YASKAWA AC Drives

Compressor Applications

Application Overview

This document provides a general application overview and is intended to familiarize the reader with the benefits of using AC drives in compressor applications.

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1 Preface

Yaskawa manufactures products used as components in a wide variety of industrial systems and equipment. The selection and application of Yaskawa products remain the responsibility of the equipment manufacturer or end user. Yaskawa accepts no responsibility for the way its products are incorporated into the final system design. Under no circumstances should any Yaskawa product be incorporated into any product or design as the exclusive or sole safety control. Without exception, all controls should be designed to detect faults dynamically and fail safely under all circumstances. All systems or equipment designed to incorporate a product manufactured by Yaskawa must be supplied to the end user with appropriate warnings and instructions as to the safe use and operation of that part. Any warnings provided by Yaskawa must be promptly provided to the end user.

◆ Intended Audience

This document is intended to familiarize the reader with the benefits of AC drives in compressor applications.

2 Compressor Types

◆ Gas Compressors

A compressor is a mechanical device that increases the pressure of a gas by decreasing the volume of that gas. There are many applications for compressors in industry. Oil and Gas, Chemical, Manufacturing, Automotive, Pharmaceutical, Semi-Conductor are examples of industries requiring large sums of air for tools and production. Many of these compressor applications benefit from the use of AC drives.

Yaskawa drives have been applied in the compressor market for several years now and will continue to do so in the years to come. An AC drive is typically applied to a compressor in order to increase the overall energy efficiency of the system or provide controlled compression by motor control rather than valves and diaphragms. With the increased cost of energy and the cost competitiveness of PM and high efficiency motors, there will be new market segments of the compressor market Yaskawa will have the ability to compete in. AC drive applications for compressors are growing by a rate of 7-10% per year. This application overview will give some further detail on two styles of compressor that Yaskawa is currently seeing, and will see in the future. Although many different types of gases can be compressed, methane, propane, oxygen, carbon dioxide etc, this analysis covers air compressors.

◆ Reciprocal Compressor

A reciprocal compressor is a simple positive displacement mechanical device that reduces the volume of a gas by increasing the pressure in a piston action. The term positive displacement refers to the engineering action of moving a medium. The positive action (movement) of the piston literally forces the gas to pressurize and the action is very much like a water pump. It is also called a piston compressor and is best shown below by a simple and well known diagram.

1. Piston
2. Gas Chamber
3. Cylinder Wall
4. Gas Inlet Valve
5. Gas Exit Valve

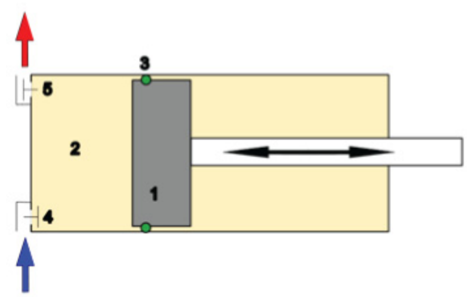

Figure 1 Diagram of a Piston Reciprocal Compressor

The piston (1) is aligned against the cylinder (3). An inlet with a one direction valve (4) allows the gas into the chamber with the support of the vacuum of the piston moving left to right. The gas is pressurized in section (2) as the piston moves from right to left in this diagram. Once the pressure reaches a certain level, an exit valve (5) opens and the pressurized gas is released out of the chamber where the cycle starts again. In a typical Air compressor, a hose connection and air hose is connected to a storage tank which in turn is connected to the (5) exit air valve. The hose keeps the air under pressure for use.

A piston compressor is usually tied directly to a crank shaft on a combustion engine, or directly to the shaft on an electric motor. It can also be connected via a chain or pulley and belts. The motor or engine typically runs until there is suitable pressure in the chamber when measured by a pressure regulator if the compressor is used with a storage tank. If there is no storage tank, the compressor runs continuously. Reciprocal compressors can act as a single stage as in *Figure 1*. However, in larger sizes, it is more likely to exit in more than one stage.

In a multi-stage application, several chambers are linked together and the gas is pressurized in several stages. For example in ***Figure 2***, Stage (1) would increase the pressure to 50 psi, stage (2) to 100 psi and stage (3) to the final desired 150 psi.

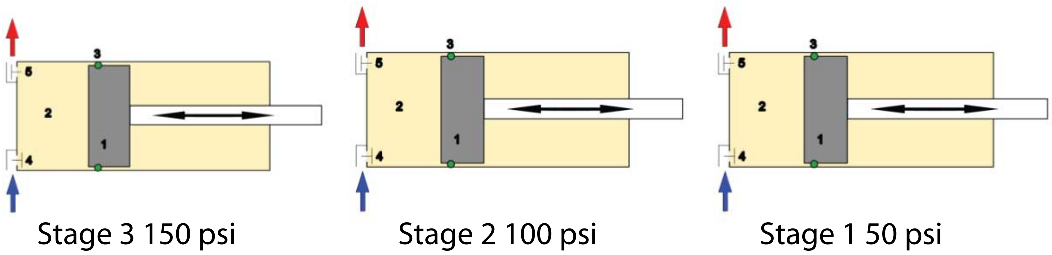

Figure 2 Diagram of multi-stage reciprocal compressor

Reciprocal Compressors are very rugged and simple; but do generate significant heat. They are used from 1-500 HP but can go larger. The positive displacement action and subsequent heat generation is not particularly efficient. Some are air cooled; but most are water or oil cooled. Some have water jackets and are closed systems. While others inject oil directly into the airstream cylinder and are then filtered out in a downstream filter process. They are viewed as a more traditional design and newer rotary screw type compressors often replace them. They are louder and often exist outside of areas where people work due to the 100-110 decibel range they often run in. Even though reciprocal compressors are older technology, it is still widely available as new product and drives are applied to them.

■ Types of Reciprocal Compressors

OIL vs. OIL Free Compressors

An oil compressor injects oil into the air stream to cool the mechanical system. Again, this is similar to a 4-cycle combustion engine where oil is used to cool the cylinder and piston. They usually have lower maximum discharge pressure capability as a result. However, multi-stage oil-free compressors, where the air is compressed by several sets of screws, can achieve pressures of over 150 psig, and output volume of over 2000 cubic feet (56.634 cubic meters) per minute at 60 degrees C and 1 atmosphere of pressure.

In an oil-free compressor, the air is compressed entirely through the action of the piston cycling back and forth, without the assistance of an oil seal. It is limited due to the temperature range of the compressor. There are very few Oil free reciprocal compressors over 20 HP. There are some simple electrical piston type pump compressors for cars, tires, inflatable equipment etc. These devices use a special lined cylinder which is not economical in higher hp ranges.

Oil-free compressors are used in applications where oil carry-over is not acceptable, such as the pharmaceutical industry and any other clean room type application. If the inlet air to the compressor is not filtered, then filtering must occur after the compressed air is released in order to assure adequate clean pressurized air.

Stationary Reciprocal OIL Compressor

A stationary reciprocal OIL compressor is meant for permanent installation in or at a factory site. It is typically built on a skid in case where the HP is below 100 HP 230V and 150 HP 460V. The compressors are permanently affixed to their surroundings. Their size dictates they are usually inside and have temps requirements of 40 deg C. Enclosure types are NEMA 1 and NEMA 12.

◆ Large Industrial Compressors

Large Industrial Compressors are compressors that are permanently affixed to a site and are larger than 150 HP. In many cases, they are placed outside of the manufacturing centers and NEMA 4 and NEMA 3R enclosures are required. Due to the location, temperature requirements for these units are 50 deg C and may require heating systems in winter and a/c in the summer months.

◆ Rotary Screw Compressors

A rotary screw compressor is a type of gas compressor which uses a rotary type positive displacement mechanism. Rotary compressors use two meshed helical gears running in constant motion.

Figure 3 Helical Gears in a Rotary Screw Compressor

And can be either oil free or oiled. The concept of this design is to push gas from the inlet end through the gears and forces into compression. The compressed gas exits at the other end. The gear noise is reduced vs. the noise from a reciprocating compressor. Although this is still a positive displace type of compressor, the temperature increase of the gas during the helical screw compression is far less than the temperature of the piton reciprocal compression. Many times this equipment can run both with oil and oil free and there are benefits to both. As opposed to some reciprocal designs, most of the mechanical portions of the equipment are air cooled. More often than not, electrical controls can exist as a part of a main frame or skid along with the compressor and will not need special cooling beyond air flow. The efficiency of this equipment depends greatly on the oil seal created between the gears if the device is oiled, or the use of timing gears for an oil free design.

They are commonly used to replace reciprocal or piston compressors where large volumes of high pressure air are needed. The gas compression process of a rotary screw is a continuous sweeping motion, so there is very little pulsation or spill-back, as occurs with piston compressors. There is no source of friction or large inertia to overcome so a rotary screw compressor does not have a high level of overload requirements. When AC drives are sized for rotary screw compressors, they are not derated. However, many rotary screw compressor motors are sized to operate in their service factor range when the compressor is running at 100% duty. Typical rotary screw compressors do not operate at 100% capacity for long periods due to the storage tanks and AC drive controls. Like reciprocal compressors, rotary screw compressors can be lined into multi-stage systems to achieve higher psi requirements.

■ Types of Rotary Screw Compressors

OIL vs. OIL FREE

In an oil rotary screw compressor, the oil performs two vital functions. The first is to act as a cooling agent for the gears and the rest of the mechanical system. The second function is to provide an oil seal along the helical gear edges to ensure there is no release of pressure during operation. This will also guarantee the proper direction of air flow along the gears. Using the oil as a seal will eliminate the need for timing gears along the shaft of the compressor. The oil is removed from the system using a separator or filter system.

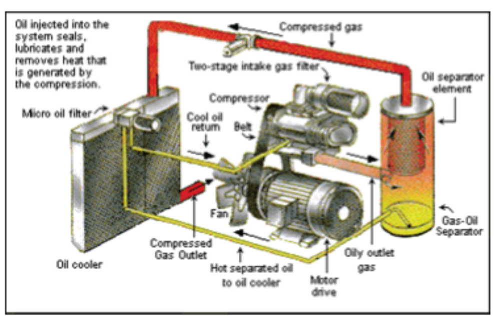

Figure 4 Diagram of a Typical Oil Rotary Screw Compressor

An oil free compressor has to use another medium (typically forced air) to maintain cool mechanics. It also requires the use of timing gears along with the helical gears to maintain proper alignment of the system to guarantee proper air flow and compression. Cooling jackets (closed systems) are sometimes used on oil free designs depending on heat requirements. There is little to outside difference between oil and oil free compressor and cannot be discerned by looking at the package. Although filtering is required for an oil and oil free system, oil free systems do not have separators. Therefore, if looking at a typical rotary screw compressor skid, look for an oil separator to determine if it is oil free variant.

Large Industrial Rotary Screw Compressors

The primary difference between the stationary and large industrial versions of rotary screw compressors is the size of the equipment. Typically large industrial units are above 75 HP 230 V and 150 HP 460 V. When these units are controlled via an AC drive, they are separately mounted. Large Industrial applications can exceed 500 HP.

3 Summary

Traditionally reciprocal compressor applications were powered electrically across the line or with gas combustion engines. When pressure would be required, the compressor would begin operating at 100% or higher into the service factor rating of the motor. The motor would continually run as long as the regulator required the motor to do so. A major mechanical drawback of the reciprocating compressor is that it must operate at a certain level in order to operate properly. This operation was a simple across the line start at full load of the motor and did not take into account air demands or other requirements. Therefore, additional to the relative inefficiency of the reciprocating compressor, much energy was used as the compressor was simply turned 'on' and 'off'. As stated above, Reciprocal compressors can operate in conditions above 60 deg C. However, in cases where the ambient can be kept under 50 deg C, AC drives are an option and can help lower electrical costs. It is important to note that the energy required to start a reciprocating compressor is higher than 150% so a drive derate is required.

Traditional rotary screw compressors operated across the line as well. However, they were still seen as an advantage over the less efficient piston type compressors. Their increased efficiency, lower HP requirement, lower temperature all were advancements over the traditional reciprocal compressors. One disadvantage of the rotary screw is its complexity with many more moving parts. Using AC drive compressors can utilize an on demand style of operation and only operate when the load requires the compressor to turn on.

◆ Advantages of AC Drives on Reciprocal and Rotary Screw Compressors

The introduction of AC drives has greatly aided many industries. In compressors, the same benefits of AC drives over across-the-line starts hold true. The overall power consumption is reduced, power surges from the in-rush during starts is reduced, and the system can deliver more constant pressure based on demand rather than simply filling up a storage tank device and run at 100% when required.

◆ Overall Benefits of AC Drives

- AC drive technology provides energy efficiency superior to all other control technologies available today in air compressor applications.
- AC drive compressors consume up to 35% less energy than fixed speed compressors sized for the same application.
- AC drive compressors vary their output, continually and automatically, to precisely match the demand for air.
- Reducing the demand for power helps cut greenhouse gas emissions that contribute to global warming. Investing in an AC drive pays for itself , often in just months, through significantly lower energy costs.

The list below, taken from Yaskawa Application Overview AO.AFD.67, illustrates benefits and features of Yaskawa drives for Compressor applications.

◆ Drive Advantages for Compressors

Drives Products	Features	Benefits
A1000, G7 or P1000 Drives	PID Control Mode	Automatically regulate speed based on load conditions. The drive employs a built-in PID Controller (an external PID device is not required).
	Cooling Fan On/Off Control	Controlling the number of times the drive fan is switched on and off increases the life-span of the cooling fan and reduces the need for maintenance.
	Flux Vector Control	With vector control, the system can operate at a stable speed regardless of the load.
	Energy saving control	V/f pattern selection saves energy while operating with light load and low speeds.
	Restart after momentary power loss.	The motor continues running even after a 2 second momentary power loss.
	Continue to run when external frequency reference is lost.	The drive enables different responses to momentary power losses.
	Avoid mechanical resonance.	The drive skips over the frequency at which resonance occurs.
	Frequency Lower Limit	Continuous motor operation at low speed with a minimum speed reference
	Reverse Prohibit	The drive can be prohibited from running in reverse by using the Reverse Prohibit Function.

4 References

The documents and websites listed in *Table 1* can be used as supplemental information to this Application Note. Yaskawa manuals can be downloaded from www.yaskawa.com.

Table 1 References

Item	Description	Type
AO.AFD.67	Application Overview Compressors	Yaskawa Application Overview
www.yaskawa.com	Website of Yaskawa America, Inc. Information on products can be found here, including technical manuals, training material, and other application notes.	—

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