

The Development of Standard KOBELION™ -VS/VX Series Screw Compressor

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Kobe Steel has developed standard screw compressors, the KOBELION-VS/VX series, which save energy, reduce unnecessary air-delivery and are eco-friendly. These world-class compressors are featured by high performance, energy efficiency, reduced noise and less lubricating oil consumption. This article introduces the main features and key technologies of the KOBELION-VS/VX series.

Introduction

Conservation of energy is gaining more attention with growing concerns about environmental protection (including CO₂ reduction to prevent global warming) and manufacturing cost reduction. Power consumption due to air compressors occupies 5% of the total energy consumed in Japan, or 20-30% of the energy used in manufacturing. Above all the mid-size hydraulic screw compressors consume 70-80% of the consumption by all the compressors. Thus the development of energy-efficient compressors in this category should contribute to the prevention of environmental deterioration (Figure 1, Figure 2).

We developed and placed on the market a reciprocal compressor in 1915 and an oil-free screw-compressor in 1956, for the first time in Japan and have kept our position as a pioneer of technology throughout our history. However, the technological competition among compressor manufacturers has matured the products to such an extent that the gaps among the compressors in the specific power (= Power input /air flow),

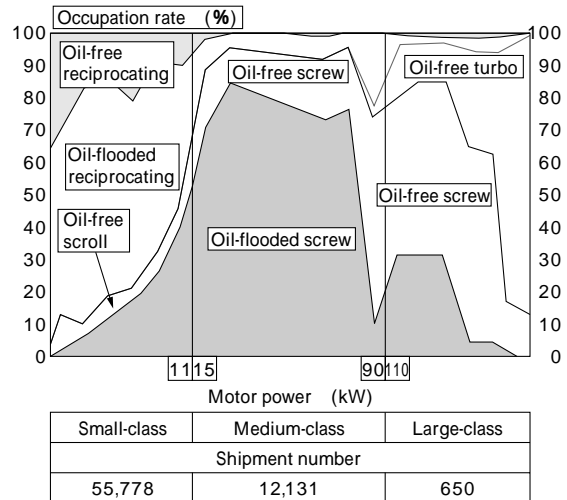


Fig. 2 Shipment number ratio of compressor

which determines the basic performances of compressors, have been reduced to less than a few percent. In such a climate, we have developed energy-efficient compressors which totally differ from conventional ones in terms of functions and performances.

1. The development concept of KOBELION-VS/VX

We have developed an innovative compressor, which does not rely on the extension of the conventional technology, by revising the basic concepts of structure and control. Our development goals are radical reduction of power losses, the highest intermediate load performance in the world, extremely low noise and high reliability and durability.

This article focuses on the 4 main features, out of many unique features of the KOBELION-VS/VX (Figure 3), that differ from other machines.

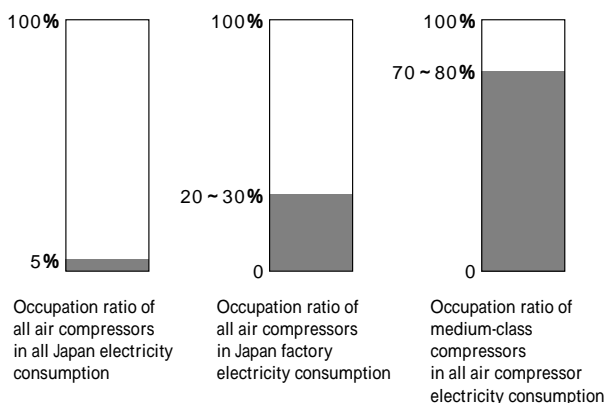


Fig. 1 Electricity consumption ratio of compressor



Fig. 3 Photographs of developed compressor

2. The features of KOBELION-VS/VX

2.1 High-speed motor connected directly to screw rotor

For the first time in the industry, we have realized an over-hang, direct-drive, mechanism which connects the compressor rotor axis directly to the motor-rotor and eliminates the motor bearing. The direct drive eliminates the power losses caused by motor bearings (1.5%) and step-up gears (1%). In order to realize this mechanism, a high-speed motor with high efficiency becomes indispensable. We have newly developed a high-speed permanent magnet motor with reduced size and weight, which doubles the maximum 3,600 RPM rotation speed of conventional induction motors to 7,200 RPM and eliminates the step-up gears and belts.

We have also eliminated the mechanical seals of the shaft by exploiting the casing structure of the motor. This reduces the mechanical loss by 3.5% and provides a reliable and tight seal which prevents oil leakages to the outside. This also contributes to reduction of noise, to reduction of number of parts by 15%, and to reduction of cost (Figure 4).

The biggest technical difficulty in realizing this over-hang direct structure was how to take measures against vibration and resonance caused by the increase of rotation speed.

The first order resonance was avoided rather easily by reducing the weight and size of the over-hanging motor-rotor and by thickening the rotor shaft. However, another resonance occurred during testing. This resonance was caused by the vibration force of the secondary element of the shaft rotation and was unexpected. Various attempts were made to prevent this and we finally succeeded in suppressing the resonance by developing an attenuator as shown in Figure 5.

The attenuator, which is installed at the end of

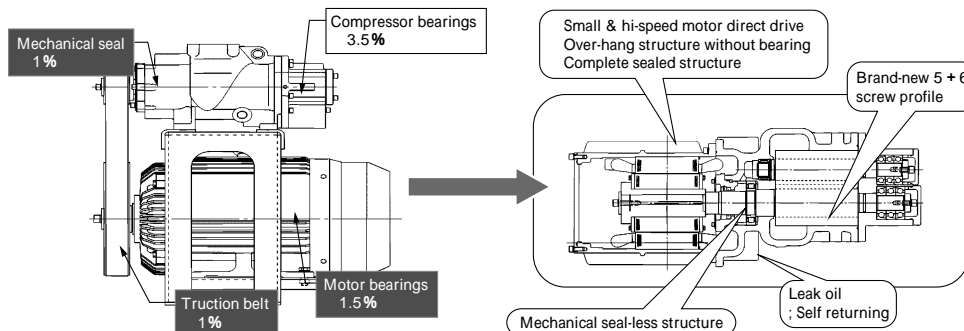


Fig. 4 Loss decrease by main body direct connection structure



Fig. 5 Appearance & concept of dumping device

the motor, consists of 10 to 15 plates of 3-5 mm in thickness which are pressurized by springs. The friction between the plates converts the vibration energy into heat when the characteristic frequency of the shaft starts to resonate with the secondary vibration component of rotation, preventing the divergence of vibration amplitude. The device provides an easy way of ameliorating the physically inevitable resonance, and is an essential mechanism for the KOBELION-VS/VX which employs a directly connected high-speed motor.

2.2 Wide range control

The theoretical power consumption of a compressor is expressed by the following equation.

$$P_{ad} = \frac{(i+1)k}{k-1} \frac{P_1 q_v}{0.06} \left[\left(\frac{P_2}{P_1} \right)^{\frac{k-1}{i+1}} - 1 \right] \text{ kW} \dots\dots\dots (1)$$

where, P_{ad} : theoretical compression power, i : number of intermediate coolers, k : polytropic exponent of air, P_1 : absolute suction pressure, P_2 : absolute discharge pressure, q_v : intake air volume.

Assuming that the i and k are constant and that

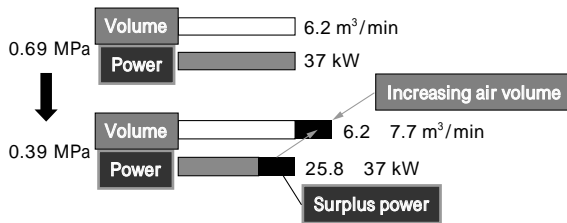


Fig. 6 Concept of air volume increase

P_1 is the almost constant atmospheric pressure, the power consumption of a compressor is abbreviated as "Power (P_{ad}) = Pressure (P_2) \times Air volume (q_v)". The air volume term is roughly proportional to the rotation speed.

The new, wide-range, control mechanism provides the constant power and air volume by controlling the rotation to the rated power of the motor in accordance with the discharge pressure. The key point is that the controllable maximum rotation becomes higher as the discharge pressure becomes lower. This means that the reduction of discharge pressure from conventionally rated 0.69 MPa to 0.39 MPa increases air volume by 25% and thus enables the saving and utilization of energy.

An example of the wide-range control for a 37 kW machine is shown in **Figure 6**. When the rated discharge pressure is 0.69 MPa, the maximum air volume is 6.2 m³/min and the required power is 37 kW. When the discharge pressure is lowered to 0.39 MPa, the power decreases to 25.8 kW, however, the air volume remains 6.2 m³/min as in the conventional machine. The common understanding of this used to be that the rotation of the motor could not be increased above the rated rotation.

The newly developed, wide-range control monitors the outlet pressure all the time and raises the air volume by increasing the rotation speed using the power spared by the pressure decrease. In this example, the air volume was increased from 6.2 m³/min to 7.7 m³/min.

The air volume increase mechanism allows choices of machines smaller by a rank, and contributes to reduced cost, space and maintenance.

2.3 Rotation control through the whole range

The KOBELION-VS/VX realized the lower rotation speed operation to 10% of the rated rotation speed. The conventional rotation controls used to be 20% of the rated rotation speed in our machines and 30% in other competitive ones (**Figure 7**).

In the conventional mechanism, the power loss of the motor coil and rotor increase as the rotation

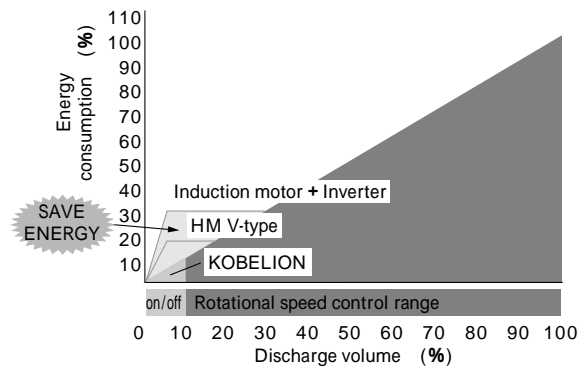


Fig. 7 Range of rotational speed control

decreases and the heat generation exceeds the cooling capacity, destabilizing the operation at lower rotations.

The KOBELION-VS/VX's new motor employs a permanent magnet which does not cause electrical loss at the rotor. The optimization of cooling and low-speed torque characteristics enable stable control at low revolutions. Furthermore, this technical development enables the restarting during pressure release, which was impossible in the conventional system, and also provides smooth air flow without fluctuation even at extremely low load conditions of 0-10%.

As a result, the pressure control valves and suction control valves are eliminated from the conventional system, improving the reliability and ease of maintenance.

2.4 Low noise design with sound quality

The maximum 5 dBA of noise reduction has been achieved 1) by eliminating noise sources such as gears through the direct connection structure and new screw profile design (**Figure 8**), 2) by reducing exhaust noise through increase of compressor body stiffness and 3) by controlling the cooling fan by a variable speed drive (**Figure 9**).

The variable speed drive controls the cooling fan rotation according to the discharge temperature, reduces the revolution at the time of low load or low ambient temperature, and improves the energy efficiency along with the noise performances.

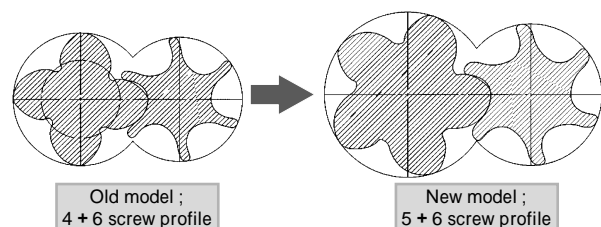


Fig. 8 Screw profile

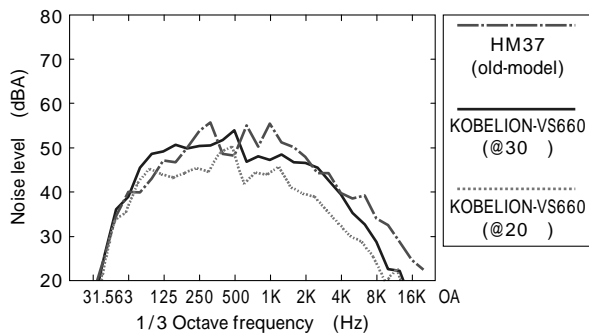


Fig. 9 Noise comparison

Conclusions

The innovative technological development of the new high speed motor, with the direct connection structure and wide-range control, highly improved the reliability of the performance and functions, and also ease of maintenance.

In addition, the structure of the main body is refined enough to completely prevent oil leakage to the outside. The maintenance parts such as mechanical seals, suction control valves, pressure control valves and motor bearings were eliminated for parts reduction, and also the cooling capacity of the packages and coolers was enhanced for the parts specification. In this way, these are also important factors for high reliability and ease of maintenance.

The ratio of variable speed machines to the total number of shipments of standard / variable speed types had previously been about 10%. However, it has been increasing since we released KOBELION-VS/VX in the market and it is now beyond 40%. We believe that this is because the innovative and energy-efficient performances are highly regarded in the market.