Centrifugal compressors can provide increased efficiency

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This article traces the development of the centrifugal compressor and looks at options for re-rating and enhancing compressor performance.

Centrifugal air compressors are ideal for applications requiring a large supply of oil-free compressed air and have been used in the process industries for many

years. They are an important component of many utility applications from water and wastewater treatment to power generation. This type of compressor is also widely used in large scale manufacturing industries, in addition to more specialised applications.

In the 1960s, when packaged centrifugal air compressors were first introduced by Ingersoll Rand and other manufacturers, a cost-effective alternative to the existing design of centrifugal compressors was provided. This expanded applications for these machines beyond the traditional process industry market.

The CENTAC packaged oil-free centrifugal compressor line from Ingersoll-Rand was introduced in 1968. Over the last 30 years, improvements have been continuously made to the original compressor. These include new materials and components, with more accurate engineering, design and production methods used to manufacture the current line of compressors.

Ingersoll-Rand's air compressor group now provides a range of aftermarket services to help users to build on their original investment. For instance, the performance of CENTAC compressors can be changed by re-rating, which involves installing a new selection of internal parts to achieve a different performance requirement. In many cases, power savings and payback can be calculated to support the need for change. Alternatively, a performance enhancement can be carried out which uses aerodynamic designs that will achieve an increase in efficiency compared to the original design. A customer's existing equipment installation can be analysed to determine whether a re-rate or an enhancement is required and to determine which changes are feasible.

Re-rate package

Re-rating is available on a wide range of new and old CENTAC compressors. Performance enhancements are normally limited to older models and are aimed mainly at machines installed in the 1970s and 1980s, which still form a significant proportion of those in service today.

For a re-rate, the change desired must be within the frame size capacity limit of the installed compressor. There are various models and flame sizes; model size relates to an outline appearance, and frame size relates to the different physical sizes or capacity ranges of the machines within a model group. There are many combinations of pressure, flow and horsepower that can be supplied in a particular frame size. Each frame size has minimum and maximum flow pressure and horsepower limits and their selection is usually determined by capacity need.

Consider a machine built with a design flow of 200[m.sup.3]/min, which is a capacity level near the middle of the frame size flow range. Because the limits of the frame size were not reached in the original design, the machine might be capable of being re-rated to a higher or

lower capacity or pressure.

When it is determined that a re-rate is possible, then component changes to meet the new needs are specified. These components will usually be parts that would have been used in the machine had it been originally configured for the desired change. In many cases of re-rate, where increased flow is desired, a larger driver (motor) is needed as well as different impellers, diffusers, bearings and other parts. The only parts of the original compressor that might remain following a re-rate are the cast iron casing and the base plate.

The engineering study and the components that are provided constitute a re-rate package. Installing a re-rate package to change flow or pressure provides an economical alternative to acquiring a new machine. In unusual circumstances, it is also possible to de-rate a centrifugal compressor to meet a lower capacity requirement. This process can be reversed by a later re-rating to meet a future expansion of compressed air demand.

Performance enhancement package

Performance enhancement of a CENTAC compressor is similar to a re-rate in some respects but is totally different in other ways. Performance enhancements add new parts to an older machine and the original horsepower can be maintained. Enhancement efficiency improvements can also be used to maintain the original capacity but with reduced horsepower.

Many older CENTAC centrifugal compressors exist in the field. They will normally have run for longer periods of time and the general effect of wear and tear on interstage cooling, impeller clearances and controls will have taken its toll on the machines' efficiency. Such compressors can benefit from a major overhaul and can be upgraded to improve their efficiency and extend the lifecycle for many more years.

The improvements to energy efficiency have been achieved in areas such as part load control; aerodynamic components; the incorporation of control technology such as the new CMC system; and the provision of new seals, bearings and other vital components.

Centrifugal compressor performance varies with inlet air density and cooling medium temperatures. Hence, most industrial compressors are rated at worst case design temperatures and barometric pressures. In the field, such compressors are normally operating at higher air densities and at a higher capacity, therefore, a greater power input is required.

The capacity of most ageing industrial centrifugal air compressors is controlled by inlet butterfly valves. These modulate the weight of air flowing into the first stage impellers, changing the capacity of the machines in proportion to the system pressure. At full load the butterfly valve is fully open, as the overall system pressure begins to rise above the set point, due to lowering of the air demand, the valve throttles the inlet flow to the point of maximum turndown. The turndown ratio capability of the compressor is established by the point at which natural surge approaches the set pressure.

If the system pressure continues to rise, when the point of maximum turndown is reached, an atmospheric by-pass valve opens to enable excess compressed air to be bled off.

Inlet butterfly valve control does reduce the capacity of the machine. However, since it introduces turbulence during throttling in the inlet of the first stage impeller, the power consumption at part load is high and the stable operating range is limited.

To improve energy efficiency, standard industrial centrifugal compressors have been fitted with inlet guide vanes, to the first stage, as original equipment. Inlet guide vanes improve the stable operating range and reduce part load power consumptions, particularly in off-design conditions, and are a typical component of a performance enhancement package.

The new aerodynamically designed impellers feature an elongated inducer section with increased blade area and a higher degree of backward lean on each blade. The enhanced

impeller geometry promotes higher stage efficiency due to additional velocity diffusion within the impeller. The result is comparable flow rates with less energy consumption and improved turndown characteristics. The impellers are part of a range of enhanced aerodynamic parts, which together yield higher stage efficiencies.

Reliability increases are an additional part of the CENTAC enhancement process. This can involve exchanging a number of components such as the pinion and shaft seals for new products using a full-floating carbon ring seal to accomplish sealing; the use of an upgraded double lip bull-gear seal; upgraded radial and thrust bearings with no moving parts; and an upgraded main oil pump using castings with enlarged suction ports and smoother interior faces.

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