

Inverter-motor Driven, Water-injected, Oil-free Screw Air Compressor, EmerauDe-Aqua® Series

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Kobe Steel has developed a series, EmerauDe-Aqua, of oil-free screw air compressors which use water injected during compression for sealing and cooling their parts. Each compressor employs Kobe Steel's original noncontact screw rotors, driven by an interior permanent magnet (IPM) high-speed motor controlled by an inverter. The motor is directly connected with the screw rotors, to assure high performance for a wide range of flow volume.

Introduction

In Japan, air compressors as a whole consume about 50 billion kWh/year of energy. This equates to 5% of the total power consumed in the country and 20 to 30% of the power consumed by the country's manufacturing industry. Japanese businesses have been incorporating various energy-saving measures to comply with the Energy Saving Act and to protect the global environment. This includes the effective use of air compressors with high energy performance. Air compressors driven by inverter motors are widely recognized as energy-saving alternatives, and many businesses are converting their compressors to this type. As a matter of fact, Kobe Steel has been delivering an increasing number of oil-flooded air compressors driven by inverter motors since 2000. In 2007, their shipment volume exceeded 50% of the total volume of compressors shipped (Fig. 1). This trend extends to oil-free air compressors which discharge oil-free air.

In response to the need, Kobe Steel developed a series of oil-free screw air compressors driven by inverter motors, the EmerauDe-Aqua series

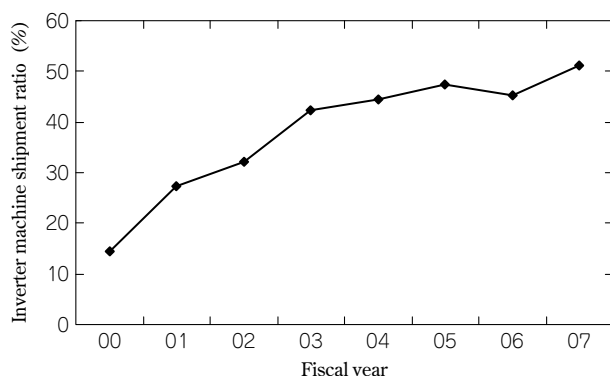


Fig. 1 Inverter machine shipment ratio in our medium-class oil-injected screw compressor

(EA400AD-VS and EA650AD-VS), which went on the market in March, 2008. The new series of compressors features water-injection, which is more suitable for inverter motor drives. Their development combines the company's own technologies, namely the technology for oil-free dry screw compressors with noncontact units and the technology for oil-flooded screw compressors driven by inverter motors. Each of the oil-flooded screw compressors comprises a main unit and a high-speed, interior permanent magnet (IPM) motor connected directly to the main unit, a form of construction termed "overhang direct connection". This paper introduces the EmerauDe-Aqua series¹⁻⁴⁾.

1. Product concept

The EmerauDe-Aqua series compressors were developed by combining the Kobe Steel's proprietary technologies for oil-free screw compressors and oil-flooded inverter driven screw compressors. The new concept aims at a highly efficient, energy-saving compressor for abating global warming. Fig. 2 shows the appearance of an EmerauDe-Aqua compressor, while Table 1 summarizes the specifications of the series of compressors.



Fig. 2 Outside view of EA650AD-VS

Table 1 Specifications

Type	EA400AD-VS	EA650AD-VS
Free air delivery (m ³ /min)	3.7~4.0	6.2~6.5
Discharge pressure (MPa)	0.69~0.59	0.69~0.59
Rated motor power output (kW)	22.7	37.7
Noise level (dBA)	62	65

2. Features of EmerauDe-Aqua series

2.1 Non-contact unit directly driven by IPM motor

Fig. 3 is a cutaway view of the main unit of an EmerauDe-Aqua series compressor. The machine has a compression chamber into which water is injected, which significantly improves its performance as compared with conventional dry oil-free screw compressors. The water injected into the chamber during compression stroke improves compression efficiency by

- cooling the discharged air and
- fluidly sealing the clearances created by the male rotor, female rotor and casing to reduce the leakage of air.

Oil is injected into the compression chambers of oil-flooded compressors in a similar manner to improve performance. In an oil-flooded compressor, the male rotor directly contacts and drives the female rotor, using the oil as lubricant. In water-injected compressors, however, such direct contact and drive result in the seizure and wear of their metallic rotors because water has much less lubricity than oil. To avoid this issue, other companies use resin rotors adapted for water injection.

Each EmerauDe-Aqua compressor employs a timing gear for driving the male and female rotors, both metallic, in a noncontact state with a minute clearance between them. The timing gear is the same type as that used in dry oil-free compressors. Water is injected only during the compression, being used only for cooling and sealing during that process. This construction prevents performance deterioration due to wear when the male and female rotors contact each other in water. Metallic rotors achieve higher compression efficiency than resin rotors because metallic rotors, with their small thermal expansion, are less susceptible to dimensional change. In addition, they can be machined with high precision

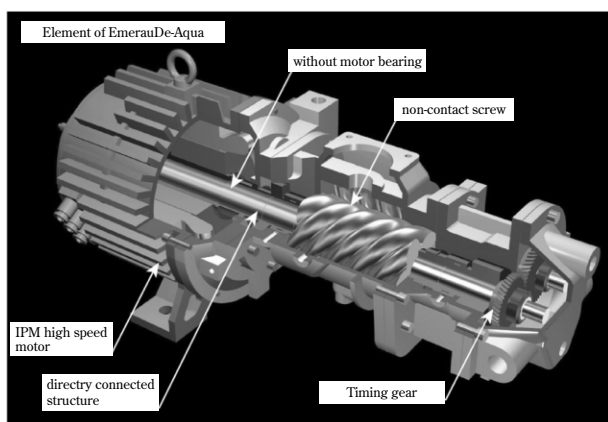


Fig. 3 Cross sectional view of EmerauDe-Aqua

such that the clearances between the rotors and between the rotors and casing are kept minimal.

The oil bath in an oil chamber lubricates the timing gears and bearings, which assures high reliability. Mechanical loss caused by the timing gears and bearings raises the temperature of the lubricant oil. The oil is cooled by water passing through the pipe provided in the oil chamber. This eliminates the need for oil recirculation and an oil cooler, which would be costly.

The shaft seal consists of a water seal, an oil seal, a hole vented to atmosphere and a drain hole. Both the vent and drain holes are provided between the seals. This arrangement prevents the water and oil from mixing. Oil leakage is prevented by an exhaust cleaner having an extremely small pressure loss. The exhaust cleaner, the same type as that used by Kobe Steel's dry oil-free screw compressors, vents the oil chamber to the atmospheric pressure.

The newly developed compressors adopt the same type of drive as that used for the inverter-driven oil-flooded screw compressors namely, an "overhang direct connection". In this type of drive, the shaft of the male rotor is directly coupled with the rotor of the electric motor in the screw compressor unit. This construction has eliminated the bearings for the electric motors. Also adopted is an IPM high-speed motor, which is excellent in overall efficiency and in performance for a wide range of partial load. As a result, the newly developed compressors have been significantly downsized and their weights reduced.

2.2 First class energy-saving performance

The EmerauDe-Aqua series compressors have achieved the largest discharge gas volumes in their class. This has been enabled by the newly developed compressor units of the water-injection type. The newly developed compressors, as well as the Kobe Steel's inverter-driven oil-flooded screw compressors, have the following three features.

- Wide range control: The power consumption of a compressor depends heavily on its discharge pressure. A low discharge pressure creates a margin in the power of the electric motor. The newly developed compressors monitor their discharge pressures such that the power margin created by lowered pressure can be used for increasing the revolutions. The increased revolution widens the control range (15 to 105% for EA650AD-VS) and increases the air volume. Fig. 4 schematically shows how the wide range control increases the air volume.
- Start up using residual pressure: The newly

developed compressors can start up immediately after shut down, when air is needed.

- Inverter driven cooling fan: The cooling capacity required for a fan depends on the operating conditions and ambient temperature. A newly developed compressor controls the revolution of the fan by its inverter. Electric power is saved by reducing the fan revolution during low load operation or when the ambient temperature is low. Fig. 5 shows the relation between the discharge temperature and the electric power consumed by the fan.

These features have made possible the discharge air volume that is the largest for any load condition, when compared with other compressors of the same class, as shown in Fig. 6.

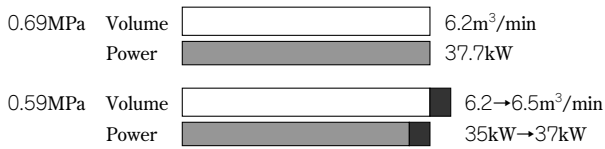


Fig. 4 Concept of air volume increase

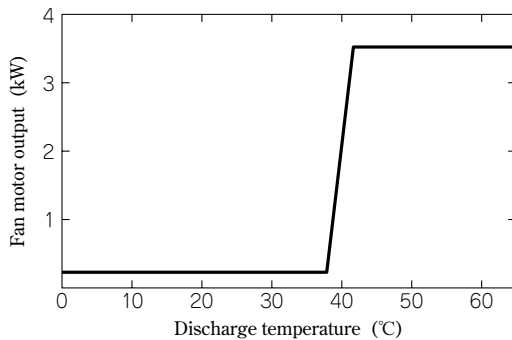


Fig. 5 Cooling fan output by inverter

2.3 Water quality management and corrosion resistance

The EmerauDe-Aqua series compressors have resolved the issue of water quality management associated with water-injection type compressors. This has been achieved by adopting a dryer drain recirculation.

Fig. 7 is a system diagram of an EmerauDe-Aqua series compressor. When initially poured into a compressor, water contains corrosive chloride ions. It also contains silica and calcium, both of which can form water scale. These can cause trouble if accumulated in the compressor in the long run.

The water drained from dryers, on the other hand, has a quality comparable to that of pure water. The newly developed compressors recover and recirculate the drain water such that the detrimental constituents are diluted. This new feature has

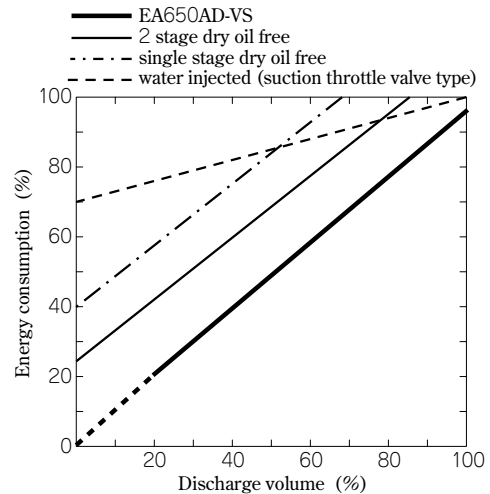


Fig. 6 Performance comparison (37kW class oil-free compressor)

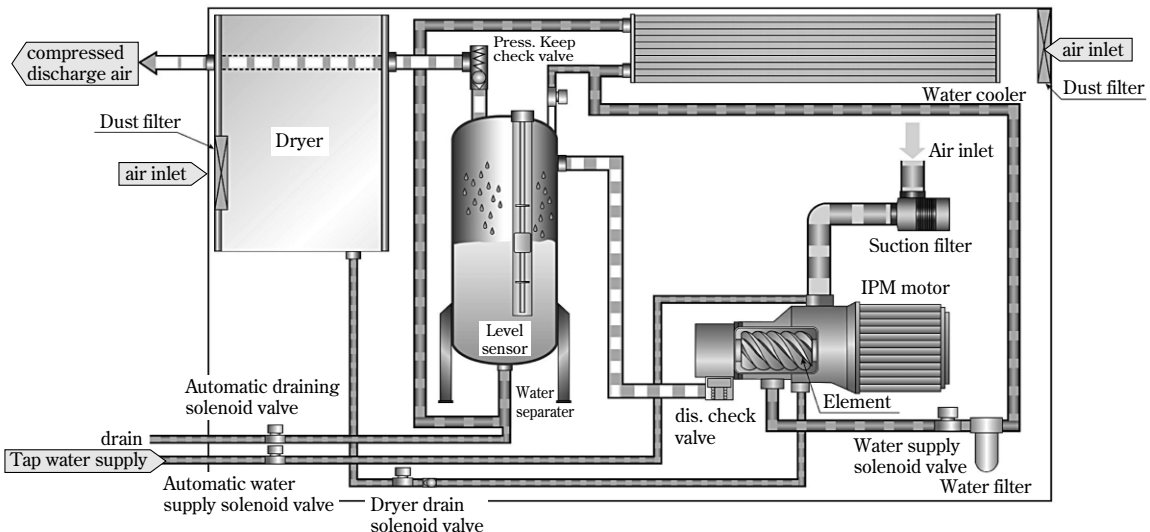


Fig. 7 System diagram

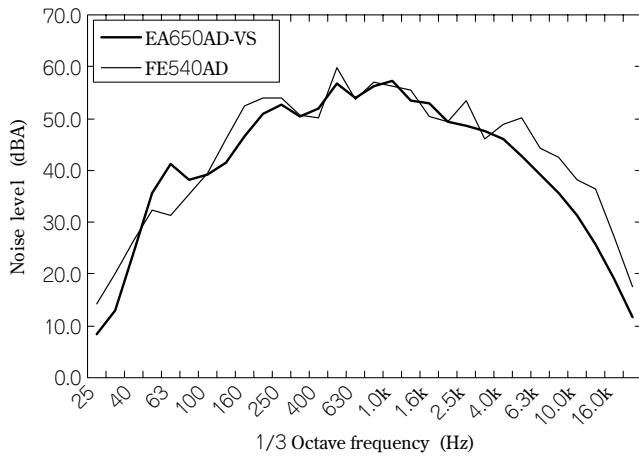


Fig. 8 Noise comparison

eliminated the water deionizing unit which has been required by conventional compressors of the water-injection type. All the water-contacting surfaces are made either of stainless steel, copper alloys, resin or rubber. Both of the measures described above assure corrosion resistance.

2.4 Most quiet of its class

The EmerauDe-Aqua series compressors are provided with measures against noise. A noise simulation technology originally developed by Kobe Steel for the noise control of railroads, construction machinery and highways was adapted for these compressors. Fig. 8 compares the noise level of the EmerauDe-Aqua, EA650AD-VS, with that of a 2-stage oil-free dry screw compressor, FE540AD, also

a product of Kobe Steel and having the same power as the former. Compared with the FE540AD, the EA650AD-VS has an improved sound quality with suppressed sound pressure levels in the high-tone range from 1.0 to 6.3kHz, which is dissonant to our ears. During full load operation, the EA650AD-VS exhibits the lowest noise level of all the machines in the same class. When operation load and/or ambient temperature are/is low, the revolution of the fan is reduced by the inverter control, further reducing the noise level.

Conclusions

The EmerauDe-Aqua series compressors accommodate today's most important environmental issues with their features of oil-free and low-noise operations, and energy saving over a wide flow range. Kobe Steel will continue to strive to develop energy-saving air compressors and contribute to the abatement of global warming and the reduction of CO₂ emissions.

References

- 1) H. NAKAMURA et al. : *R&D Kobe Steel Engineering Reports*, Vol.55, No.2(2005), pp.97-99.
- 2) J. TOTSUKA : *R&D Kobe Steel Engineering Reports*, Vol.58, No.2(2008), p.103.
- 3) J. TOTSUKA : *Hydraulics & Pneumatics(in Japanese)*, Vol.48, No.2(2009), pp.28-31.
- 4) J. TOTSUKA : *R&D Kobe Steel Engineering Reports*, Vol.59, No.2(2009), pp.45-47.