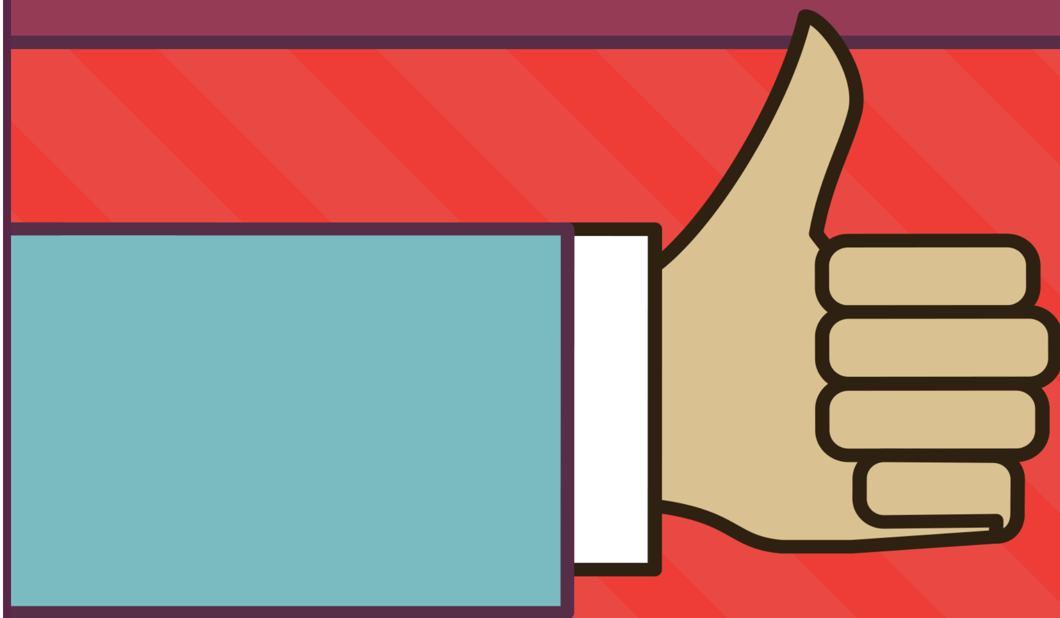
IMPROVING RELIABILITY



Mike Minnerly and Taylor Birckbichler, Elliott Group, USA, discuss how a rerate of a refiner's poorly performing hot gas expander resolved its reliability issues.

COVER STORY

Hot gas expanders have long been used in fluid catalytic cracking (FCC) applications to convert thermal energy to mechanical energy which, in turn, can be used to drive the main air blower or an electric generator. This system is ideal for refineries operating in regions with high power costs. However, the abrasive nature of the FCC flue gas has led to problems with expander reliability, forcing unplanned outages to address the effects of catalyst erosion and/or deposition.

This article examines the rerate of a poorly performing hot gas expander operated by a US refiner. Elliott Group was contracted to retrofit a flow path that would resolve the reliability issues of the non-Elliott expander, and allow the refiner to operate the FCC for the desired five year campaign. Elliott ultimately developed a solution that combined proven flow path technology, while maintaining many of the existing expander components and auxiliary systems, to minimise capital cost. The expander was installed during a planned outage to reduce any schedule impacts.

Expander rerate case study

The original hot gas expander in this case study was installed at the refinery in 1979, and was completely replaced by the original equipment manufacturer (OEM) in 2000. Following five years of reliability issues, including primary erosion, severe secondary erosion/disk cutting, and piping acoustic vibration, a third-party supplier redesigned the unit in 2005. After two unsuccessful operating campaigns for the redesigned expander, Elliott was contacted in 2011 to consult on unit vibration, and to repair the disk secondary erosion.

As a first step, the company conducted a finite element analysis to evaluate the disk stresses and determined that the disk was viable for weld repair. It recommended shape milling of the damaged areas to provide a uniform welding surface, laser welding of the disk tenons using a Waspaloy filler metal, machining of the tenon tips to maintain the original geometry, and coating of the tenons to help mitigate future cutting. The refiner elected to forego the weld repair option and instead opted for a more comprehensive rerate of the expander to prevent similar damage from occurring in the future. The damaged disk was blended to remove any stress risers and coated for use as an emergency spare.

Elliott evaluated the rerate to optimise the flow path of the unit by incorporating an Elliott TH-100 expander design (Figure 1). Several of the expander's existing components were reused, including the exhaust casing, seal housing, and bearing pedestal. New components included the inlet casing and support, stator assembly, rotor, diffuser, bearings and seals, and baseplate.

Inlet casing and support/stator assembly

The new inlet casing assembly incorporated the TH-100 flow path design (Figure 2). The inlet casing consisted of a one-piece forged outer barrel that removed pressure-containing welds, four canted struts to help reduce strut cracking, and a new inlet casing support.

Elliott also integrated an expansion joint into the inlet casing assembly for the rerate. The difference between the inlet and exhaust gas temperature, and the resultant variance in thermal expansion, are significant sources of reliability issues that could eventually lead to expander failure if left unchecked. The expansion joint absorbs deflection to the thermal growth from both the exhaust casing and the inlet casing. This minimises the stresses on the attachment bolts and flanges, thereby preventing bolt failure, and reducing flange distortion and flue gas leaks.

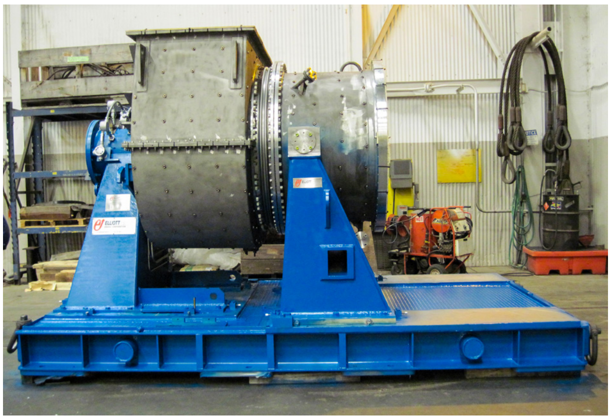


Figure 1. Rerated TH-100 expander as received after the first five year run.

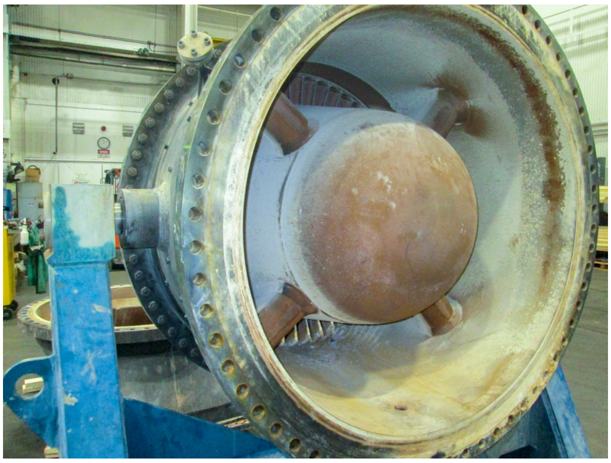


Figure 2. TH-100 expander intake casing assembly as received after the first five year run.

Figure 3. TH-100 rotor blades as received after the first five year run.

Elliott's boltless stator assembly was secured to the casing with locating keys and shear rings. This design removes expensive, high-temperature bolting that can fracture during operations and lead to machine damage. High-temperature hardware also has the potential to seize during disassembly, complicating equipment maintenance and repair.

The company's stator vane is an aerodynamic, tapered, twisted free vortex design that is matched to the tapered, twisted rotor blades. The blade shape minimises erosion of the airfoils caused by conservative stator exit velocities, while maintaining efficiency. The stator assembly distributes gas flow and entrained catalytic particles more evenly along the entire height of the blades and eliminates secondary erosion at the platforms of the rotor blades.

Rotor

Elliott's rotor assembly has blades and disks that can be manufactured from high-performance superalloys such as Waspaloy or the RK1000 superalloy, which has excellent corrosion resistance and is particularly effective against sulfide penetration that promotes hot corrosion. For the rerate application, Waspaloy blades and disks were used (Figure 3). A sacrificial chrome carbide coating was applied to the airfoils to aid in preventing erosion of the base material.

The TH expander rotor design incorporates an axial spline to attach the rotor disk to the shaft rather than the radial pins and rabbet fits typical of other designs. The spline design contributes to rotor reliability by maintaining concentricity and avoiding the stresses incurred by rabbet shrink fitting. The TH design also features a reliable blade root. The enhanced fir tree design features four lands instead of three, reducing stress at the blade root and extending blade life. A no-stress locking rivet removes the need to peen the blade root in position, and thus eliminates the stress on the metal that peening can cause.

To be able to reuse the bearing pedestal, Elliott matched the shaft dimensions of the OEM rotor, forgoing the longer, more stable rotor assembly that is typical for the TH expander product line. The rerated expander, as packaged, also included new bearings, seals, diffuser, exhaust transition piece, and a new baseplate.

Benefits

In addition to the individual benefits offered by each of the new components, the combined TH-100 flow path changes produced a power output 20% greater than the OEM design. Blade containment was improved with the increased material thickness over the rotating blades, and the reduced throttling at the inlet butterfly valve lowered the inlet piping noise.

Rerate results

All of the design changes for this refiner were implemented in 2012, and the new flow path operated without issue until a planned outage in October 2017, a five-and-a-half-year run. This was the longest operating campaign to date for this refiner.

Elliott performed both the field service and unit overhaul for the outage. During the 30 day turnaround window, the unit was removed from the refinery and shipped to the company's service centre in Pittsburgh, Pennsylvania, US. The inlet casing assembly was disassembled, and the casing and nose cone underwent non-destructive testing (Figure 4). No cracking was found on any of the four nose cone struts, and following a pressure test of the expansion joint, the casing was accepted for reuse.

The stator assembly was replaced with the customer-supplied spare part to minimise the overhaul schedule. A visual inspection of the spent stator assembly, however, revealed no signs of cracking or erosion.

Figure 4. TH-100 nose cone struts after cleaning and non-destructive testing.

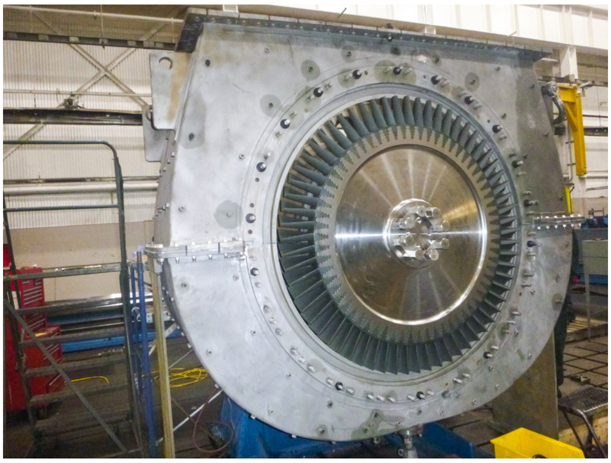


Figure 5. Cleaned and partially reassembled TH-100 expander.

Similarly, the spare rotor and bearing pedestal were used as part of the build. The rotor blades, which had previously seen severe primary and secondary erosion, survived the operating campaign with only some tip wear that has been attributed to catalyst buildup on the rotor shroud ring. This type of wear is repairable and the blades are expected to be returned to service.

Elliott will perform more detailed inspections on the spent components and make any needed repairs to ensure the refiner has adequate parts in the event of an emergency. Based on the operating campaign, Elliott and the refiner are currently evaluating a complete conversion to the TH-100 expander design.

Other FCC expander rerates

Hot gas expander flow path improvements can be implemented in any FCC application to improve overall expander reliability as evidenced by other expander upgrades to similar units.

Recently, a refiner in Spain experienced considerable casing distortion in components coming out of service after a four year run. The plant's existing inlet casing assembly consists of the inlet casing, a separate intermediate casing, and a separate nose cone floating on pins inside the inlet casing. Elliott replaced the intermediate casing with a drop-in expansion joint to absorb some of the casing stress and eliminate some of the resulting casing distortion. The equipment was commissioned and went into operation without issue in mid-April 2018.

For another Spanish customer with an existing expander roughly equivalent to an Elliot TH-85 expander, the company developed a special hybrid replacement inlet casing. The hybrid design consists of a one-piece forged outer casing with a nose cone that is welded in place using eight struts. The eight struts are canted backwards from the nose cone to the outer casing to help prevent cracking of the strut welds, a common maintenance issue with non-Elliott hot gas expanders. The new inlet casing, scheduled to be installed in autumn 2018, is designed to be dropped into place with minimal field machining required.

As with the refiner in the case study examined here, the changes implemented should extend the maintenance cycles for these two plants and the overall life of their upgraded equipment.

Conclusion

In the case study outlined in this article, Elliott was contracted to retrofit a flow path that would resolve the reliability issues of a non-Elliott expander, including primary erosion, severe secondary erosion/disk cutting, and piping acoustic vibration, which allowed the refiner to operate the FCC for the desired five year campaign. The company developed a solution that combined the Elliott TH-100 flow path technology, while maintaining many of the existing expander components and auxiliary systems, to minimise capital cost and reduce any schedule impacts by installing the expander during a planned outage.