Cycle Gas Compressor for Polyolefin, DH series

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To meet the growing demands for polyethylene (PE) and polypropylene (PP), many plants have been and are being built. In addition, plant capacities are being increased year by year to achieve high plant performance. Kobe steel has developed and improved compressors to meet their needs. This paper reports on a cycle gas compressor, one of the most important apparatuses for polyolefin plants, focusing on its special features and the outlook for the future.

Introduction

Worldwide plastic production exceeded 260 million tonnes in 2007 [1]. Production decreased in 2008 due to the world recession, but steady growth is expected, primarily in developing nations. In the long run, demand will continue strong for the general-purpose polyolefin resins, e.g., polyethylene (PE) and polypropylene (PP). This demand is driven by increasing consumption in the BRIC and other developing countries that are achieving significant economic growth. The demand is also expected to recover in Europe and North America, which have been major consumers for some time. In response, large PE/PP manufacturing plants are being built one after another in the BRIC countries and oil producing countries, especially in the Middle East. In 2009, many plants either started or were planning to start production.

Kobe Steel manufactures and sells to these PE/PP manufacturing plants a series of cycle gas compressors (DH series), as well as kneading mixers and pelletizers. The mixers and pelletizers are used for making pellets, a primary product, from granular polymer produced by gas phase polymerization in a reactor. The cycle gas compressors are used for the gas phase polymerization (hereinafter referred to as "polyolefin applications"). In recent years, Kobe Steel has delivered over 70% of the compressors imported by the People's Republic of China and has achieved significant sales also in Southeast Asia and the Middle East (**Table 1**).

This paper introduces the features of the DH series compressors used in polyolefin plants (**Fig. 1**) and describes the outlook for the future.

Table 1 Reference list of model DH for polyolefin plant

Delivery	Area	Plant	Model	Driver rating (kW)
2006	Russia	PE	DH9M	3560
2006	Germany	PP	DH9M	1650
2006	Germany	PP	DH7JM	1500
2007	Korea	PP	DH7JM	3450
2007	Korea	PP	DH7JM	1100
2007	China	PE	DH9M	5100
2007	Korea	PP	DH7JM	1300
2008	Thailand	PE	DH9M	4550
2008	Austria	PP	DH7JM	930
2008	China	PE	DH9M	5000
2008	Thailand	PP	DH7JM	1200
2008	Thailand	PP	DH7JM	4000
2008	Saudi Arabia	PP	DH7JM	1400
2009	UAE	PE	DH9M	4400
2009	UAE	PP	DH7JM	3250
2009	UAE	PP	DH9M	2800
2009	China	PE	DH9M	4900
2009	China	PE	DH9M	5510
2009	China	PE	DH9M	4900
2009	China	PP	DH9M	6000
2009	China	PP	DH9M	1750
2009	China	PP	DH9M	1380
2010	China	PE	DH9M	4900
2010	China	PP	DH9M	1550
2010	China	PP	DH7JM	2950

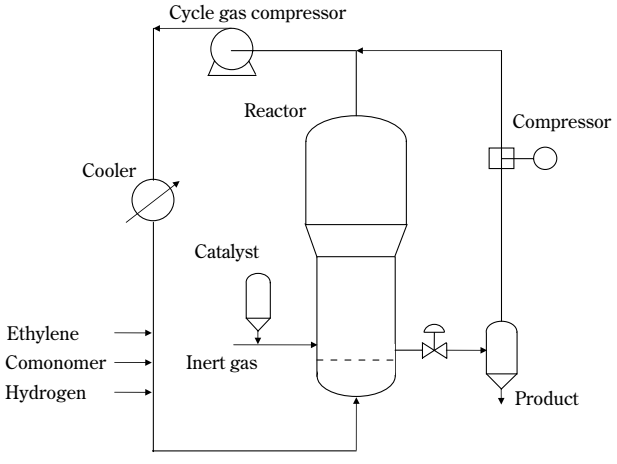

Fig. 1 Typical polyolefin plant process [2]

1. Features of the body structure

Polyolefin plants typically employ single-stage compressors because such an application requires a compressor with a low pressure ratio. They also adopt compressor units having cylindrical casings (a barrel type) because they require medium pressures. **Table 2** summarizes the specifications of Model DH9M, which represents typical compressors made by Kobe Steel. The compressor unit consists essentially of a compressor and an electric motor that drives the compressor via a coupling.

Fig. 2 shows the external appearance of the compressor. This compressor meets the requirements of API STANDARD 617, Chapter 2, American Petroleum Institute. **Fig. 3** is a cross-sectional view of a DH series compressor used for polyolefin applications. The compressor includes an impeller, a thrust bearing and a rotor shaft. The impeller is attached to an end of the rotor shaft such that the impeller overhangs at the shaft end beyond the bearing. The shaft-seal consists of a tandem dry gas seal disposed on the bearing side of the impeller so as to prevent the process gas from leaking outside. The overhung single-stage structure requires only one seal, facilitating maintenance work better than a single axial compressor with an inboard rotor would. The impeller, however, produces a large thrust force, so the thrust bearing must be carefully selected. The bearing is housed in a bearing box and is attached to the casing of the compressor. The compressor also includes an inlet guide vane as a standard feature. The guide vane enables an efficient adjustment of the compressor's capacity by varying the circumferential velocity component at the impeller inlet to change the impeller characteristics.

Table 2 Typical specification of compressor

Model		DH9M (Single stage barrel casing type)
GAS		Hydrocarbon, Hydrogen, Nitrogen
Suction volume	(m^3/h)	57,290
Suction pressure	(MPaA)	2.50
Suction temperature	(℃)	85.00
Discharge pressure	(MPaA)	2.67
Rated speed	(rpm)	2,977
Driver type		Induction motor
Driver rated output	(kW)	5,100
Shaft seal		Tandem dry gas seal
Capacity control method		Inlet guide vane device

Fig. 2 Example of model DH

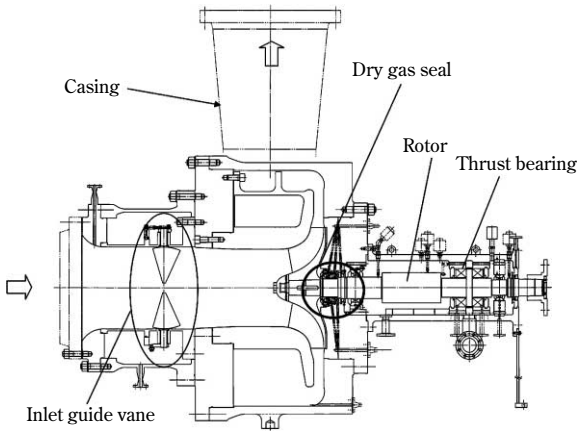

Fig. 3 Construction of model DH

2. Impeller

In polyolefin applications, compressors are used to circulate gas through the polymerization process. Such an application requires a compressor with a large capacity and low pressure ratio. For high mechanical reliability, the compressor typically uses an electric motor for direct drive via a coupling without gears.

To satisfy the requirements, Kobe Steel's compressors adopt impellers of a high specific speed type that is suitable for large capacity. In addition, conventional impellers are prone to surging caused by a small pressure variation because of their small pressure margins between the design points and the surging points. Therefore, Kobe Steel has developed an impeller with a sufficient pressure margin particularly for polyolefin applications.

3. Measures against polymer dust

3.1 Countermeasure against polymer dust in impellers

In most polyolefin applications, the compressors must handle process gas containing polymer dust.

Conventional impellers for gas applications are of a covered type, each consisting of a hub, blades and a cover, which are assembled to form a gas passage. The compressors for polyolefin applications used to have impellers of this type. Such a covered impeller, if used for the polyolefin process, often suffers from vibration caused by the imbalance of the rotor. The imbalance is a result of the dust of PE/PP contained in the process gas, accumulating on the portions where the gas flow becomes stagnant. Such portions include the labyrinth seal between the casing and the inlet cover disk of the impeller. The accumulated dust can also block the gas passage, which deteriorates compressor performance. Thus, such compressors require frequent maintenance which disrupts operation.

To resolve the issue, Kobe Steel developed a unique open-type impeller in 1999. The covered type impellers that had been delivered to the customers were replaced with this open type with the cooperation of the customers. The developed impellers have been used for similar applications after demonstrating their performance. The development involved a three-dimensional viscous flow analysis. **Fig. 4** shows examples of flow analyses conducted on a covered impeller and an open impeller. The figures represent relative Mach numbers measured in the vicinity of the shroud of the gas passage between the impeller blades. In comparison with the covered impeller, the open impeller, as shown, maintains a higher speed particularly at the impeller inlet, suppressing the low speed region. The results show that the open impeller effectively prevents dust from accumulating at the portion where the gas flow becomes stagnant, a condition found in the inlet portion of the covered impeller. The back surface of the impeller is profiled to control the buffer gas in such a way that the process gas does not flow in reverse along the back surface.

More than twenty machines, including the ones converted from the covered type to open type, are currently in service, demonstrating their effectiveness against dust-containing gas.

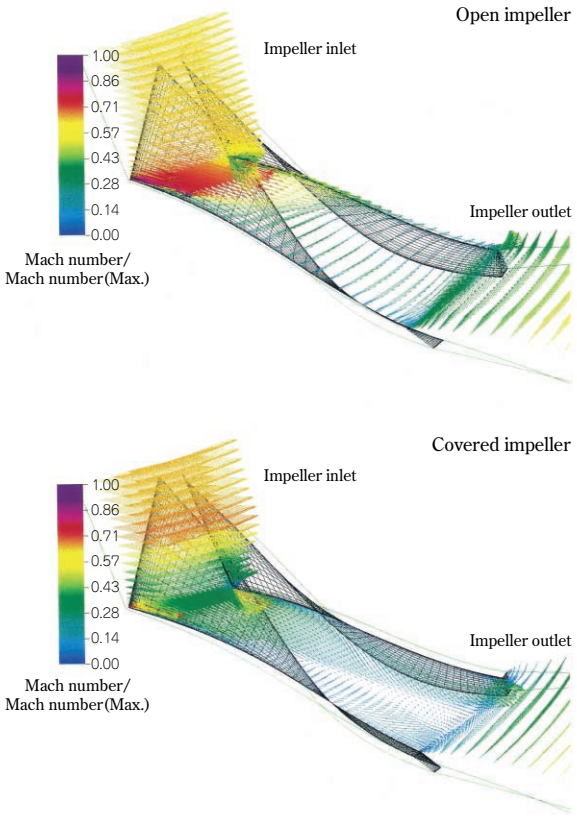

Fig. 4 Example of flow analysis of impeller

3.2 Inlet guide vane

Inlet guide vanes are provided at the suction port of a compressor for controlling the compressor capacity. The gas flow becomes stagnant at the feedthrough inside the duct where the vanes are attached. This part requires modification to prevent the dust from accumulating. Kobe Steel developed a dual structure in which an extra chamber is provided outside the gas passage of the inlet guide vane. The same gas as that used as the buffer gas for dry seal is fed through in such a way that a small amount of gas seeps into the process. This eliminates the stagnant zone and prevents the accumulation of dust. Similarly, nitrogen gas may be introduced into the outer chamber to prevent dust accumulation.

3.3 Gas seal system

To seal the shaft, the developed compressor employs a tandem dry gas seal, the seal commonly used for centrifugal gas compressors. In general, the seal uses buffer gas which is discharged from the compressor, filtered and fed into the primary seal to maintain a narrow gap in the seal. In the polyolefin applications, however, the discharge gas cannot be used for the buffer gas, since it contains dust. Thus, the buffer gas consists of, for example, ethylene or propylene, a gas which is inert even if mixed in the process.

A labyrinth seal is provided between the primary

seal and secondary seal. The nitrogen supplied into the labyrinth seal escapes into a flare line; so does a small amount of the buffer gas. The anomaly of the dry gas seal is detected by a flow/pressure sensor provided in the flare line. For further protection, a separation seal is provided on the atmosphere side of the secondary seal. The nitrogen supplied into the separation seal prevents the lubricant from seeping into the shaft-seal from the bearing.

4. Ease of maintenance

The developed compressor is of a large size for processing a large volume. Kobe Steel constructed the compressor in such a way that its rotor assembly, including the impeller and shaft-seal, can be disassembled on the side opposite to the suction port. This facilitates the inspection of the impeller, bearing and shaft-seal. The construction allows the inspection of the rotor assembly without disassembling the heavy main body and attracts favorable comment from customers. **Fig. 5** and **Fig. 6** show examples of the rotor assembly being dismantled.

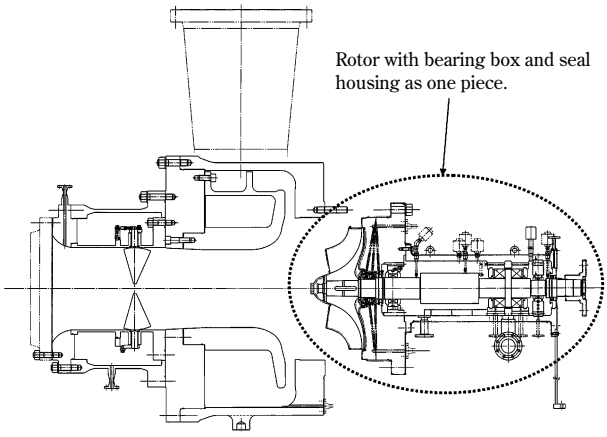

Fig. 5 Dismantling of rotor assembly from compressor casing

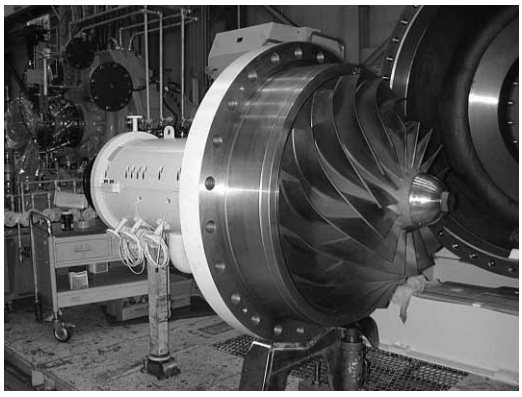

Fig. 6 Example of dismantling of rotor assembly

5. Response to special requirements

5.1 Measures against high load caused by piping

PE and PP plants require pipes with large diameters for handling large capacities. In addition, such a plant consists of a small number of mechanical components, making the piping fairly simple. This leaves only a little room for absorbing the elongation of the pipes caused by, for example, thermal expansion. Thus, some plants require nozzle loads and moments almost three times higher than those specified by API. Kobe Steel responds to the requirements by elaborating the base structures to reduce the piping load and moment, as well as increasing nozzle strength.

5.2 Measures against plant shut down

In a plant that polymerizes polyolefin, an emergency shut down results in a large amount of polymerized powder being left inside the reactor. The residual powder must be removed when restarting the plant, which takes a lot of time and effort.

Many customers strongly desire to continue operation as long as possible without shutting down their compressors. Kobe Steel has developed a system that restarts immediately after instantaneous power failures. Kobe Steel's compressor systems meet various customer needs. On of them includes a system that keeps the compressor running when the motor shuts down, using a turbine that utilizes the energy of process gas and stops the polymerization reaction gradually.

6. Future outlook

6.1 Upsizing of plants

Fig. 7 shows the capacities of compressors delivered by Kobe Steel each year. As seen from the figure, the plans are becoming larger and larger with the background of increasing demand and the need for higher productivity. New demand is emerging for compressors larger than any that have ever been delivered. In response to such needs, Kobe Steel will continue developing a new series of compressors with larger capacities and modifying the existing series to have improved impellers with higher specific speed.

6.2 Controlling starting current of motors

As the compressors have become larger, their

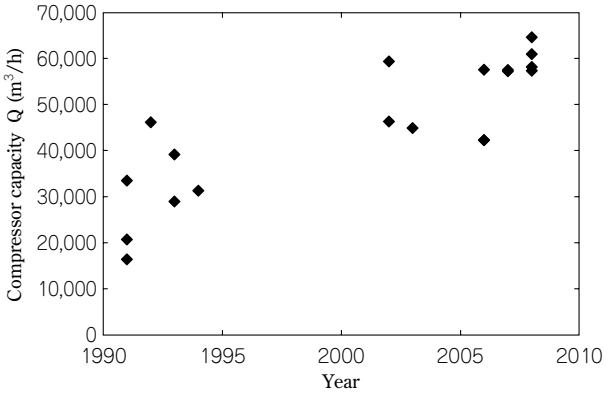

Fig. 7 Transition of compressor capacity

electric motors have required a greater output. Thus, the starting current of the motors must be restricted even more tightly to meet the specifications of the power facilities of the plants. A similar problem exists for conventional systems; however, the current restriction is much tighter for larger plants and is becoming an important factor in plant design.

Conclusions

The cycle gas compressors used for gas phase polymerization of PE/PP processes have simple structures. Such a compressor requires high reliability for stable operation, particularly because it is used for gas containing dust. Kobe Steel, one of the few manufacturers with broad experience in various processes, is striving to develop products to meet the customer need for larger compressors.

References

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