Oil Injection Rotary Screw Compressors Contributing to Environmental Protection and Energy Conservation

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OVERVIEW: Hitachi's long history in the field of air compressors reached 100 years in 2011 financial year. Over this time Hitachi has undertaken ongoing research and development and drawn on a wide range of technologies to meet customer needs. Along with a growing awareness of environmental problems, recent years have also seen demand from around the world for higher efficiency and larger energy savings from air compressors which consume a significant proportion of the electric power used in factories. To meet these needs in the coming 100 years, Hitachi intends to expand its air compressor business globally and operate it more speedily.

INTRODUCTION

AIR compressors are an essential source of motive power in factories and play an important role supplying air in factories and elsewhere.

Hitachi has a long history in the field of air compressors and has undertaken ongoing product development to meet customer needs since supplying its first 100-HP air compressor in 1911, just one year after the company was formed. This means that 2011 financial year marks the 100th anniversary of its involvement with this product (see Fig. 1).

The power consumed by air compressors and

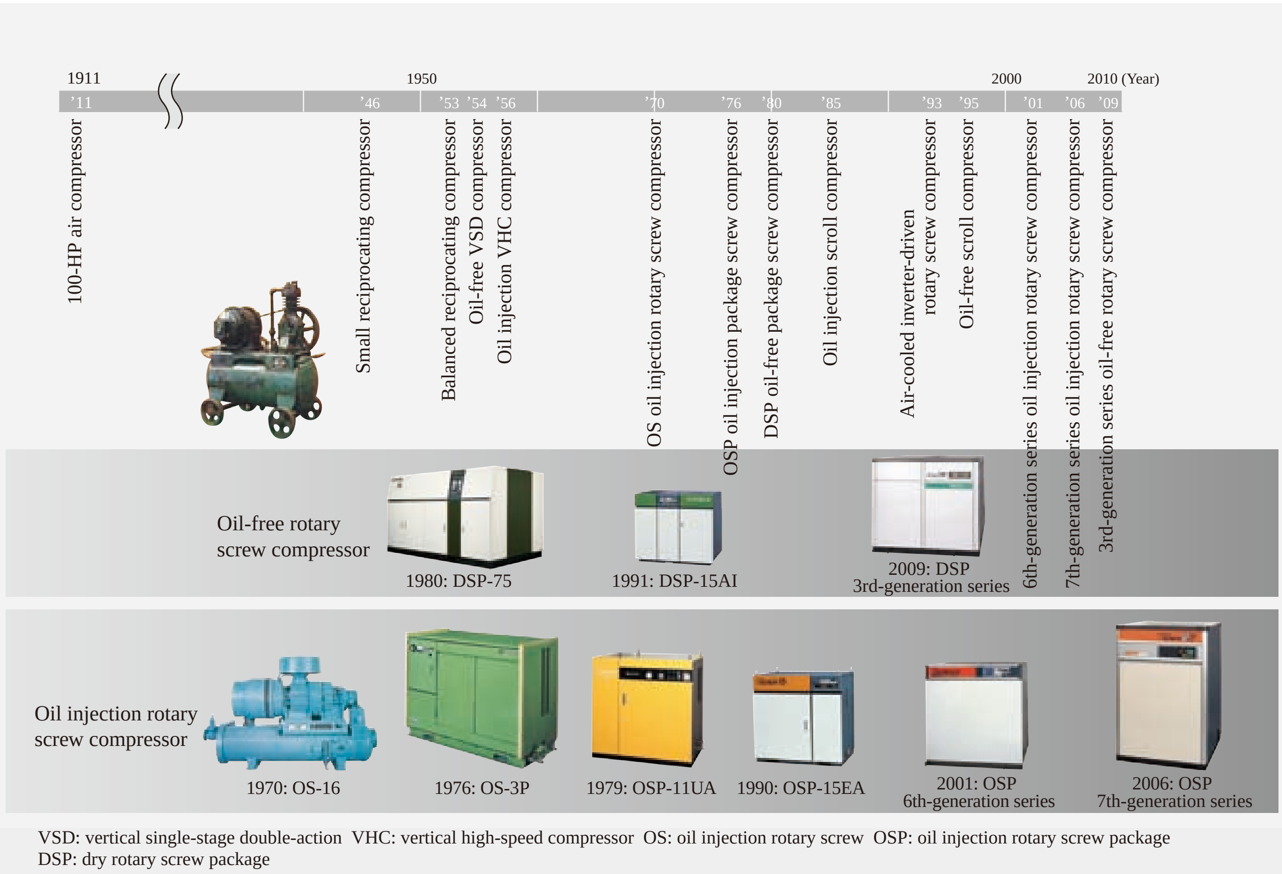

Fig. 1—History of Air Compressors at Hitachi.
Having delivered its first 100-HP air compressor in 1911, Hitachi is now celebrating the 100th anniversary in 2011.

associated systems makes up a significant proportion of total factory electricity consumption and demand for higher energy efficiency in air compressors is strengthening rapidly for this reason as well as to reduce CO_2 (carbon dioxide) emissions to prevent global warming prompted by the growing awareness of the environment.

Oil injection rotary screw compressors have become the mainstay among air compressors which are used in a wide range of industrial fields. This article describes what Hitachi is doing to improve their energy consumption and efficiency and how it operates its business globally.

PRODUCT DEVELOPMENT TARGETING ENERGY EFFICIENCY

The power consumed by air compressors and their associated systems makes up around 20 to 25% of total electricity consumption by factory equipment (see Fig. 2). There is a strong need to improve the energy consumption and efficiency of air compressors and this is expected to grow throughout the world not only because of the cost savings that result from more energy-efficient plant but also to help protect the environment in ways such as preventing global warming.

Oil Injection Rotary Screw Compressors

Hitachi currently produces and markets its seventh generation of seventh-generation series oil injection package screw compressors, the result of an ongoing program of new series development with aims that include making the units more energy efficient and easier for customers to use (see Fig. 3). The seventh-generation series meets a demand for energy efficiency that is growing globally and features a new compressor unit which is the core component in a rotary screw compressor. The shape of the screw rotor tooth surface has a major impact on the compressor noise and other performance factors and the seventh-generation series features a new highly efficient low-noise gear design that was developed to maintain stability in the contact between screw rotor tooth faces.

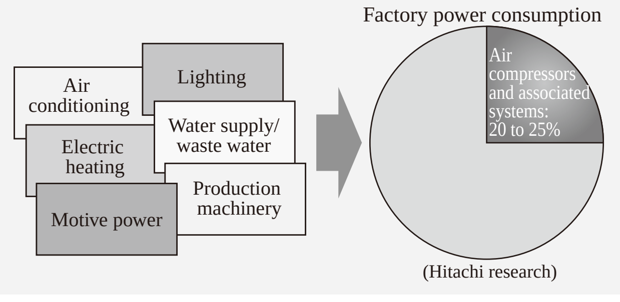

Fig. 2—Typical Factory Power Consumption.
Air compressors and their associated systems consume around 20 to 25% of the power used in a typical factory.

Fig. 3—7th-generation Series of Oil Injection Rotary Screw Compressors.
The current product range extends from 7.5 kW to 75 kW and also includes 132-kW/160-kW models.

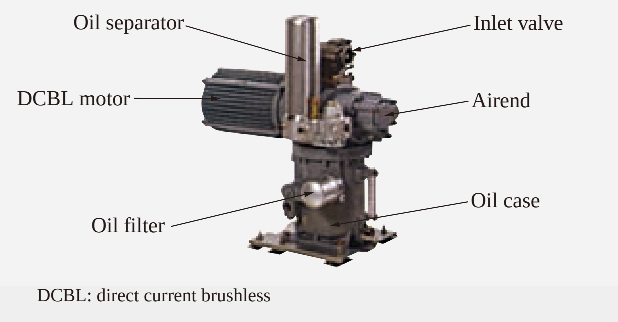

Fig. 4—Integrated Design Combines Main Air Compressor Components in Single Unit.
The 22-kW and 37-kW variable-speed capacity control mechanisms integrate a DCBL motor together with the main air compressor components into a single unit to reduce power transmission losses and pressure losses

To improve the energy efficiency of the air compressors, the variable-speed capacity control mechanism uses DCBL (direct current brushless) permanent magnet motors that incorporate Hitachi variable-speed drive technology and range in capacity from 22 to 75 kW (see Fig. 4).

The system is also designed to reduce pressure loss within the unit, with energy efficiency being achieved throughout the total unit, not just in the airend itself.

RESEARCH AND DEVELOPMENT TARGETING OPTIMUM EFFICIENCY

Air compressors have a long history dating back to the industrial revolution and research and

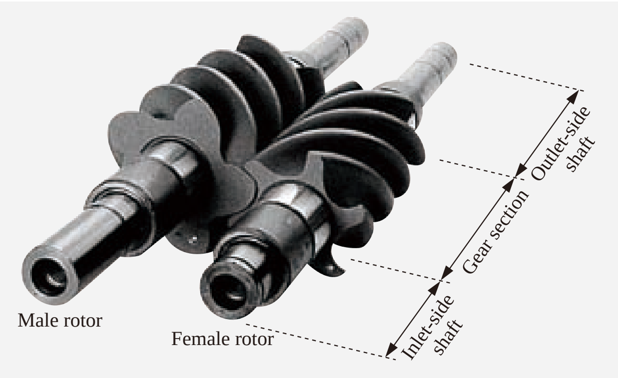

Fig. 5—Screw Rotors.
The screw rotors consist of a gear section with a proprietary thread profile and shafts at either end.

development have been ongoing in a range of different areas. In particular, the rapid advances in computing technology in recent years have made it possible to analyze various phenomena that occur during rotary screw compressor operation. The following sections describe a quantitative method for evaluating the clearance between the male and female rotors (which has a strong correlation with compressor performance) and a coupled system simulator which performs simultaneous analysis of both electrical and mechanical models of the compressor and motor, both of which were developed based on these analyses.

Quantitative Method for Determining Clearance between Male and Female Rotors

The main components of an airend are a pair of screw rotors. The airend operates by the rotation of the rotor shafts which progressively compresses the air in the channel formed between the rotors (see Fig. 5). Accordingly, reducing the clearance between the rotors is essential to improving the efficiency. However, because the rotors have a complex shape formed from multiple curved surfaces and because the resulting gap has a three-dimensional shape, obtaining a quantitative understanding of the clearance has been a very difficult and time-consuming task in the past.

The factors that influence the clearance between the male and female rotors include the profile error and the thermal deformation of the rotors and casing. Accordingly, a quantitative value for the clearance can be obtained by summing the rotor surface deflections associated with each factor and then determining the position at which the gap between the rotor surfaces is minimized. Unfortunately, the calculation is very cumbersome because of the need to obtain minima for each point of contact.

In response, Hitachi developed a method for calculating the gap based on a logical coordinate system by summing the deflection in the direction of the rotor surface normal due to each factor in order to optimize the clearance between the male and female rotors[1]. Because this method can determine and optimize the clearance between the rotors without requiring cumbersome computation, it is making a major contribution to reducing the power consumption and improving the efficiency of rotary screw compressors (see Fig. 6 and Fig. 7).

Coupled Electrical/Mechanical Analysis and its Application

Recent years have seen the ongoing development of environments for constructing simulators for a range of different equipment that utilize a number of different analysis techniques to study the dynamic behavior of entire systems[2]. By linking simulators together, it should be possible to achieve greater accuracy than when individual phenomena are analyzed using fixed

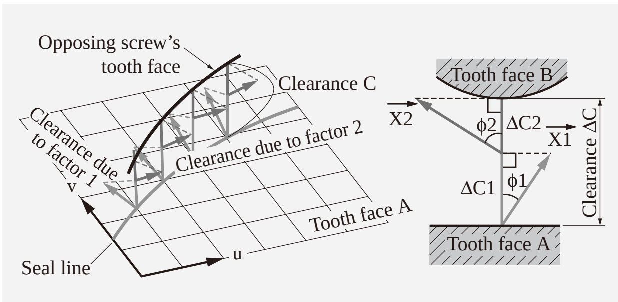

Fig. 6—Summing of Clearances Based on Logical Coordinates.
The change in clearance (ΔC) is calculated by summing the normal vector components of the deflections due to each factor.

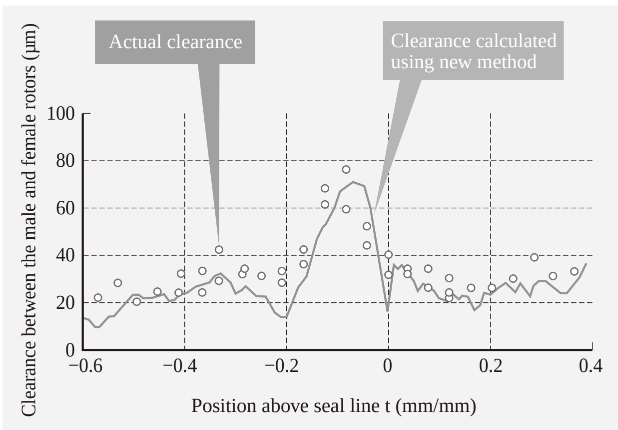

Fig. 7—Comparison of Actual Clearances and Clearances Calculated Using New Method.
The clearances calculated using the new method show good agreement with the actual clearances.

boundary conditions and, because this approach allows the analysis of unsteady state cases such as equipment startup, it makes it possible to undertake desktop investigations into numerous different situations that occur in practical operation.

The construction of a coupled simulator for rotary screw compressors requires an analytical model that considers the interaction between separate models of the motor, compressor mechanics, and air pressure. Fig. 8 shows an analysis of startup behavior made using a coupled simulator(3). The blue lines in the graphs represent the calculation results and the grey lines represent measurements taken from the actual compressor. The results show good agreement between calculation and measurement. Also, because the simulator is able to achieve good accuracy when calculating special cases such as the drop in torque associated with the operation of the inlet valve or the increase in torque at startup, it allows optimum control of the motor to be used to reduce the compressor's power consumption. This use of the coupled simulator also helps speed up product development.

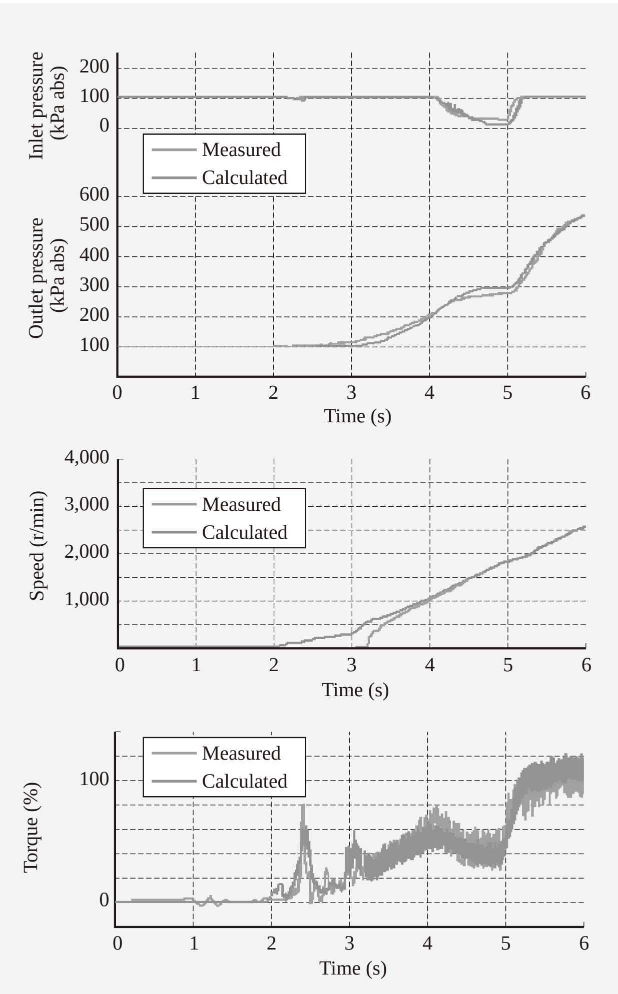

Fig. 8—Comparison of Actual Values and Results from Rotary Screw Compressor Simulator.
The simulation of startup operation predicts actual behavior with a high degree of accuracy.

Fig. 9—Hitachi Industrial Equipment (Nanjing) Co., Ltd. Premises.
Hitachi Industrial Equipment (Nanjing) Co., Ltd. commenced production in 2005 and enlarged the size of its plant in 2010 to expand production.

GLOBAL OPERATIONS

In addition to exporting compressors manufactured in Japan to the global market, Hitachi started overseas production in 1995 when it established an assembly plant for air compressors in Malaysia. In recent years, Hitachi has also been working to establish the infrastructure to meet the growing international demand for efficiency and energy conservation. Hitachi established Hitachi Industrial Equipment (Nanjing) Co., Ltd. and commenced production of air compressors in 2005 to satisfy the growing number of orders from the Chinese market (which has been experiencing rapid economic growth) and then went on to expand the size of the production facility in 2010 in response to further demand growth (see Fig. 9).

CONCLUSIONS

This article has described what Hitachi is doing to improve the energy consumption and efficiency of its oil injection rotary screw compressors and how it operates its business globally.

It is clear that customer needs for air compressors over the next 100 years will continue their rapid, dramatic, and global growth, even more so than over the last 100 years.

Through its air compressor business as elsewhere, Hitachi intends to continue utilizing group synergies and responding promptly to customer needs to help create a sustainable society.

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