CENTRIFUGAL AIR COMPRESSORS
MODULAR DESIGNS TO REDUCE
CAPITAL AND OPERATING COSTS

In many aspects, air compressors are very similar to pumps. In recent years, manufacturers have moved toward modularized designs, improvements in other mechanical aspects, and the addition of increasingly advanced control strategies and diagnostic capabilities. For plant operators, these improvements ensure the reliable, cost-effective availability of dry, oil-free compressed air for numerous plant and process operations.

Compressed air is an essential requirement for combustion systems, air-separation processes, pneumatic-conveying systems, plant and instrument air, and other applications in almost every type of industry. While the basic design of the centrifugal air compressor has remained unchanged for many years, vendors of these workhorse machines are well aware of the need to continuously advance their designs, in order to keep pushing the performance envelope.

API-certified compressors
Many of these continuous-improvement efforts have been aimed at reducing capital and operating costs. For instance, in recent years, advances in everything from the mechanical design of the entire package, to the seal and bearing design, to the broader diagnostic capabilities of today’s advanced control systems, have resulted in demonstrable improvements in both the mechanical and aerodynamic performance, and the electrical efficiency of centrifugal air compressors, which have improved reliability and reduced costs.

While the air compressors that are used for oil-and-gas, petroleum-refining and petrochemical applications must meet the rigorous specifications of American Petroleum Institute (API) standards, such as API 672 and API 617 and their global equivalents, such specialized compressors tend to use the same basic air end - the heart of the compressor - as today’s standard industrial units. The specialization of API-certified compressors comes from the additional specifications that are related to testing and inspection, and from upgrades to the basic design, custom engineering of the skid, the use of advanced materials of construction, and the addition of different enclosures, additional instrumentation, controls and piping, proximity probes, redundant lubrication system components, and welded stainless steel connections for the oil piping.

While all of these specialized upgrades can raise the cost of an API compressor considerably, the good news for industrial operators is that many of today’s regular industrial air compressors now include – as standard – many of the same performance-enhancing add-ons that were once reserved for customized or highly engineered API compressors.

For example, advanced interstage coolers with low approach temperatures are now part of many standard packages. Such high-efficiency coolers typically employ compact, highly efficient shell-and-tube coolers, high-density-plate coolers, or plate-fin coolers to remove the heat buildup that occurs between air compression stages within the centrifugal compressor.

Siemens is profiting from the strong growth of the plastics market in China. The company has supplied three compressor trains with a total of six compressors and three steam turbines for China’s largest olefin plant. This facility will have a capacity of one million tons of ethylene and 500,000 tons of propylene per year. The entire compressor train is more than 20 meters long and weighs 400 tons. The picture shows a compressor train which is similar to that in Dushanzi.
Modular designs reduce costs
In recent years, nearly all of the major manufacturers have begun to offer centrifugal air compressor systems that are assembled from a number of standardized, pre-engineered modules. Today’s, air compressors with modular designs are available from such vendors as AG Kühnle, Cooper Compression, Man Turbo, FS-Elliott, Dresser-Rand, Siemens Power Generation Industrial Applications and General Electric. The use of pre-engineered, pre-assembled modular components greatly reduces the number of overall components and parts compared to conventional designs. This reduction in parts lowers capital costs and shortens assembly times, and modular designs allow all internal parts to be pre-assembled in a shop environment, under more controlled working conditions than those found in a typical plant environment. Meanwhile, for the user, modular designs make it easier for maintenance engineers to gain ready access to work on various compressor subsystems. For instance, individual control, intercooler or lubrication modules can be accessed for maintenance or repairs without disturbing or disassembling the whole unit.

Today’s modular designs also give operators unprecedented flexibility when it comes to modifying the system parameters to meet changing facility needs with minor, module-specific adjustments or replacements. For instance, if the facility’s compressed-air needs change over time, due to demand for higher or lower flow, the engineer only needs to exchange one or two individual modules to upgrade and adapt the existing compressor.

Increased performance
In addition to modularization, the performance and reliability of today’s centrifugal air compressors are being improved thanks to ongoing improvements in other aspects of their mechanical designs. For instance, many manufacturers have improved compressor reliability by continuously improving the rotor shaft bearings, using such designs as hydrostatic bearings, non-contact magnetic bearings, self-adjusting bearings, and double-acting thrust bearings to minimize vibration over the full range of operating load.

And every vendor takes pride in its state-of-the-art impeller designs. Most of today’s impellers are made from hardened steel to withstand the corrosive and erosive effect of atmospheric contaminants and water vapor, and incorporate state-of-the-art backward-leaning design, with intricate, propri-
tary three-dimensional configurations – which requires complex, five-axis milling during manufacturing – for optimal aerodynamic performance.

Man Turbo f.i. improved the design of its RIK, RIKT and RIO centrifugal compressors, which are designed mainly for large-scale air-separation plants, by replacing the first inline impeller with an overhung open impeller with no shroud. Compared to the previous design, such an impeller has a higher specific volumetric flow (dimensionless volume coefficient) at similar or better efficiencies, says the company.

Advanced control systems and diagnostic capabilities

Today’s manufacturers continue to add control system capabilities to improve overall air compressor control, to improve system reliability and energy efficiency in the face of varying demand, and to assist with troubleshooting, and predictive and preventive maintenance efforts.

For instance, the Regulus control system on FS-Elliott’s Polaris P-300 centrifugal air compressor is a programmable logic controller (PLC) with an intuitive touch-screen interface that allows the operator to view and control all operational parameters, including system status, history, mode selection, setpoint values, system data and diagnostics and testing.

While standalone control is important, most of today’s centrifugal compressors also include a serial port that allows the unit to interface seamlessly to the facility’s plantwide distributed control system (DCS). This allows the user to monitor and manage all of air compressor needs either right at the unit, or from any remote location.

The control systems that come as standard on many of today’s industrial centrifugal air compressors now routinely allow for greater process monitoring and diagnostics than ever before, letting operators track, for instance, the real-time status of such critical operational factors as pressure and temperature, surge detection, aerodynamic performance, rotor and bearing vibration, shaft displacement, rotor axial position, water temperature and flow in the cooling system, lube oil supply, and even the temperature inside an enclosed room to detect any heat buildup from the motor.

Coping with fluctuating demand

Producing compressed air is an inherently costly and energy-intensive operation. As a result, compressor manufacturers are always seeking ways to improve the energy efficiency of their units.

While compressed air is an essential requirement for many chemical processes, and industrial and manufacturing operations, very few facilities have a constant demand for it – instead, the need for compressed air typically varies from day to day, and sometimes from hour to hour.

The conventional approach for coping with such fluctuating demand has been to run the compressor at a constant rate, and to simply vent the unneeded compressed air to the atmosphere. But this is an inherently costly and energy-inefficient approach.

In recent years, to reduce energy consumption and match the compressor operation more effectively with the application requirements, many positive-displacement compressors (such as screw and reciprocating-piston compressors) have been equipped with variable speed drive (VSD) capabilities, to modulate the speed of the motor, or variable frequency drive (VFD) capabilities, to modulate the frequency of the incoming power.
Rather than allowing the compressor to simply run idle when demand for compressed air falls, these systems use pressure sensors, frequency converters and microprocessor-based controls to continuously adjust the motor speed, allowing the compressor to provide the required air supply at the required pressure while greatly reducing the electrical demand of the overall system.

However, while the use of VSD and VFD has become commonplace for positive-displacement compressors, except for rare exceptions, such systems are not appropriate for centrifugal air compressors. Because the output of air from a centrifugal compressor is a function of the motor speed, any reduction in speed would hinder the unit’s ability to deliver a given volume of air at a given discharge pressure.

Instead, to maximize energy efficiency and minimize costly air bleed in the face of variable demand, today’s centrifugal air compressors tend to rely on inlet guide vanes, with or without diffusers and throttling valves, to modulate the amount of inlet air coming into the unit, and this allows such designs to meet variations in product demand more energy efficiently compared to units that rely on blow-off valves.

One exception, however, is the ZB VSD centrifugal air compressor from Atlas Copco. Designed for low-pressure compressed air applications, this compact system (weighing just 1,200 kg) does include VSD capabilities as a standard feature. To achieve larger flow volumes, multiple ZB VSD units can be connected in parallel.

The ZB VSD is also directly driven by a permanent magnet synchronous, which reduces energy losses and cooling requirements and offering higher speeds in a more compact design than conventional designs, according to the firm. Atlas Copco also offers the heavy-duty GT Series centrifugal air compressors to serve large-scale cryogenic air-separation units producing oxygen and nitrogen, and the H-Series and ZH-Series centrifugal air compressors for a variety of industrial, refining and petrochemical applications.

Several years ago, a major redesign helped AG Kuhnle, Kopp & Kausch modularized SFO and SFOG centrifugal compressors to achieve stage efficiency of greater than 90 % in most applications. According to the company, this represents “best-in-class” isentropic (stage) efficiency. This efficiency, combined with the use of inlet guide vanes and inlet diffuser guide vanes, and an advanced control system, allows the SFO and SFOG compressors to accommodate turndown ratios as great as 35 % without the need to bleed off unwanted compressed air. Turndown ratios of 50-70 % are more typical throughout the industry. These two product lines are designed for relatively low-pressure applications, and have a power rating to 10,000 kW, producing compressed air flows of 1-150 m3/sec at discharge pressures up to 3 bars.

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