

Screw Compressors: Types, Application Range And Control

Written by Heinz P. Bloch, P.E. Contributing Editor
Tuesday, 01 January 2008 00:00

Part I of II...

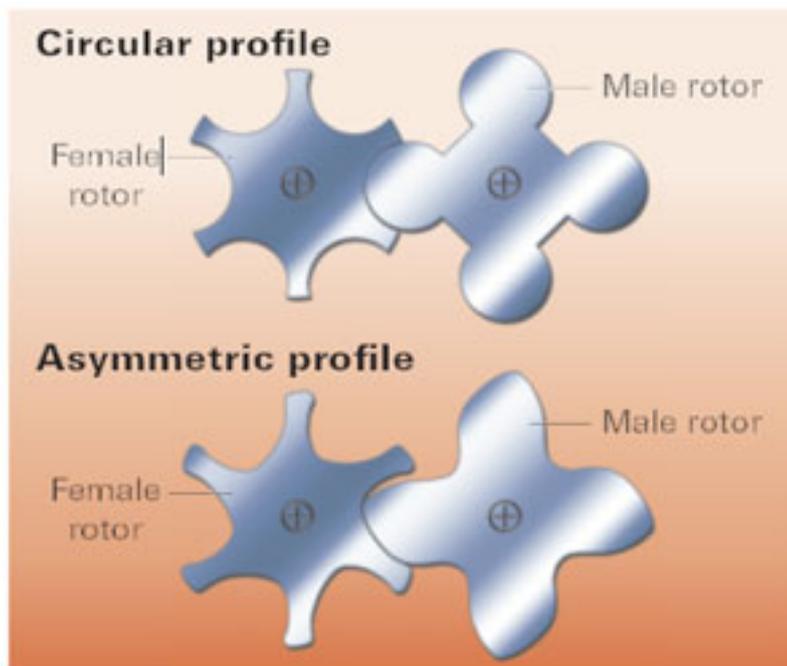


Fig 1. Typical screw compressor rotor profiles

The point of this two-part article is to alert the reader to the (often considerable) merits of twin-screw rotary compressors and to set the record straight on wet screw machines. For both dry screw and wet screw compressors, typical rotor profiles are shown in Fig. 1. These machines represent a sub-set of the machinery group making up rotating positive-displacement compressors. Of the various machines available, twin rotary screw compressors are used primarily in higher pressure air and process gas services, the subject of this article, whereas certain other rotary piston blowers and single-screw compressors are often used in lower pressure, high-volume applications. They are not covered here.

Rotating positive-displacement machines (like the one shown in Fig. 2) offer the same advantage as reciprocating positive-displacement equipment with regard to flow vs. pressure relationships, i.e., nearly constant inlet flow volume under varying discharge pressure

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conditions. Unlike centrifugal and axial machines, screw compressors do not have a surge limitation. Thus, there is no minimum throughput requirement for rotating positive displacement compressors.

The rotor tip speeds on rotary screw and rotary piston blowers are low; this allows for liquid injection or liquid flooding, which facilitates handling of contaminated gases. By design, the rotors are self-cleaning during operation, but contaminants must be kept away from the bearings. Likewise, dirt in the compression space has to be removed by filtration or other means.

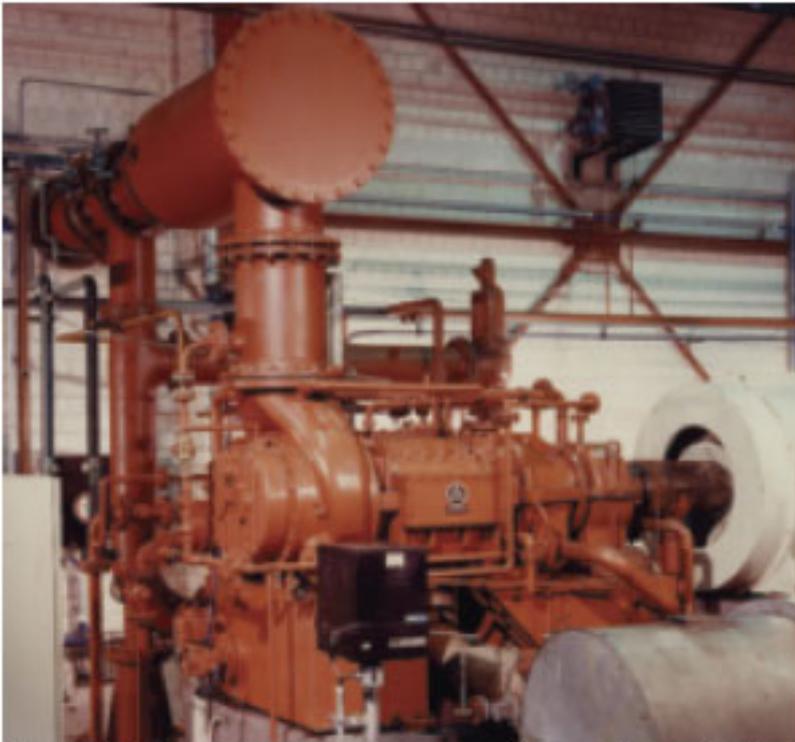


Fig. 2. Mid-size twin-screw compressor (Source: Aerzen USA, Coatesville, PA and Aerzen, Germany)

Oil-free vs. oil-flooded models

Rotary screw compressors are available in oil-free or oilflooded construction. Technically speaking, oil-free refers to not having oil in the compression space, but bearings still require lubrication by a clean medium. This lubricant is typically clean oil, although clean pressurized water can also be used [Ref. 1]. In fact, while pressurized water represents less well-known advanced technology, it has nevertheless been applied for decades. In the hands of truly competent compressor manufacturers, water-flooded screw compressors have been remarkably effective and successful in some of the dirtiest services [Ref. 1].

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While oil-free twin-screw compressors are widely called dry screw machines, at least one prominent manufacturer defines and designates as “dry screw” any screw compressor equipped with timing gears. Therefore, whether the compression space is dry, oil-flooded or water-injected makes no difference: With timing gears keeping the two screws synchronized, it should be labeled a dry screw machine. Without timing gears, it cannot function as a dry screw machine, because the resulting contact of mating rotors would destroy the machine. If there are no timing gears, a separating liquid must be used. Any separating liquid circulating in the compression space will make it a wet screw machine [Ref. 2].

Fields of application for oil-free machines include all processes that cannot tolerate contamination of the compressed gas or where the lubricating oil would be contaminated by the gas. Oil-flooded machines can achieve slightly higher efficiencies than “dry screw” machines and can utilize the oil for cooling as well [Ref. 3]. The same statements could be made for water-flooded machines. In some instances, the bearing lube circuit must be totally separate from the fluid circuit used in the compression space. Whenever this requirement is disregarded, the purchaser/user may end up with either high maintenance costs or low equipment reliability.

Properly designed rotary screw compressors are constructed with no metallic contact whatsoever inside the compression chambers, either between the rotors themselves or between these and the walls of the housing. Although originally intended for air compression, rotary screw compressors are now found in numerous services in the petrochemical and related industries. These include air separation plants, industrial refrigeration plants, evaporation plants, mining and metallurgical plants.

Practically all gases can be compressed: ammonia, argon, ethylene, acetylene, butadiene, chlorine gas, hydrochloric gas, natural gas, flare gas, blast furnace gas, swamp gas, helium, lime-kiln gas, coking-plant gas and carbon monoxide gas can be compressed with screw machines. The same is true for all hydrocarbon combinations; town gas, air/methane gas, propane, propylene, flue gas, crude gas, sulfur dioxide, oxide of nitrogen, nitrogen, styrene gas, vinyl chloride gas and hydrogen gas can be found on the reference tabulations of experienced manufacturers.

One manufacturer alone has at least 20 oil-flooded twinscrew compressors in successful service with three years between shutdowns. While process conditions vary widely, there are perhaps several manufacturers with similar experience. Their compressors may not be lowest installed cost, but they usually represent best value and lowest possible life cycle cost by wide margins.

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Application ranges

Application limits for rotary screw compressors are set by the pressure and temperature ranges and by the maximum allowable speeds of the machines. Oil-free rotary screw compressors can be mechanically loaded with pressure differences up to 12 bar, and oil-flooded compressors up to 20 bar. Higher pressure differences are possible in special cases. Flow volumes up to 60,000 m³/hr (~35,000 acfm) have been accommodated in these compressors.

The maximum allowable compression ratio for one twin-screw compressor stage is that which will not cause the final compression temperature to rise above the permitted value of 250 C (482 F). This compression ratio and the associated temperature will to a very large extent depend on the specific heat ratio (c_p/c_v) of the gas to be compressed. For example, where the specific heat ratio (c_p/c_v) equals 1.4, the maximum compression ratio would be approximately 4.5, and where the specific heat ratio (c_p/c_v) equals 1.2, the maximum compression ratio would be approximately 10 for an oil-free twin-screw compressor stage.

Multistage (multi-casing) arrangements are not uncommon and can result in pressure ranges from approximately 0.1 bar absolute to 40 bar. Even 100 bar has been reached in some instances. Interstage cooling is used in many of these applications. Depending on compressor size, speeds from 2000 to 20,000 rpm can be encountered. The limiting factor is often the circumferential speed of the male rotor, which typically ranges from 40 to approximately 120 m/sec, and up to a maximum of 150 m/sec for very light gases.

Volume control

In principle, it is necessary to consider the volume-control options for dry-running and for oil-injection-type screw compressors separately.

Controlling dry screw compressors...

- Control by variable speed Because screw compressors displace the medium positively, the most advantageous volume control strategy is to vary the speed. This may be done by using variable speed electric motors, steam turbine drive, hydraulic or hydro-mechanical torque

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converters and other means.

Speed may typically be reduced to about 50 percent of the maximum permissible speed. Induced flow volume and power transmitted through the coupling are thus reduced in roughly the same proportion. The allowable turndown depends on the adequacy of bearing lubrication at low speed and on the compressor discharge temperature. Even a 70 percent flow reduction is possible in special cases. In other words, the throughput is curtailed to as low as 30 percent of normal. As mentioned earlier, there is no surge limit (a minimum flow below which the gas would alternate between forward and reverse flow) for these positive displacement machine.

- **Bypass** Using this method, the surplus gas volume is allowed to flow back to the intake side by way of a compressor discharge pressure controller. An intermediate cooler brings the surplus gas volume down to intake temperature.

- **Full-load/idling-speed governor**

As soon as a predetermined final pressure is attained, a pressure controller operates a diaphragm valve that opens a bypass between the discharge and suction sides of the compressor. When this occurs, the compressor idles until pressure in the system drops to a predetermined minimum value. The valve will close once again on receiving an impulse from a pressure sensor. This brings the compressor back to full load.

- **Suction throttle control**

This method of control is suitable for air compressors only. As in the case of the full-load/idling-speed control method, a predetermined maximum pressure in the system, for example in a compressed air receiver, causes pressure on the discharge side to be relieved down to atmospheric pressure. Simultaneously, the suction side of the system is throttled down to about 0.15 bar absolute pressure. When pressure in the entire system has dropped to the permissible minimum value, full load is once again restored.

Controlling oil-injected screw compressors...

- **Suction throttle control**

Since the final compression temperature is governed by the injected oil, a greater range of compression ratios can be accommodated. This permits the main flow volume to be varied within wide limits.

- **Built-in volume governor**

Large compressors are frequently equipped with an internal volume-regulating device. A slide valve that is shaped to match the contours of the housing is built into the lower part of the housing. It is designed to move in a direction parallel to the rotors, whereby the effective length of the rotors can be shortened. The range of this control mode is typically between about 10% and 100%. Compared with suction throttling, this type of control offers more efficient operation.

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Coming in Part II

The concluding installment in this series will discuss oilfree vs. oil-flooded rotary screw compressors and available seal design options.

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