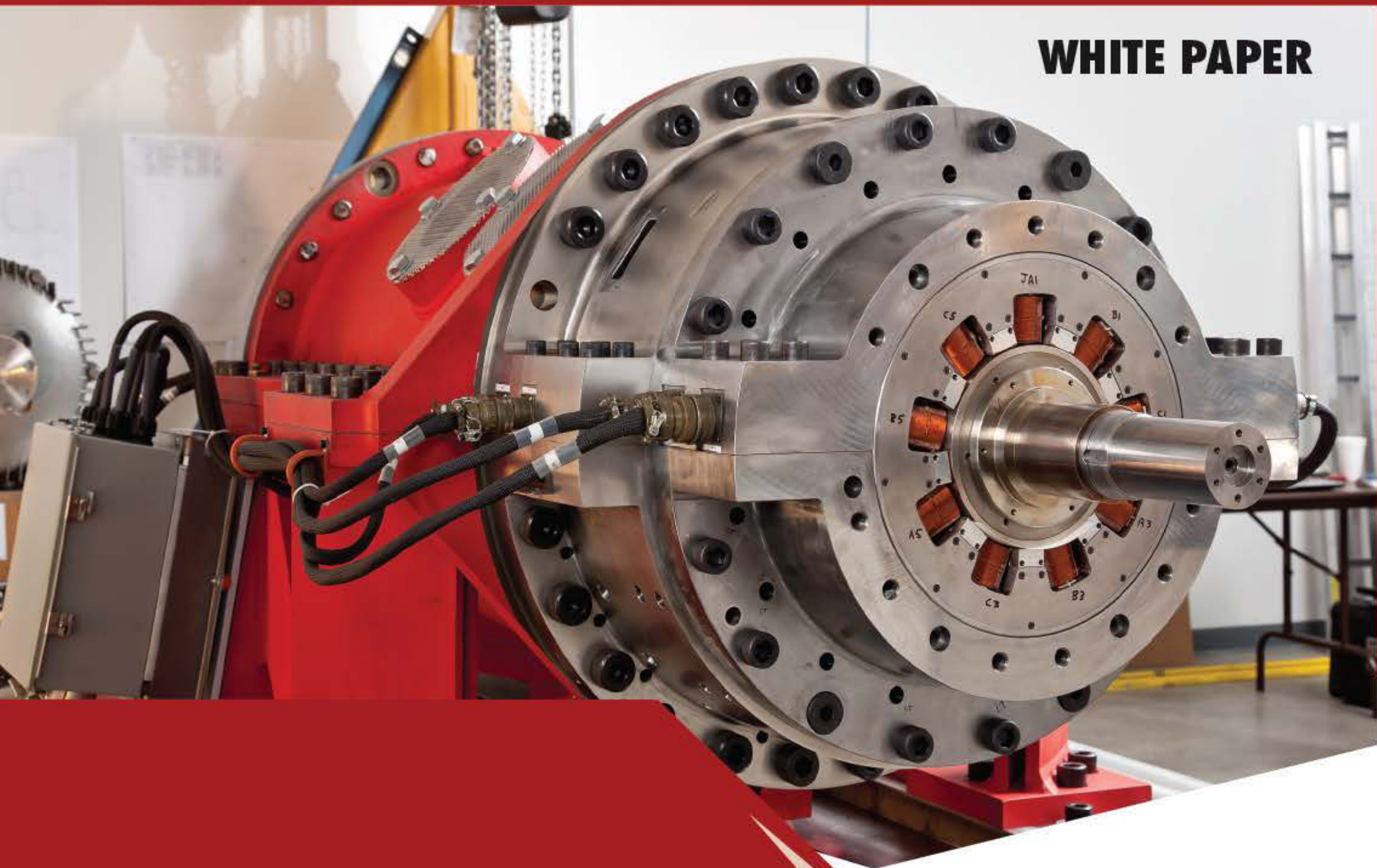
WHITE PAPER



DRESSER-RAND.

Bringing energy and the environment into harmony.®

IMPROVING ROTATING MACHINERY PERFORMANCE WITH DRESSER-RAND'S SYNCHRONY® ACTIVE MAGNETIC BEARINGS

ABSTRACT

Rotating machinery is a key driver of many industrial processes, and because it requires a great deal of maintenance in order to remain operable, there is significant opportunity to take advantage of savings by improving machine performance and increasing operational efficiency. Fluid film technology, in particular, is extremely maintenance intensive and between the auxiliary systems required for lubrication and energy losses due to friction, it can often be a major source of inefficiency. This paper will focus primarily on Dresser-Rand's Synchrony® active magnetic bearings (AMB) and how their implementation can reduce the environmental footprint of rotating machinery, lower maintenance expenditures, increase efficiency, and overcome the limitations that typically plague oil-lubricated and fluid film bearings in processes associated with a wide range of industries. It will include a detailed technical overview of how Synchrony AMBs work and the operational advantages they provide. It will also discuss how recent technological advances in miniaturization and standardization have made AMBs a much more economical option than they have been in the past, along with an examination of rotating equipment applications where AMB technology is being used today and where it can be implemented in the future.

INTRODUCTION

In a day and age when environmental consciousness and sustainability are at the forefront of mechanical design, the demand for innovative products that can help owners and operators cut energy costs and improve process efficiency is becoming increasingly prominent.

Fluid film bearing technology has dominated the rotating equipment industry for more than 100 years, but as manufacturers, producers and service providers are being asked to operate in much harsher physical environments, their limitations are becoming problematic. In addition to being very maintenance intensive, oil-lubricated and fluid film bearings experience energy losses due to friction, and on high-speed rotating applications, these losses can represent a significant portion of total energy consumption. Their reliance on lubricants and various cleaning agents to perform properly does not align with the increasing emphasis to remain green and as a result, the development of cleaner, more reliable alternatives has become important.

In recent years, active magnetic bearings have proved to be one of the most economical alternatives to fluid film technology. With minimal losses due to friction, extended product life and virtually no maintenance requirements, they are becoming increasingly popular in a broad range of operations, including those seen in manufacturing, refining and HVAC applications.

Synchrony AMBs represent an efficient bearing solution for rotating equipment in a number of different industrial processes. Capable of operating in temperatures as high as 350° F and with a mean time in between failures (MTBF) of more than 80,000 hours, they provide a level of performance, reliability and sustainability that fluid film and oil-lubricated bearings simply are not capable of providing.

Stator and rotor for active magnetic bearing (AMB)

OVERVIEW OF SYNCHRONY ACTIVE MAGNETIC BEARING TECHNOLOGY

Contrary to popular belief, active magnetic bearings have been in use for almost 50 years. Although in the past size and complexity have limited their implementation to a small number of niche applications, technological advances in miniaturization and standardization of AMBs and their control systems over the last decade have made them a much more feasible product for rotating equipment in a wide range of industries.

HOW SYNCHRONY AMBs WORK

Active magnetic bearings operate on the principle of magnetic levitation. As seen in Figure 1 below, stationary electromagnets are positioned around the rotating assembly of a machine. Typically, two radial magnetic bearings are used to support and position the shaft in the lateral (radial) directions and one thrust bearing is used to support and position the shaft along the longitudinal (axial) direction. A shaft that is completely supported by magnetic bearings provides support along five axes: two axes for each radial bearing (x-y) and one translational axis (z) for the thrust bearing. Because they require no contact between stationary and rotating components, magnetic bearings offer little frictional resistance to motion along the rotational axis.

Each Synchrony magnetic bearing consists of a stator, which contains the electromagnets and the position sensors; and the rotor, which rotates with the shaft. When the bearing is operating, each rotor is located in the center of the corresponding stator. The position of the shaft is controlled using a closed-loop feedback system that uses position sensors to detect any local displacements from the shaft.

Using an advanced controlling algorithm, the controller processes signals from these position sensors and calculates how to re-distribute the currents in the electromagnets to restore the shaft to its centered position. Power amplifiers in the controller then readjust the currents in the electromagnets according to these calculations. This cycle is repeated approximately 15,000 times per second.

Much like other types of bearings, Synchrony AMBs provide stiffness and damping. However, unlike other bearings, stiffness and damping vary as a function of disturbance frequency. It is often convenient to describe the bearing as a transfer function with an amplitude and phase that vary with frequency. The optimization of this transfer function is a critical step in ensuring that the magnetic bearing performance has adequate stability and force rejection capability over a broad spectrum of frequencies. Stiffness and damping specifications can be altered by simply changing the control algorithm.

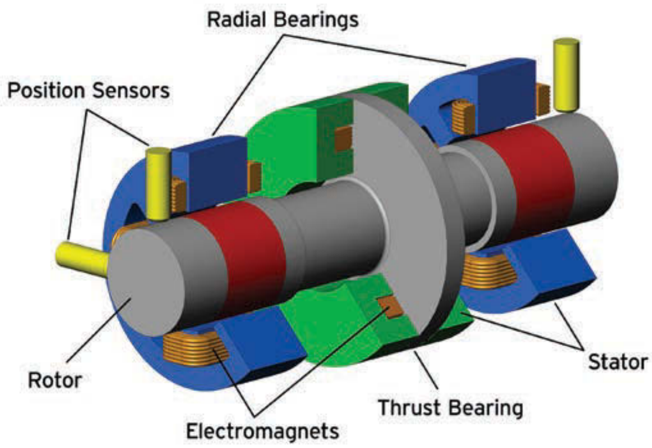


Figure 1. Cutaway of a shaft under 5-axis support showing AMB components

HOW ADVANCES IN MINIATURIZATION AND STANDARDIZATION HAVE MADE AMBs MORE ECONOMICAL

REDUCED SIZE

In the early stages of their development, the bearing pressure of an AMB was many times less than that of a conventional bearing. Because load capacity is directly correlated with bearing pressure, early AMBs had to be very large in order to adequately support rotating machinery.

In recent years, the design and construction of AMB actuators has improved such that the actual size of AMBs has been significantly reduced. Bearing pressure for AMBs has been improved by increasing the amount of electrical steel at the bore of the stator where force is created. The outer diameter of the stator has also been reduced by splitting the flux paths and isolating the electromagnets. Finally, the length of radial magnetic bearings has been shortened by developing position sensors that can be integrated into the electromagnets. Through all of these design innovations, the average size of radial magnetic bearings has been reduced by more than 30 percent.

REDUCTION IN THE SIZE OF CONTROLLERS

Historically, the size of AMB controllers has also limited their use to select applications. However, through the implementation of frequency-modulated (FM) sensing techniques and digital electronics, the size of electronic hardware has been greatly reduced and the signal-to-noise ratio has substantially increased.

Dresser-Rand's recent design innovations have also systematically miniaturized and eliminated many controlling components, including sensor conditioning electronics, analog-to-digital converters and amplifiers. The size of digital processing systems has been reduced and the use of integrated architecture that handles network communications and generates the timing signals to switch the transistors in the power amplifiers has improved AMB performance. Once as big as a large refrigerator, AMB controllers are now comparable to the size of a DVD player.

SIMPLIFIED SYSTEMS

In the past, engineers that encountered a magnetic bearing system for the first time were often shocked by the quantity and complexity of the cables and connections. Between electromagnets, coils, sensors, and temperature probes, typical AMB systems required anywhere from 30 to 40 separate wires. In addition, many of these wires carried large currents (20-50 A) and were routed to control rooms as far as 300 feet (~90 meters) away. This drove up material costs due to copper usage and created a number of issues related to electromagnetic interference (EMI).

Final wiring of multi-sector, radial AMB stator

Dresser-Rand's new, compact controllers can be integrated into the casing of the machine, mounted on the exterior of the machine or located on the machine skid. This significantly shortens the wires between the controller and the magnetic bearings. As a result, cables and connections have been greatly simplified. EMI has also been reduced and no special tuning of the sensors is required. Controllers are supplied with 48 VDC and 300 VDC from a power supply located at a convenient place such as a motor control center.

HOW SYNCHRONY AMBs COMPARE TO OTHER BEARING TECHNOLOGY

Though oil-lubricated and fluid film bearings are highly prevalent throughout the rotating equipment industry today, their maintenance-intensive nature is becoming less and less aligned with manufacturers, producers and service providers desire to cut costs, boost production and increase the environmental friendliness of industrial operations. Through many of the technical advances in miniaturization and standardization discussed in the previous section, active magnetic bearing technology now offers a number of financial and operational benefits that conventional bearing technology is not capable of providing. The advantages that Synchrony AMBs offer when compared to other types of bearings are outlined in the sub-sections below.

NO ENERGY LOSSES DUE TO FRICTION

Fluid film bearings lose energy in the form of heat, regardless of how efficient they are. Even in bearings coated with highly advanced lubricants, friction cannot be completely eliminated. Many manufacturers tout their bearings as "anti-friction" alternatives; however, almost all of them require physical contact between surfaces. As a result, they are subject to energy losses.

In Synchrony magnetic bearings, the rotor is completely suspended in the stator by electromagnets. This virtually eliminates the presence of any friction and prevents energy from being lost due to slippage between surfaces.

REDUCED MAINTENANCE EXPENDITURES

Even adequately lubricated bearings experience wear and tear over time. Because their failure can have such catastrophic effects on the operation of rotating machinery, they require a great deal of maintenance. This is especially true in applications where bearings are required to operate at very high speeds. Furthermore, because conventional bearings rely on a perfectly smooth contact surface to operate, very minor occurrences of corrosion, contamination and/or deformation can render them inoperable.

Synchrony AMBs don't require any pumps, sumps, gearboxes, or lubrication and because they are frictionless, they experience essentially no wear and tear. This reduces, and in some cases, completely eliminates, the need for many of the manpower-intensive activities typically associated with bearing maintenance, such as cleaning, lubricating, repairing, and replacing. This increases uptime and productivity.

HIGH PERFORMANCE AND RELIABILITY IN EXTREME OPERATING CONDITIONS

Nearly all bearings require a smooth contact surface between rotating and stationary components. As a result, high temperature environments that deform steel and other metallic elements can be extremely problematic. Cold environments can also pose significant issues for lubricants because as temperature drops, lubricant viscosity increases. This hinders its ability to flow and to reduce friction between surfaces.

The MTBF for a Synchrony AMB exceeds 80,000 hours. They also can perform effectively in temperatures as high as 350° F and as low as -70° F, making them ideal for use in applications that have to withstand extreme environmental conditions, such as those in processing, manufacturing and/or subsea activities.

ENVIRONMENTALLY FRIENDLY

Fluid film bearings require dedicated lube oil systems and extensive maintenance in order to sustain optimal performance. This includes changing and disposing of the lube oil and cleaning the oil system with other hazardous and corrosive chemicals. AMBs, on the other hand, do not require the use of any harmful chemicals. In addition to reducing a machine's environmental footprint, this eliminates chemical disposal costs and removes fire hazards caused by flammable substances. By eliminating contact, magnetic bearings also produce less noise and reduce vibration.

EXTENDED PRODUCT LIFE AND LOWER TOTAL COST OF OWNERSHIP

The acquisition cost of active magnetic bearings is often less than the oil lubrication system that it eliminates. In addition to significantly reducing maintenance costs over the course of a machine's useful life, processes that feature magnetic bearing technology typically experience less downtime. This can translate into a substantial amount of money saved considering the fact that in some applications (such as those in the oil and gas industry), the cost of having a machine down can be as high as $1 million per day.

IMPROVED HEALTH MONITORING

Health monitoring is critical to keeping machinery up and running and because of this, rotating equipment typically requires a dedicated vibration monitoring system consisting of proximity probes, conditioning electronics, high-speed data acquisition systems, digital processors, and other expensive hardware. In many instances, these systems can cost tens of thousands of dollars.

With Synchrony AMBs, this capability is inherent, and as a result, health monitoring can be performed without the use of any additional hardware. This is made possible by highly advanced sensors located on each bearing that continuously measure critical system parameters such as shaft position, temperature, force, flux, voltage, and current. All of this data can then be used to identify trends and flag abnormalities so that systems can be checked and measures can be taken to prevent machine failures and breakdowns before causing operational interruptions.

Furthermore, much of the data processing can be performed by the magnetic bearing controller itself rather than by a separate data acquisition system. The results of these calculations can then be sent over high-speed Ethernet networks, and when integrated with computer software, visualization of orbits, advanced diagnostics, trending, archiving, and alarming can all be achieved.

ACTIVE MAGNETIC BEARING APPLICATIONS

OIL AND GAS

DIRECT DRIVE SOLUTIONS

Synchrony active magnetic bearings can be used on compressors, turboexpanders, motors, and pumps in nearly every phase of oil and gas production. From extraction and refinement, to transport and storage, AMBs are ideal for operation in highly demanding environments where reliability and cleanliness are of the utmost importance. Because they don't require the use of any external monitoring hardware, they also can be used in applications where availability of space is an issue, including refinement, offshore drilling, and/or subsurface operations. For mission-critical machines, Synchrony AMB's optional fault-tolerant controlling system uses redundant channels of actuation, sensing, processing, and amplification, which help improve reliability and protect the machine in the event that AMBs aren't operating properly.

Dresser-Rand's DATUM® C hermetically sealed, integral high-speed, motor-driven compact compressor is designed for use in natural gas pipeline and process gas applications (onshore and offshore). With a small footprint and modular compressor bundle, it minimizes the need for auxiliary systems and buildings, which provides cost savings during installation. Because it uses Synchrony AMBs, the DATUM C compressor also offers a number of environmental advantages, including quiet operation, reduced footprint, no on-site leakage from shaft seals, and zero emissions. In addition, the unit can remain pressurized during shutdowns, resulting in reduced start-up time.

Dresser-Rand DATUM C bundle

Dresser-Rand's DATUM® integrated compression system (DATUM® ICS) also uses AMB technology and is uniquely suited for sub-sea operations. It can serve as a more versatile and energy-efficient means of removing liquid from product streams while increasing the pressure of dehydrated outlet gas. The centrifugal separator in the DATUM ICS provides the motor cooling system with a cleaner and dryer gas when compared to other solutions that use gas as a cooling medium, and with higher system reliability and extended intervention intervals, operating costs are reduced. The replacement of traditional compression models with the DATUM ICS can result in as much as a 45 percent reduced footprint and a 35 percent reduction in overall weight.

WATER AND WASTEWATER

HIGH-SPEED CENTRIFUGAL BLOWERS

A recent study revealed that nearly half of the total energy consumed in a wastewater treatment plant is represented by the operation of blowers during the aeration process[1]. Using a Synchrony high-speed motor, centrifugal blowers (or turbo blowers) are capable of reducing energy usage during aeration by as much as 40 percent.
In addition, turbo blowers require less space,

[1] *Retrieved 17 June 2014 from http://epa.gov/statelocalclimate/documents/pdf/wastewater-guide.pdf*

less maintenance and operate much quieter than conventional units. Synchrony magnetic bearings are also less susceptible to dirt and contamination and through improved health monitoring electronics, operating personnel are able to closely monitor the performance of rotating machinery, resulting in better process optimization.

AEROSPACE AND DEFENSE

TURBINE AND GENERATOR SETS

Turbomachinery operations in the aerospace and defense industries present a number of unique and difficult challenges that aren't typically encountered in any other fields; where conventional bearing machinery has failed, active magnetic bearings applications have thrived. AMBs can be used to improve the performance of power and propulsion systems in airborne, naval and ground-based systems.

Turbine gen-sets that feature Synchrony AMBs are more compact and lightweight. They are ideal for use in highly demanding applications that require mobility, durability and low maintenance, such as portable power systems, aircraft-ground power units, auxiliary power units (APU), and naval propulsion systems.

RENEWABLE ENERGY

HIGH-SPEED GENERATORS FOR ORGANIC RANKINE CYCLE (ORC)

Because of the green and sustainable benefits they provide, active magnetic bearings are becoming increasingly popular options for a wide range of solutions throughout the renewable/recoverable energy industry.

A Synchrony high-speed generator harnesses the energy in fluid streams to produce electric power. With minimal energy losses due to friction and no need for oil-based lubricants, magnetic bearings in the generator help boost process efficiency and reduce costly maintenance expenditures. Other applications include energy recovery from pressure letdown systems (e.g., steam and natural gas), as well as geothermal and solar power generation systems.

Compact controller and radial AMB stator

HVAC

HIGH-SPEED MOTORS FOR CHILLERS

HVAC chillers typically consume very high amounts of energy. However, by replacing fluid film bearings, gears and low-speed induction motors with high-speed motors that feature magnetic bearings, energy can be conserved and efficiency can be improved at both full and partial loading capacities.

Chillers that use magnetic bearing technology are up to 40 percent more energy efficient than conventional centrifugal chillers. This equates into millions of dollars in savings over the useful life of a machine. Initial capital costs and maintenance expenditures are also lower in chillers that use magnetic bearings because they do not require positive pressure lubrication systems. The absence of these systems also eliminates performance degradation caused by non-condensables and/or oil contamination of refrigerants.

Synchrony high-speed motors (up to 20,000 rpm) provide compression of R134a in large chillers. Equipped with variable frequency drives (VFDs) and oil-less drive trains, these units translate into better value for the end user and a greener environment. The reduction in electrical power also lowers the Global Warming Potential (GWP) of the chiller and its compatibility with R134a reduces the Ozone Depleting Potential (ODP) to zero as well.

CONCLUSION

As manufacturers, producers and service providers continue to look for ways to improve the reliability of their machines and reduce the environmental footprint of their operations, the demand for sustainable mechanical technologies that can improve uptime and provide measurable advantages when compared to conventional products are increasingly important.

Though at one time limited by their size and complexity to niche applications in very specific fields, active magnetic bearings now have a proven track record of serving as a highly economical alternative to conventional bearing technology in a wide range of industries. As reliability, robustness and efficiency become more and more critical to the successful operation of rotating machinery in some of today's most demanding environments, the role of AMBs will become more prominent.

Dresser-Rand
4655 Technology Drive
Salem, Virginia 24153
Phone: (Int'l +1) 540-444-4200
Fax: (Int'l +1) 540-444-4201

www.dresser-rand.com
www.synchrony.com