IMPROVING THE PROCESS

Pallavi Baddam, Mitsubishi Heavy Industries Compressor International, USA, discusses how upgrading and revamping syngas turbines in existing ammonia plants can increase capacity and improve the process.

Ammonia is the most important and basic building block of the fertilizer industry. The industrial method for ammonia synthesis is the Haber-Bosch process, invented by Fritz Haber in the early 1900s and developed for the industry by Carl Bosch in 1913. This process synthesises ammonia from molecular nitrogen and hydrogen by feeding the reactants over iron catalysts at high temperature and pressure. The synthesis gas (syngas) needs to be compressed to high pressures, ranging from 100 to 250 bar, for ammonia synthesis. To achieve this, modern plants employ centrifugal compressors, which are usually driven by steam turbines that use the steam produced from excess process heat. Synthesis gas compressors driven by steam turbines play an important role in the ammonia plant. They are specially designed to cope with high speeds (exceeding 10 000 rpm) and high output powers (up to 45 000 KW).

The total world production of ammonia is estimated to be approximately 146 – 160 million t. The world's largest plants produce approximately 3000 tpd. On a recent project, Mitsubishi Heavy Industries Compressor Corp. (MCO) supplied syngas turbines to the world's largest ammonia plants (3300 tpd). While the ammonia prices continue to have an upward trend due to lower supplies in regions such as Black Sea, its demand tends to increase continuously. Therefore, it is expected that the demand for ammonia will increase to nearly 200 million t in 2018 and there are plans to build plants that can produce 4000 – 5000 tpd. Hence, the design

Figure 1. The existing syngas turbine casing in a customer's plant (Russia) before modernisation.

Figure 2. Additional unknown screw inside turbine casing.

Figure 3. No serration on the flange.

capacity of these ammonia plants have increased significantly in the past few decades.

Building new ammonia plants can be quite an undertaking due to its complex processes and high CAPEX. Therefore, the operators of ammonia plants are always exploring ways to increase the production capacity. Most of the operators are keen on increasing their production capabilities by upgrading their existing plants. This approach not only helps the operators to stay competitive, but also produce ammonia in cost-effective and energy efficient ways. Recent studies show that the debottlenecking projects for ammonia plants after 30 – 40 years operation within Europe and former Soviet Union (FSU) regions have become increasingly common. The process licensors are also making significant strides in modifying their original processes to achieve this goal. While numerous strides are made for improvements in increasing capacity, improving the processes, etc., this article introduces MHI's experience in upgrading/revamping syngas turbines in existing plants.

Case study 1: reduction in overall steam consumption by replacing internals

A customer in Russia has been operating a 30 year old syngas turbine in an ammonia plant. The efficiency of the steam turbine deteriorated over time due to various reasons and, as a result, steam consumption increased. Therefore, the customer requested that the steam consumption was reduced.

The present condition and turbine history was analysed. It was concluded that steam reduction could be achieved by replacing the turbine internals without replacing the casing. Upgrading the internal components shown in Figure 1, such as the rotor, diaphragms, nozzles and labyrinths, helped improve the overall efficiency of the syngas steam turbine.

From analysis of the turbine operating history, it was found that the syngas turbine was operating with a conventional nozzle and blade design, which is relatively older technology. In the case of conventional nozzles and blades, the first stage of speed control accounts for a large part of total loss, i.e. tip leaking loss, frictional loss, nozzle and blade losses related to their profiles, etc. Due to these losses, stage efficiency is reduced. In order to increase the efficiency, the conventional nozzle and blade have to be improved and optimised in order to reduce the above mentioned losses. As a result, several modifications, such as gauging optimisation, pitch and cord optimisation, profile modifications, etc., were performed on the nozzle and blade design. These modifications helped improve efficiency by minimising the losses. Integral shroud blades (ISBs) were also developed. ISBs can enhance blade rigidity by forming grouped structure for higher profile performance with small gauging. ISBs also do not have tenon caulking as the shroud is integrated with the blade. The stage efficiency was increased by using a combination of a new nozzle and the integral shrouded blade design.

In addition to this, slant labyrinths were used for high pressure side and extraction portion. This helped decrease the seal leakgage and improve the efficiency. The performance of the syngas turbine was evaluated before and after revamp, as shown in Table 1. The data was collected over a period of two days of operation. It was found that the steam consumption was reduced by 15% as a result of increasing the efficiency of the steam turbine.

Case study 2: repairing the existing turbine casing and replacing internals

The same customer also had a spare synthesis gas turbine manufactured by MCO. A portion of the existing turbine

Figure 4. Damaged baffle plate.

Figure 5. Cut piping.

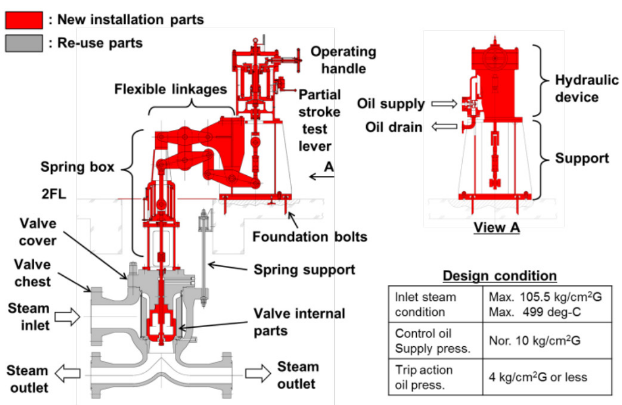

Figure 6. Modernised hydraulic trip and throttle valve (TTV).

casing had been modified by another original equipment manufacturer (OEM). A comprehensive survey/investigation was conducted to document the present state of the equipment, where it was found that the existing spare unit could be restored by using modernisation techniques involving installation of a new turbine rotor and internal parts. The existing turbine casing was then shipped to MCO's factory in Hiroshima, Japan. Figure 2 shows the existing turbine casing pictured in the customer's plant prior to restoration.

Step 1: inspection of the existing turbine casing

In order to re-use the existing turbine casing, MCO measured important dimensions, such as flatness of the horizontal surface of the casing, contact surfaces to internal parts, and each screw position. These measurements were then compared with the original drawings. The purpose of the inspection was to check the distortion of the horizontal surface, as well as the parts on the casing that have been modified. Flatness measurements were taken.

The discrepancies from the measured values to the values on the original drawings were captured and analysed. Figures 2 – 5 show distortion and damaged parts, such as additional machining within the casing and unknown screws and piping. An additional inner casing was installed to the existing turbine to match the other OEM's design. The other OEM's design philosophy was completely different to MCO's. An additional inner casing was not required for MCO's design and proved futile. Oversized screw machining was performed for unknown screws and a new plug was welded and installed.

Figure 3 showed no serration on the flanges. Longer periods of operation wore the serration, leading to leakage. Therefore, new flanges were installed.

Figure 4 shows a deformed baffle plate due to operation, which was installed between the turbine casing and bearing pedestal. The deformed baffle plate was removed and a new baffle plate was installed.

Figure 5 shows cut piping. This piping leads to the gland sealing within the turbine. This was cut due to unknown reasons. New piping and flanges were installed to ensure the gland sealing system works as desired.

Step 2: repairing the existing turbine casing

The damages found as a result of a flatness inspection discussed above (Figures 2 – 5) were repaired to increase performance. The turbine casing was repainted after NDT testing and the horizontal surface was machined within the acceptable tolerance for new turbines. A hydrostatic test was performed for the repaired casing applying the same pressure as stated per the original casing technical specification in order to check that there was no leakage.

Additional damages found were repaired by manufacturing new parts, cutting and re-welding the existing parts as required. In addition to the casing repair, the new turbine rotor manufactured was tested, inspected and installed.

Table 1. Turbine performance evaluation results

Operating condition	Inlet steam consumption (tph)		Steam consumption reduction (tph)
	After revamp	Before revamp	
Guarantee base condition	320.3	335.4	15.1 ↓

External (auxiliary) modifications – hydraulic trip and throttle valve

The trip and throttle valve (TTV) plays a very important role in steam turbine operation. The main function of the TTV is to stop turbine operation safely in the event of an emergency shutdown. The original TTV design was mechanically operated and lacked smooth control due to heavy structural design. Long-term operations caused sticktion at the TTV stem due to accumulated dust from the outside environment, causing the TTV to be dysfunctional after longer periods of operation.

Figures 6 and 7 show the modernised hydraulic TTV. This upgrade involves revamping an existing mechanically operated TTV to operate hydraulically by adding new installation parts, shown in red. This modification allows the existing valve body and cover to be reused. This feature allows a customer to upgrade to a hydraulically operated valve with minimal part changes and reduce onsite work. The valve and hydraulic parts can be overhauled separately for ease of installation and maintenance. The main advantages for this upgrade are a smooth valve operation by hydraulic force and the ease of conducting online checks for sticktion by 'partial stroke test device'. In addition to the above, there is no possibility of fire by unexpected oil leakage, because the hydraulic portion is located separately from the hot TTV body.

Conclusions

Revamping or modernising the existing syngas turbine and auxiliary parts in a plant can sometimes prove to be cost-effective in lieu of replacing it with a newer one. However, this type of initiative has to be carefully reviewed jointly by the operator and the OEM in order to completely understand the merits and demerits. The OEM would have to carefully consider the original design tolerances, operating philosophy and required guarantees prior to performing an upgrade. Utilising the existing footprint and modifying the equipment in order to improve efficiency is feasible provided an OEM has extensive experience in doing so. MCO carefully compares the merit of these upgrade/footprint replacement initiatives with new units and provides a detailed study report that enables the operator to make decisions that ensure cost benefits. WF

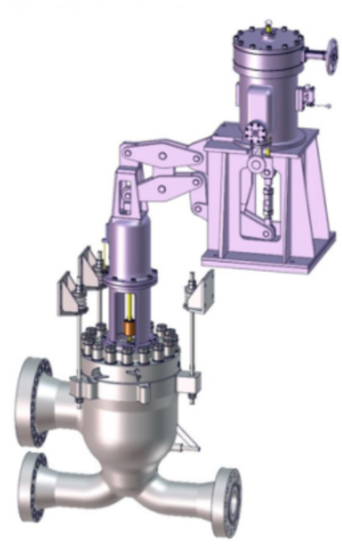

Figure 7. 3D model for modernised TTV.