World's Largest Capacity Oil-free Screw Compressor, MODEL KS80

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Large capacity oil-free screw compressors are mainly used in petrochemical plants such as styrene monomer and linear alkyl benzene plants, where suction and discharge pressures are relatively low and a large capacity is needed. Recently, these plants have tended to become larger and the capacity required of the compressor has also tended to increase. To satisfy such a market needs Kobe Steel has developed the world's largest capacity oil-free screw compressor, MODEL KS80, using the design technology and manufacturing technique of the large screw compressor. In this paper, the design concepts and features of MODEL KS80 are introduced.

Introduction

Kobe Steel's oil-free screw compressors are widely used for process gases in various industrial fields, such as petrochemistry, general chemistry, petroleum refining and the gas industry. Large capacity oil-free screw compressors, which work at low pressures, are used in petrochemical plants. Examples are found in the production of styrene monomer and linear alkylbenzene. The former is used as the raw material for, e.g., polyester resin, synthetic rubber and styrene resins, while the latter is used as synthetic lubricant and as the raw material for detergents. Kobe Steel has delivered many oil-free screw compressors, including EX-series compressors, which have large capacities and are designed for the low pressure required by those applications.

Recently, as styrene monomer plants have become larger, the required flow rate in the process stream has increased. In response to market needs, Kobe Steel has developed an oil-free screw compressor for process gas, MODEL KS80, which has the world's largest volume capacity. This paper introduces the design concepts and features of the newly developed MODEL KS80.

1. Applications

The following are the typical applications of large oil-free screw compressors:

- off-gas compressors for styrene monomer plants
- recycle gas compressors for linear alkylbenzene plants.

These applications may involve

1) large capacity
2) low discharge pressure
3) gas containing foreign matter
4) the possible polymerization of the monomer during compression and
5) water injection into the compressor chambers for suppressing the temperature rise caused by gas compression and for removing foreign matter from the gas.

The MODEL KS80 compressors are designed to satisfy these requirements.

2. Design specification

Table 1 compares the displacement volume of KS80LZ, the standard type of MODEL KS80 compressor, to that of KS63EX, the largest machine among the Kobe Steel's EX-SERIES compressors. KS80LZ has a pair of rotors, the size of the world's largest class, and achieves a displacement volume 20% above that of the KS63EX for a given rotor circumferential velocity.

The following describes the features of MODEL KS80.

2.1 Nozzle arrangement

As shown in **Fig. 1**, MODEL KS80 has suction and discharge nozzles, both directed downward. The advantages of this arrangement are as follows:

1) It enables to simplify the arrangement of a large silencer and piping in the same direction;
2) It does not require dismounting of the silencer and the associated piping from the compressor when compressor needs to be dismantled, which improves the workability for maintenance and other jobs; and
3) The discharge nozzle, directed downward, promotes the drainage of water injected inside the rotor chamber, as well as the discharge of

Table 1 Comparison of theoretical displacement volume at same tip speed

Specification	KS80LZ	KS63EX
Male rotor speed (rpm)	3,675	4,570
Theoretical displacement volume (m^3/h)	96,000	80,000

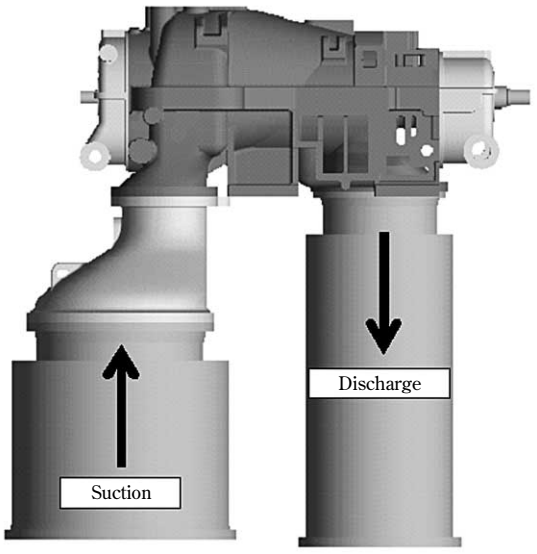

Fig. 1 Compressor nozzle layout of MODEL KS80

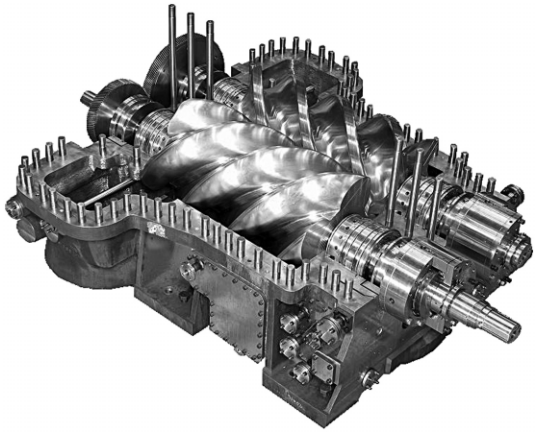

Fig. 2 Horizontally split compressor casing

solvent and foreign matter. Furthermore, the downward configuration protects the rotor from being damaged by solid matter, such as polymer, which might otherwise fall on the rotors.

2.2 Casing

Kobe Steel's large compressors adopt horizontally split casings, as shown in **Fig. 2**. This casing simplifies the assembly and disassembly of the compressor and facilitates the maintenance work.

The standard casing is cast from carbon steel. An option is available for protecting the interior surfaces of the rotor chamber from corrosion. In this alternative, austenitic stainless steel layers several millimeters thick are formed by clad welding. This is a suitable alternative for applications, for example, those in which water is injected. This clad welding is a technology put to practical use by Kobe Steel after years of trial and error. It should be noted that the

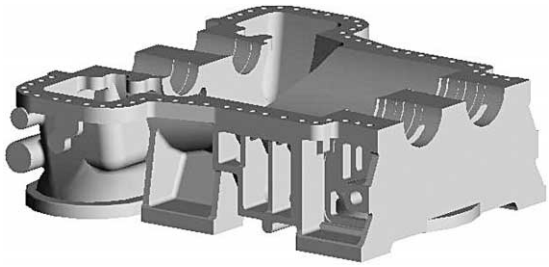

Fig. 3 3-D model of compressor casing

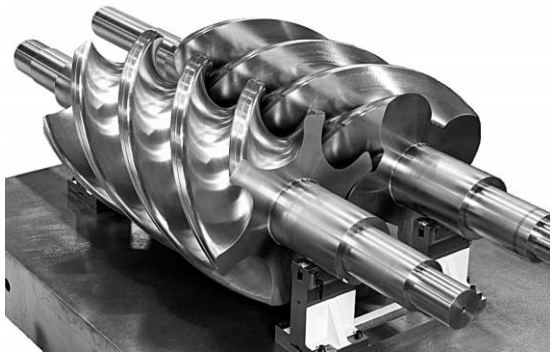

Fig. 4 Stainless steel rotor

clad structure, which also has excellent erosion resistance, is now used by many off-gas applications for styrene monomer. The clad structure also has the advantages of lower cost and better material availability compared with cast stainless steel.

Because the oil-free screw compressor has a complex casing structure, a 3D-CAD model, as shown in **Fig. 3**, is used to analyze the cast casing and the thermal deformation caused by temperature distribution. In addition, solidification simulation is adapted to prevent casting defects by predicting the defect positions before casting such a casing.

2.3 Rotors

The rotors are made of either forged carbon steel or of forged stainless steel, depending on their applications. Stainless steel rotors (**Fig. 4**), having high erosion resistance, are used for applications which involves, for example, water injection.

The rotors for MODEL KS80, as well as other EX-SERIES compressors, adopt the construction of non cooling by oil. The fabrication of such a rotor does not involve any welding step, thus reducing the cost and shortening the lead time. In an application where the suction and discharge pressures are low, the gas load acting on the rotors becomes small enough for the rotor shaft and bearing to secure enough rigidity with small diameters. This enables smaller sized bearings and shaft seals to be used, downsizing the compressor.

2.4 Shaft seals

Shaft sealing is one of the most important technologies for process gas compressors. Kobe Steel offers several options for the shaft seals of oil-free screw compressors, so that the users can select the type of shaft seal that best suits the specifications required by their applications. The following three types of shaft seal are commonly used in large compressors for petrochemical applications:

1) carbon ring seal with seal gas;
2) bearing oil film seal; and
3) dry gas seal (hydrostatic type).

MODEL KS80 compressors allow the use of any one of these shaft seals. Conventionally, a Kobe Steel large compressor has been built such that a hydrostatic-type dry gas seal is mounted/dismounted in the axial direction after the upper and lower bodies of the split casing are fastened together. MODEL KS80 compressors, on the other hand, are designed such that the hydrostatic-type dry gas seal can be mounted/dismounted in the horizontal direction before the upper and lower bodies of the split casing are fastened together. This construction facilitates the assembly and disassembly of the compressors and improves the maintenance workability.

2.5 Timing gear

The timing gears of Kobe Steel oil-free screw compressors have split construction, as shown in **Fig. 5**, to enable the backlash adjustment of gears. A gear backlash adjusted smaller than the rotor backlash prevents the rotors from contacting each other in the event of an emergency stop and improves the reliability of the compressors.

A high strength material is selected for the timing gears of MODEL KS80 compressors to ensure sufficient strength without increasing the gear size along the shaft direction. This minimizes the weight increase of the gears and improves the rotor stability.

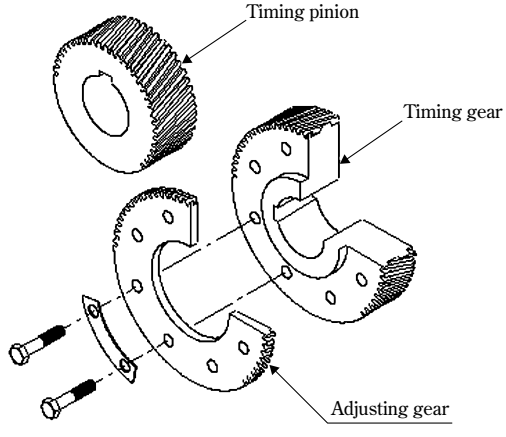

Fig. 5 Split piece timing gear

2.6 Water injection system

Water injection requires a nozzle designed for spraying water such that the water can easily vaporize. To ensure the uniform distribution of the sprayed water in the process gas, water is injected in the direction opposite to the gas flow. This minimizes the amount of erosion caused to casings and rotors by the injected water.

2.7 Silencers

To reduce the acoustic energy in the process gas pipes, each oil-free screw compressor made by Kobe Steel has silencers on both its suction and discharge nozzles. Generally, pulsation at the discharge side is greater than that at the suction side. Thus, the key is to reduce the acoustic energy at the discharge side effectively.

The rotational speeds of large screw compressors are relatively slow, and thus the frequencies of their discharge pulsation are low. Therefore, the low frequency pulse must be reduced to decrease the acoustic energy inside the discharge piping effectively. A wider range of pulses must be reduced for some applications, such as the off-gas application for styrene monomer, where a steam turbine is used for variable speed operation.

Kobe Steel owns the technology for designing silencers that are best suited for the respective gas and required acoustic characteristics. Thus, MODEL KS80 compressors can use a silencer designed to meet customer's needs.

2.8 Piping layout

Kobe Steel uses a 3D-CAD for piping layouts when designing compressor units (**Fig. 6**). The 3D-CAD allows advance checking of the piping interference and workability.

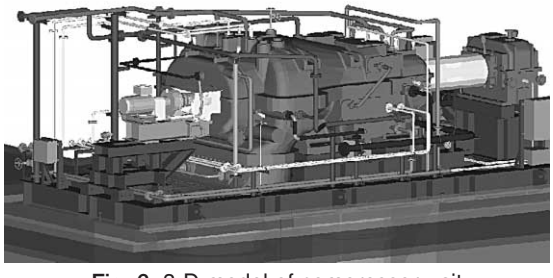

Fig. 6 3-D model of compressor unit

3. Build verification test

Kobe Steel conducts in-house test runs before shipping to verify the designed performance and stable operation. Furthermore, the tests on MODEL KS80 compressors include measuring the acoustic pressure inside the silencers, as described in Section 2.7, to confirm that the acoustic energy inside the piping is reduced as designed.

4. Future prospects

Fig. 7 shows a KS80LZ compressor delivered to a styrene monomer plant. The sales of MODEL KS80 compressors for such low-pressure, large-capacity applications are expected to expand. In addition, Kobe Steel will continue striving to satisfy market demands.

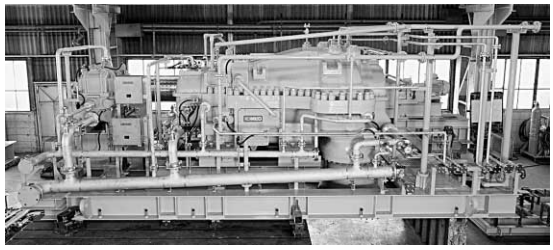

Fig. 7 World's largest capacity oil-free screw gas compressor for styrene monomer plant

Conclusions

Kobe Steel has been developing, designing, manufacturing and delivering many oil-free screw compressors for over fifty years. Kobe Steel will strive to expand the applications of oil-free screw compressors by developing new models and upgrading the existing models to meet market needs, making use of the company's technology and know-how.