OLD TECHNOLOGY, NEW APPLICATION

ADAPTING INTEGRALLY GEARED COMPRESSORS FOR HIGH-TEMPERATURE APPLICATIONS

BY MEGAN SCHAENZER AND AXEL SPANEL

Historically, axial compressors have been the technology of choice for meeting high-flow requirements in blast furnace blower (BFB), fluid catalytic cracking (FCC), and propane dehydrogenation (PDH) applications. Axial compressors offer high efficiency and predictable performance. However, these compressors come with trade-offs, including a large footprint, long lead times, frequent maintenance, and a substantial risk for blade damage at surge conditions.

Based on proven integrally geared compressor technology, single-stage overhung compressors (SOCs) have emerged as a reliable alternative to axial compressors. Siemens Energy currently offers an SOC that can achieve pressure ratios of 2.5 or higher in a single stage and up to six in tandem design.

Tandem arrangement features two SOCs connected on opposite ends of a double-ended steam turbine driver (with or without interstage cooling). The non-cooled variation is particularly well suited for BFB and FCC processes, because the higher discharge temperature reduces heating duties for the blast furnace or regenerator, leading to lower energy consumption and higher plant efficiency.

AXIAL VS. OVERHUNG IMPELLER COMPRESSORS

Operators often cite intensive maintenance as one of the biggest drawbacks of axial compressors. The complexity of these machines and the high number of intricate parts largely attribute to this drawback. A single axial compressor can contain as many as 400 blades, making routine inspections cumbersome. The need to remove cones for bearing and/or seal exchange, along with the requirement for heavy lifting equipment when servicing the rotor, also contribute to increased operating expenses (OPEX).

Because these high-flow applications also need to meet pressure requirements, several compressor stages are necessary, and the footprint of the train becomes very large. For example, in BFB applications, 10 or more stages may be required. The increased footprint and compressor stages also contribute to a higher capital expenditure (CAPEX) and longer lead time.

Historically, SOCs have not been a viable alternative to axial compressors. This has changed in recent years because design enhancements have enabled these machines to achieve comparable flow rates and pressure ratios to axial machines in fewer stages.

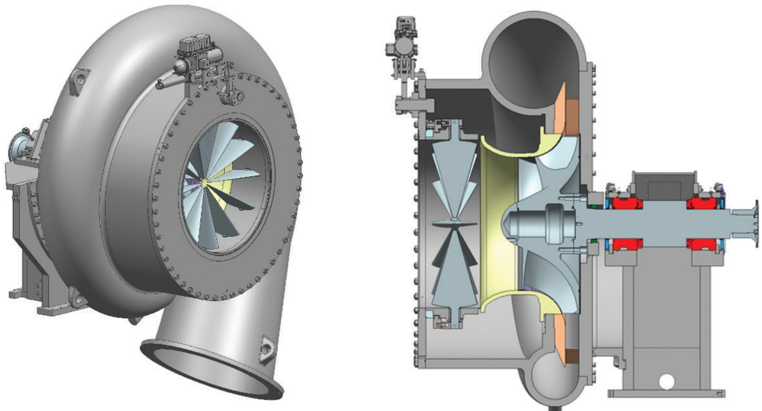

Figure 1. Single-Stage Overhung Siemens STC-GV

An SOC is made up of one compressor stage fixed to the end of a high-speed shaft. The shaft is mounted in a housing that contains the bearings and is directly connected to the driver.

For any project, an optimal combination of shaft speed and impeller size can be specified to meet the unique requirements of the application. The overhung impellers can be fitted with adjustable inlet guide vanes (IGVs) to manage turndown while maintaining high efficiency. Combining these features allows for high-volume flows and energy efficiency (even under partial loads). It also results in a compact footprint.

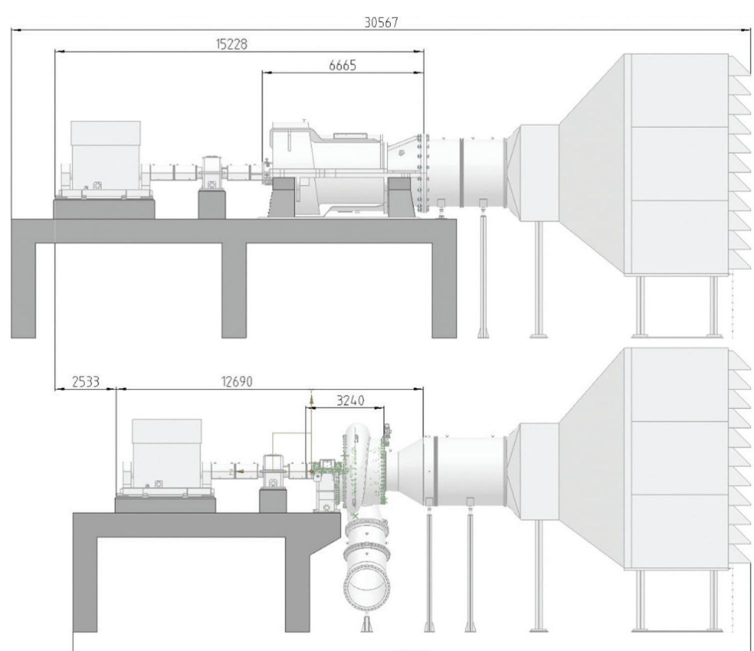

Figure 2. Single-Stage Overhung Compressor Train (Bottom) Vs. Axial Compressor Train (Top)

Other notable advantages of SOCs include:

• **CAPEX –** The cost of an SOC can be as low as one-third of an axial compressor with similar performance characteristics. Fewer components also mean end users can reduce spare part inventories and associated costs. With Siemens Energy's STC-GV SOC, which is based on the proven integrally geared compressor design, more than 90% of parts are standardized (e.g., volute, low-solidity diffuser, IGV, contour ring, etc.)

• **OPEX/Maintenance –** Fewer stages and a simpler design contribute to lower maintenance requirements for SOCs. Oil consumption is also reduced by 25% when compared to axial machines. The requirement for jacking oil is eliminated entirely.

The simplified design makes maintenance tasks easier to carry out. Bearings on the STC-GV can be inspected without lifting the upper half of the compressor. The overall maintenance weight of the unit (i.e., the weight of parts that require lifting) is also 80% lower. Including a base frame, the entire compressor assembly can be moved with a single lift.

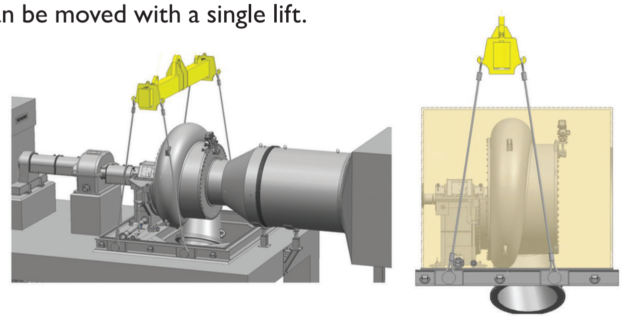

Figure 3. Single-stage overhung compressor and base frame can be moved using a single lift.

• **Flexibility –** The STC-GV SOC was designed with an adjustable volute position for increased installation flexibility. A steam turbine, gas turbine, or electric motor can drive the compressor, without any modifications to the compressor design, because of its modular design. For example, if the steam supply at the facility decreases over time, the steam turbine can be removed and replaced with a motor and intermediate gearbox. In such cases, the compressor itself can remain in place with no design changes.

• **Lead Time –** Typical lead time for an SOC is approximately 25% to 30% shorter than an axial compressor.

NON-INTERCOOLED VARIATION

While SOCs are gaining traction as an alternative to axial compressors, previous overhung models were designed to minimize compressor power requirements. In practice, this meant an interstage cooler was included between the two stages of the tandem design. However, in FCC and BFB applications, intercooling is disadvantageous because more energy input is required in the furnace or regenerator to reach the required temperatures, which means lower process efficiency and a higher carbon footprint.

To address this issue, Siemens Energy has released a version of its single-stage overhung design in tandem arrangement with no interstage cooling (Figure 4). The variation uses the same components as the cooled tandem design, including the same shaft and internal components, but it incorporates several innovative features to accommodate thermal effects of the high-temperature gas entering the 2nd stage.

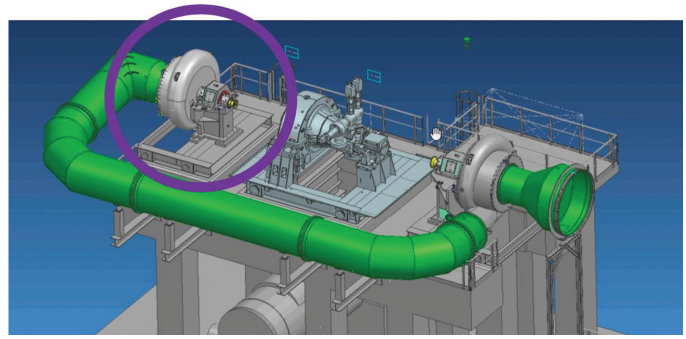

Figure 4. Tandem Single-Stage Overhung Compressor Design With Single-Stage Overhung Impellers On Each End Of The Steam Turbine

The key to the robust thermal isolation design is a three-point support system that allows for thermal expansion without generating high stresses or loss of alignment in the rotor. This contrasts the intercooled design, which features a volute that is rigidly bolted to the rotor casing through a half-circle flange. The half-circle flange bolting is possible because the intercooler keeps the temperature difference between the components low. With the three-point support, the rigid connection is eliminated, and higher temperature discrepancies are easily managed.

The volute itself is very similar to the intercooled design but uses G20MN5 (is a commonly used cast alloy steel for pressure casings within industrial applications) as the casing material because of its high strength at elevated temperatures and relatively high thermal conductivity when compared to other cast alloy steels. The thermal conductivity of G20MN5 allows the volute to quickly reach a thermal "steady-state" condition (i.e., temperature uniformity) during operation.

These features (and others) result in a robust design with discharge temperatures as high as 626°F (330°C) and achievable discharge pressures up to 87 psi (6 bar).

MAKING THE RIGHT CHOICE

Axial compressors continue to serve as a reliable and efficient option for compression in high-flow process applications. However, advancements in SOCs have made them a viable, and in many cases, more economical alternative — with fewer maintenance requirements, shorter lead times, and lower CAPEX requirements.

Although some operators may view SOCs as a novel solution, these machines are based on well-established integrally geared compressor technology and have accumulated millions of hours of uninterrupted service in a broad range of industrial applications. Siemens Energy developed the first integrally geared compressor in 1948. In total, the company has more than 2300 integrally geared units in operation worldwide, many of which are used in applications with flows exceeding 500,000 m^3/hour.

The non-intercooled tandem SOC builds on the same design of past models, but with select features that ensure high performance and reliability when handling high-temperature gases. With these modifications, the compressor can meet standard customer requirements in FCC and BFB applications and, at the very minimum, should be evaluated as an alternative to axial compressors during compressor selection.