HIGH PRESSURE, HIGH STANDARDS

Takao Koga, KOBELCO EDTI COMPRESSORS, INC., USA, examines high pressure screw gas compressors.

Now there is good news for the oil and gas, refining, petrochemical, gas separation and power industries. The good news is that high pressure screw gas compressors (API-619) are now available up to the high pressure range of 100 barG (1500 psiG), allowing the high pressure screw compressor to cover most of the traditional reciprocating compressor applications, and also some applications handled by small centrifugal compressors. It means that industries can fully enjoy the higher reliability and long term continuous operation with lower maintenance offered by the high pressure screw gas compressors, without suffering from difficulties due to the frequent maintenance required by reciprocating compressors. The high pressure screw compressor also provides for suitable operation compressing low molecular weight gases (such as hydrogen) and changeable process conditions, not generally suitable for centrifugal compressors.

Traditionally, (1) reciprocating compressors (API-618) have been recognised as suitable for high pressure, middle/small gas flow rates and low molecular weight gas service. (2) Centrifugal compressors (API-617) have been recognised to be suitable for larger gas flow rates, middle pressure, low pressure ratio and heavier molecular weight gas service. (3) Screw compressors (API-619, oil injected type) have been recognised to be suitable for middle/low pressure, high pressure ratio, middle gas flow rate and low molecular weight gas (even pure hydrogen) services. Conventionally, screw compressors (oil injected type) have been mainly used for process refrigeration service and other middle pressure services, in the range of up to 30 barG (430 psiG), as well as for low pressure hydrogen services, which are generally in the range of approximately 10 barG (150 barG) (Figure 2).

Typical screw gas compressor

Figure 1 is a cutaway drawing of a typical oil injected screw gas compressor. There are two rotors inside the casing and they contact each other at lobe surface via an oil film.

Oil is supplied not only to the bearing and seal, but also to the rotor chamber directly and oil will act as lubricant, coolant and sealant in the rotor chamber. Typically, the male rotor is driven by a directly coupled 2 pole or 4 pole electric motor and drives the female rotor. An external gear unit is typically not used, since the tip speed of the oil injected screw gas compressor is in the proper design range when driven at motor speed.

Since oil is injected into the rotor chamber, the seal area between the lobe and bearing is no longer necessary. There is one mechanical seal located at the drive shaft end. There are typically sleeve type journal bearings on either end of the rotor lobes. Thrust bearings are typically tilting pad type and are located on the outer side of the journal bearings. The oil and gas mixture is discharged through the compressor discharge nozzle into an oil separation system located downstream of the compressor. Oil separated in the oil separation system is circulated in the compressor lube system.

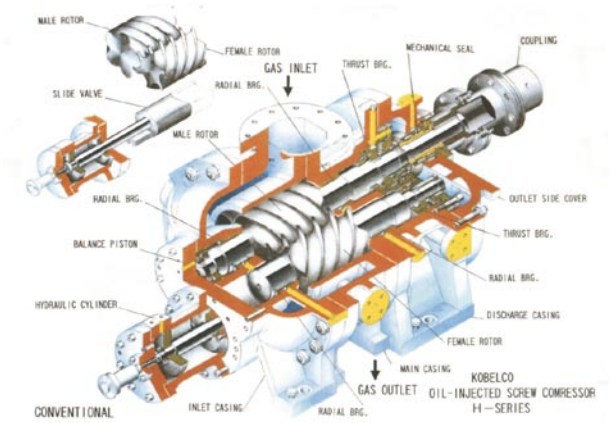

Figure 1. Oil injected screw compressor.

Figure 2. Hydrogen tail gas for pressure swing adsorption (PSA) process.

As a quite unique built-in mechanism, a slide valve is used to load and unload the compressor to maintain suction pressure or discharge pressure. There is a spool valve to switch over the oil lines to pressurise the slide valve cylinders to load side or unload side. Typical control range by the built-in slide valve is from 15 - 100% stepless by inlet volume.

As a summary, the general benefits of oil injected screw compressors are well known in the market, and are as follows:

- High reliability. No spare compressor required even for continuous operation.
- Less maintenance. Very few wearing parts: mechanical seal (less running costs).
- Continuous operation for a long time. Longer overhauling interval.
- No compression ratio limitation. Extremely high compression ratio can be handled by single stage.
- Simple structure (less initial cost).
- Simple system (no gear, no seal gas unit).
- Tremendous power savings. Easy turndown control by built-in slide valve (from 15 - 100% without any step).
- Low noise. Easy to achieve 85 dBA at 3 ft (1 m).
- No pulsation and vibration issues.
- No emission issues.
- No passing critical speed (screw compressor has a rigid shaft).
- Almost no influence of gas composition change (positive displacement).

Unique characteristics

Here is a list of some of the major and unique characteristics of the oil injected screw gas compressor, which create great benefits to the users.

Power consumption savings by built-in slide valve

The slide valve as an unloader adjusts the inlet volume of the compressor and this equates as power savings. A slide valve is located just beneath the rotors and moved in axial direction. The slide valve is moved typically by a hydraulic cylinder with oil utilised from the compressor lube oil line. Moving the slide valve to the suction side attains full load and unloading is achieved by moving the slide valve towards the discharge port. At full load position, the entire length of the rotor is utilised to draw the gas so that inlet volume of the compressor can be maximised. By moving the slide valve to the unloaded position (i.e. discharge side), the length of the compression chamber is shortened. As a result, inlet volume of the compressor is reduced. Compression is done with less inlet volume of the compressor so that theoretical brake horsepower is reduced.

High compression ratio limitation

Since the oil acts as coolant and sealant, the limit on compression ratio is very high. Discharge temperature can

be adjusted by oil flow rate, i.e. oil can be injected into the rotor chamber to absorb the compression heat in the oil injected screw gas compressor.

When a very high pressure ratio is required, a tandem arrangement of two stage compressors combined in one casing is employed to improve efficiency. Typically, this tandem arrangement is used when pressure ratio is larger than 7:1 and can be applied to ratios of more than 50:1. Since oil will act as a coolant at the intermediate stage, an external inter cooler for this stage is unnecessary.

Low maintenance cost

Thanks to the lube oil system, the rotors and many other parts of the compressor have an oil film on their surfaces. The life of the rotors is long enough so that a spare set is not required. The mechanical seal is typically one per casing and the total structure of the compressor is quite simple so that the maintenance cost is quite low.

Variety of oil selection to meet the handled gas

Lube oil is selected by the need to be compatible with process gas. Not only mineral based oil, but also synthetic oil has recently been used to expand the application range of oil injected screw gas compressors. Hydrotreated mineral based oil has typically been used, but recently many are changing to synthetic oil.

For a process with a heavy hydrocarbon, mineral based oil is subject to dilution, however, less dilution can be expected with poly alkylene glycol synthetic oil (PAG).

PAG is hygroscopic, however, it has extremely less dilution for heavy hydrocarbon compared to mineral oil. By using PAG synthetic oil, oil injected screw gas compressor can be used for heavy hydrocarbon applications as well.

Thanks to the well known benefits described above, oil injected screw compressors have been developed for various applications of process gas services since the 1970s.

High pressure screw gas compressor

Since the late 1990s, KOBELCO has performed extensive design and research while developing the first high pressure screw gas compressor (API-619), which could achieve up to 60 barG (860 psiG). This was accomplished when KOBELCO introduced its new rotor profile, known as the 5+7 lobes arrangement (Figure 3). As a result, the KOBELCO high pressure screw gas compressors have been welcomed within a variety of industries and are now used more frequently for various process gas services, mainly replacing the previous services delegated to reciprocating compressors (API-618), as well as replacing some services previously delegated to small centrifugal compressors (API-617). For example, high pressure screw gas compressors are used for fuel gas boosting services for highly efficient aeroderivative gas turbines (Figure 4a); hydrogen services for gasoline desulfurisation unit (GDU) processes; steam methane reformer (SMR) processes; platformer, continuous catalytic reformer (CCR) processes and so on (Figure 4b). The specific benefits provided by screw gas compressors include: more reliable, longer maintenance free intervals of operation; lower noise and lower emissions mean they are more environmentally friendly; screw compressors allow for a smaller installation area and a less complex foundation is required. Screw compressors are more flexible in handling variable and changing operating conditions (turndown, gas pressure changes, gas composition changes, etc.) In addition, the screw gas compressor provides tremendous power savings via the built-in slide valve mechanism, and can also manage to achieve tight limits on the oil content in the discharge gas, typically in the range of 0.1 ppm by weight. Tighter requirements in the ppb level can also be supplied utilising KOBELCO's sophisticated oil separation systems with many successful experiences, especially for catalytic processes.

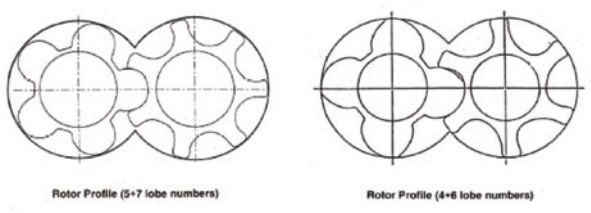

Figure 3. Rotor profile comparison. High pressure 5+7 lobes and conventional 4+6 lobes.

Figure 4a. Fuel gas booster for aeroderivative gas turbine (GE LM6000).

Figure 4b. Hydrogen booster for refinery continuous catalytic reformer (CCR) process.

Figure 5. Higher pressure (70 bar = 1000 psiG) screw gas compressor package.

Due to the tremendous advantages offered by the high pressure screw gas compressor, its use and list of successful applications are growing. High pressure screw gas compressors continue to be utilised for many new applications requiring high pressure gas compression within various industries.

After the established good reputation of the high pressure screw gas compressors since the late 1990s, and further demand for high reliability and low maintenance operation from industries, starting in the middle of 2000s, KOBELCO developed higher pressure screw gas compressors (API-619), which are now available up to the pressure range of 100 barG (1500 psiG). This was accomplished by adding the technically essential key elements, such as rotors, seal and bearings. As a result, the high pressure screw gas compressor now covers most of the traditional refinery process gas applications, such as hydrogen make-up and recycle services for ultra low sulfur diesel (ULSD) process and hydrotreating process, previously handled by reciprocating and smaller centrifugal compressors, as well as the higher pressure requirements of the newer, most efficient gas turbines throughout the world.

KOBELCO has already delivered several sets of higher pressure screw gas compressor packages to industries in the US and Canada, with process required discharge pressures in the range of 70 barG (1000 psiG) (Figure 5).

Conclusion

The positive displacement screw gas compressor continues to offer the original great design benefits, such as higher reliability; lower maintenance; environmental friendliness; flexibility for changeable operating conditions; plus power saving by the slide valve mechanism. In addition, higher pressure screw gas compressors can now bring even more benefits to the customer for a much wider range of applications in the oil and gas, refining, petrochemical, gas separation and power industries. The screw gas compressor is expected to remain an industry standard for various process gas services in industries for pressure services to 100 barG (1500 psiG).