressure measurement to send a signal back to the microprocessor. This removes multiple parts and components operating in series, while reducing troubleshooting time.

Today's rotary screw designs are easier to troubleshoot from another perspective. Liquid refrigerant solenoid valves used for periodic pumpdown on reciprocating designs had a tendency to leak. If the valve leaked, refrigerant would flow back into the compressor. This problem would be virtually undetectable until the compressor failed from a slug of liquid refrigerant.

Most maintenance manuals provide typical operating ranges and suggest checking various temperatures and pressures on a regular basis. Suction superheat, a variable used extensively in troubleshooting, is dissimilar between a rotary screw and a reciprocating chiller. For example, on a rotary screw chiller 4°F to 10°F (2°C to 6°C) of superheat at full load conditions illustrates normal operation. However, on a reciprocating design, 4°F to 10°F (2°C to 6°C) of superheat may indicate a column of liquid due to an open expansion valve or another problem. However, subcooling temperatures remain similar at full load conditions (12°F to 20°F [7°C to 11°C]) and can be product dependent.

These benefits provide the customer with a more reliable system than the previous generation of reciprocating chillers. Some equipment room operators are accustomed to working with reciprocating technology, thus it may take time before they are comfortable with working on rotary screw designs.



Figure 1: Dual-rotor rotary screw compressor.



Figure 2: Mono-rotor rotary screw compressor.

Maintenance

Any type of equipment will require maintenance. However, equipment that has fewer moving parts will be less susceptible to scheduled maintenance and repair. Various rotary screw compressors have different maintenance requirements. It is best to contact the compressor OEM for maintenance information.

Typical reciprocating compressors have several internal oil lines and O-rings compared to rotary screw compressor designs. These delicate reciprocating parts have the tendency to crack or break, mandating compressor replacement. In addition, reciprocating chillers have more parts that increase the number of piping joints susceptible to leaking.

Unlike rotary screw compressors, reciprocating compressors require an overhaul approximately every five years. Rebuilding a compressor requires a clean environment to prevent debris from entering into the system. It is impossible to replicate factory conditions, such as temperature-controlled clean rooms, in the field. Therefore, the possibility of debris entering into the system is possible and eventually can lead to premature compressor failure.

Overhauls include replacement of the main bearings, crankshaft, crank pin, piston pin, cylinder pin, piston rings, valves,

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valve springs, O-rings and seals on reciprocating compressors. Replacing these components requires extensive compressor knowledge that many people may not have. One experienced technician said that most people do not even bother with the overhaul because it is cheaper to allow the compressor to operate until it fails and then replace it. Rotary screw compressors do not require scheduled rebuilds or overhauls.

Regardless of compressor type or manufacturer, a yearly oil analysis should be conducted. At start-up, an oil sample should be sent to a qualified lab so that the results can be used as a benchmark. Each year this analysis should be completed and changes in compound traces should be noted. Many problems can be discerned from an oil analysis including a contaminated system, premature failure or incorrect servicing.

Replacement parts on reciprocating compressors may become more difficult to find. Parts may be discontinued due to availability or from the loss of part numbers (unless they have been captured on databases).

Conclusion

The rotary screw compressor has advanced since its inception in 1878. Current manufacturing machinery is able to produce tolerances capable of properly sealing the compression cycle of a refrigeration system. Advanced machining capability coupled with innovative design opportunities will allow continuous design improvements resulting in more energy efficient machines in the future. The industry has drifted away from reciprocating compressors and has embraced rotary screw compressor technology as a result of increased reliability, simplified design and reduced maintenance. These benefits have been acknowledged not only by satisfied customers and by manufacturers.

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