

Refurbishment of the Eroded Outlet Nozzle of a Recycled Gas Compressor Turbine Housing

Pulsed Laser Beam Welding Leads the Race

During the routine inspection of the inner casing of a steam turbine, erosion-related wear was detected, particularly in the area of the gas outlet nozzle. Partial deposition welding was considered as a repair method to prevent an imminent plant shutdown if the wall thickness failed to meet the minimum requirements. Due to its unique advantages, especially in conjunction with the tight schedule, the customer project lead manager decided in favour of pulsed laser beam welding.

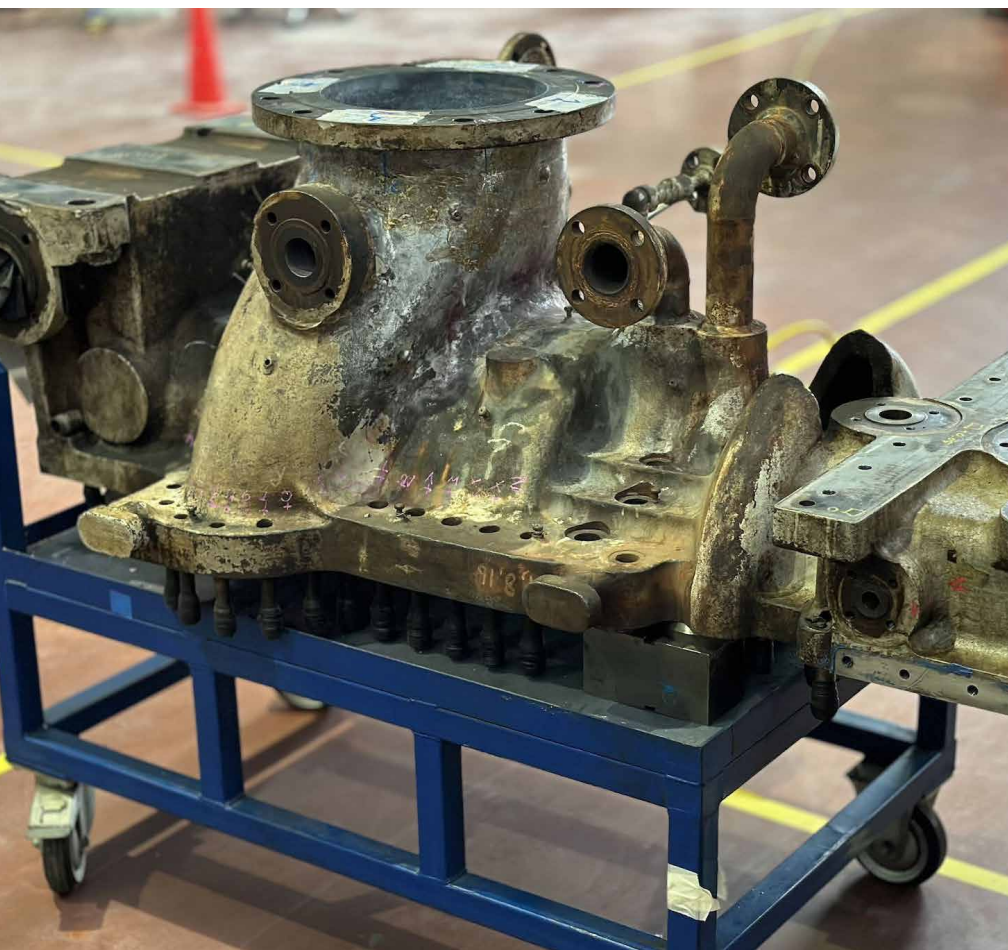


Fig. 1: Housing of the recycled gas compressor turbine (© DSI-Thailand)

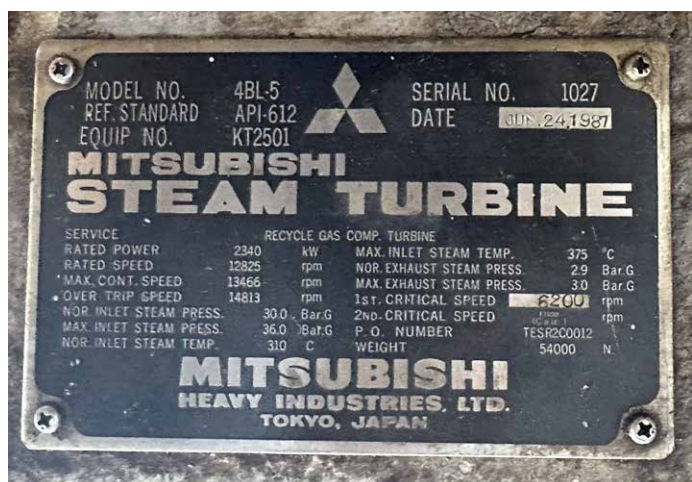


Fig. 2: Turbine nameplate (© DSI-Thailand)

The endoscope inspections were carried out with regard to the scheduled shutdown of the plant in six months time to determine whether repair work was required. During previous inspections and overhauls, gradual erosion-related wear of the inner wall surface had already been detected, which was very advanced in some areas. The area in the gas outlet nozzle was particularly affected. In some places, a critical approach to the calculated minimum wall thickness was localized. If the thickness drops below this, the turbine must be taken out of operation with immediate effect and the entire production plant shut down.

Unique Advantages of Pulsed Laser Beam Welding

The 4BL-5 recycled gas compressor turbine (Fig. 1) manufactured by Mitsubishi Heavy Industries is part of the core equipment of a company in the oil and gas industry based in Sri Racha on the east coast of the Gulf of Thailand. Technical data (Fig. 2) of the turbine:

- Year built 1987
- Base material A216 WCA (ASTM 216)
- Nominal power 2.340 kW
- Nominal speed 12,800 rpm
- Exhaust pressure 2.9 bar G
- •Max. operation temperature 375 °C.

To avoid the worst-case scenario of an imminent plant shutdown, partial deposition welding was considered as a repair method, especially in the areas where erosion was most progressed. The wear profile in the selected repair areas (Fig. 3), based on an original wall thickness of 30 mm, was between a minimum erosion depth of 4 mm and a maximum of 11 mm.

Instead of choosing a classic arc welding process – which would have involved ad-

ditional effort (keyword: heat pre- and post-treatment) – the customer opted for pulsed laser beam welding, particularly because of its unique advantages. Its use was directly related to the tight schedule, as the process requires no post-processing of the base material either during or after the welding process. The entire plant shut-down was scheduled for 18 days. Of these, five days were scheduled for the repair welding, including the necessary preparations and extensive quality controls.

Advantages of pulsed laser beam welding:

- Welding within a few milliseconds, which is impossible with classical arc welding methods. Only by welding with pulsed light and its speed, the unique advantages can be earned
- no heat pre- and/or post-treatment, “welding at room temperature”, also appropriate for critical steel materials
- very small Heat Affected Zone (HAZ) of about 0.1-0.2 mm
- no critical microstructural changes, no coarse grain formation which weaken the metal structure
- very low energy supply to the base material (only about 30 J), thanks to the pulsed laser and its speed
- almost no distortion compared to classic arc welding methods.

Conclusion: The fully metallurgical bonding of base material and filler material proven by the fusion line offers almost the same mechanical-technological properties as the base material – without any heat treatment!

Qualification Procedures: Trust but Verify

The customer contracted DSI Laser Service (Thailand), a service provider for pulsed laser beam welding founded in 2000 and based in Chonburi, Thailand, to carry out the refurbishment. The welding process was preceded by extensive qualification procedures such as Welding Procedure Specification (WPS) and Welding Procedure Qualification Record (WPQR). These were used to qualify both the pulsed laser beam welding process and the welder as the operator of the machine. The qualification processes were carried out and monitored by an



Fig. 3: Part of the eroded areas in the gas outlet nozzle (© DSI-Thailand)



Fig. 4: Measuring setup for checking any welding distortion (© DSI-Thailand)

authorised third party: The Department of Production Engineering at KMUTT University in Bangkok, Thailand, represented by Dr. Titinan Methong, was selected by the end customer.

The assessments of the test plate welds were carried out by KMUTT's Welding

Research and Consulting Center, which is affiliated with the university. The WPS and the WPQR followed the specifications AWS C7.4/C7.4M:2017 (*Process Specification and Operator Qualification for Laser Beam Welding*) and AWS D14.6/D14.6M:2012 (*Specification for Welding of Rotating Elements of Equipment*), the latter

by special customer request, although the component to be welded was not the rotating part of the component (turbine rotor), but “only” its static housing.

Regulations and Standards Regarding Refurbishment and Quality Control

After successful completion of the qualification processes, the following repair and quality control (QC) procedures were defined by the end customer together with the authorised third party:

Repair Sequence

- Determination of the actual housing dimensions, taking into account the shape and position tolerances, in particular the flanges and the reference surfaces.
- Preparation for pulsed laser beam welding: mechanical surface preparation of the intended welding areas by manual grinding.
- Setting up measuring devices (dial gauges) for continuous distortion monitoring during the ongoing pulsed laser beam welding process: A total of four dial gauges were installed around the turbine exhaust flange, each offset by 90° to each other, two dial gauges on the outer edge of the flange and two on the lower edge of the flange (Fig. 4).

Pulsed Laser Beam Welding Process

The deposit thickness to be welded was between 4 and 11 mm (Fig. 5). Taking into account the base material A216 WCA (ASTM 216), the filler material DSI M NICR625 (Inconel 625, material no. 2.4856), wire diameter 1.2 mm, was selected. Welding was carried out using an AL-Flak 1200 F fiber laser machine from the manufacturer Alpha Laser, whose welding direction movements were controlled by the operator using a joystick, while the filler material was fed in manually (Fig. 6). At 1,200 W pulsed laser power, the melting pool diameter was 4.8 mm.

Quality Control During and After the Welding Process

The following quality control procedures were used during the pulsed laser beam welding process:



Fig. 5: Areas repaired by pulsed laser beam welding (© DSI-Thailand)



Fig. 6: Structure of component and fiber laser machine during pulsed laser beam welding (© DSI-Thailand)

- Visual testing (VT) and liquid penetrant testing (PT), each after 3 mm of build-up welding
- Continuous monitoring of any welding distortion that may occur (Fig. 4).

The following procedures were used for the final quality control:

- Visual and penetrant testing,
- Magnetic particle testing (MT) (Fig. 7),
- Radiographic Testing/Gamma Ray (RT) by third party (Fig. 8),

- Ultrasonic testing (UT) by third party (Fig. 9),
- Determination of the housing dimensions with regard to possible welding distortion (result: max. welding distortion = 0.025 mm)

Pulsed laser beam welding offers a complete metallurgical bond without bonding defects, cracks, pores and similar welding defects. At the same time, this technology offers unique advantages that classic arc welding processes such as TIG, MIG, MAG or manual arc welding cannot provide. ■



Fig. 7: Various methods were used for the final quality control, the picture shows the magnetic particle testing at the gas outlet nozzle (© DSI-Thailand)

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Fig. 8: Radiographic testing at the gas outlet nozzle (© DSI-Thailand)



Fig. 9: Ultrasonic testing at the gas outlet nozzle (© DSI-Thailand)