Repair of a steam turbine in Thailand using pulsed laser beam welding

Fig. 1 • Placing the turbine rotor on the head lathe for mechanical pre-machining of the damaged surfaces.

Welding with the pulsed laser beam provides a new approach to the weldability of metallic materials. In particular, the solid-state laser (Nd:YAG) with the possibility of guiding the laser beam independently of the laser to any location in a structure via fibre optic cables offers new possibilities for pulsed laser beam welding. In addition, steel materials that undergo a structural transformation during cooling and thus form a heat-affected zone (HAZ) behave differently when welded with the pulsed laser beam than in conventional welding processes. The extremely short welding time due to a pulse frequency of a few milliseconds and the resulting very fast cooling time ($_{t8/5}$) results in a HAZ that is only a few tenths of a mm narrow and avoids the formation of the critical coarse grain zone due to the parameters. These facts result in a different laser-specific classification of the weldability of metallic materials.

For almost 20 years now, DSI Laser Service (Thailand) Co., Ltd. from Chonburi, near Bangkok, has been using this knowledge to successfully perform pulsed laser beam welding on large components using mobile laser welding systems from Alpha Laser GmbH, Puchheim in Bavaria/Germany. In addition to its main business area as a laser welding service provider in various industries (automotive industry, oil and gas industry, petrochemical industry and recently also in aviation), DSI (Thailand) is also active as an authorised dealer for Alpha Laser welding systems in Thailand. For 15 years, DSI (Thailand) has been certified according to DIN EN ISO 3834-2 by DVS Zert, audited by DVS SLV Hannover, which also provides technical support to DSI (Thailand).

The rotor repaired by DSI (Thailand) **(Fig. 1)** is the rotor of a steam turbine built by Siemens in 2005. The 37 MW turbine is used in the company's own power plant at a Thai cement factory, with excess capacity being sold to EGAT (Electricity Generating Authority of Thailand). EGAT is the largest Thai electricity supplier, operating 45 power plants with a total capacity of 15,548 MW. EGAT maintains its own workshops, which are specialised in turbine repairs, among other things. In an EGAT workshop located in the north of the state capital Bangkok, pulsed laser repair welding began in November 2018 and lasted four weeks without mechanical pre- and post-processing.

Fig. 2 • The Nd:YAG pulsed laser welding machine "900W ALFlak fibre" from the German manufacturer Alpha Laser in the welding application at the turbine rotor in Thailand.

What was the wear on the rotor to be repaired?

The rotor of the turbine is oil-bearing. Due to a faulty operation during the operation of the turbine, a "deficient lubrication" occurred, i.e. an insufficient, "tearing off" lubricating film between the rotor shaft, which rotates at 3,000 revolutions per minute, and its mountings. The metallic friction and the resulting heat development caused cracks at both rotor shaft ends. After an initial damage assessment, cracks up to a depth of 2 mm were expected. Cracks up to a depth of 7 mm were found during the subsequent magnetic particle inspection (MT inspection) and during mechanical machining of the flaws on a head lathe.

Technical data

The rotor material is ASTM A335 P22. The EN ISO 21952-A CrMo1 (formerly 1.7339) with D = 0,8 mm, specified by

EGAT, was used as welding filler. The laser used was a Nd:YAG pulsed laser welding machine **(Fig. 2)** with an average laser output power of 900 W. The wavelength was 1,059 nm. The welding was performed with a pulse frequency of 33.6 Hz, a pulse duration of 3.5 ms, a beam diameter of 2.5 mm and the shielding gas Ar 99.9%. A pWPS (pWPS-DSI-EGAT-Turbine-18.11.12) was available with all further necessary data. The DSI (Thailand) laser beam welders used had a valid operator's test according to ISO 14732:2013 for deposition welding.

Training, testing and certification of pulsed laser beam welders

In addition to metallurgical knowledge, compliance with the high quality requirements of repair welding on a turbine operating at several thousand revolutions per minute requires very well-trained welders. The project management of the turbine rotor repair was carried out by the two DSI colleagues with the most experience in metallurgical and laser welding technology: the General Manager Miss Thongplew Banpao and the pulsed laser technology expert Mr. Thanapol Pradissun. The training of the DSI (Thailand) laser beam welders qualified in both build-up welding and joint welding was carried out at the company's own DSI (Thailand) Laser Welding Academy. The training was tested and

Fig. 3 • The turbine shaft mechanically prepared for welding.

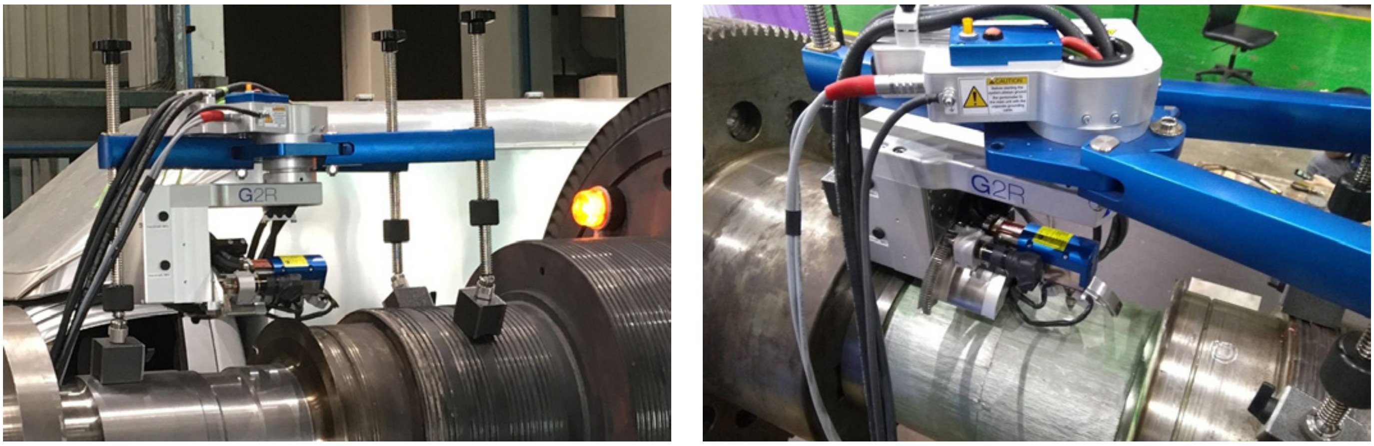

Fig. 4 • The measuring device installed before and during welding for stress testing of the turbine shaft.

Fig. 5 • On-site welding on the turbine rotor.

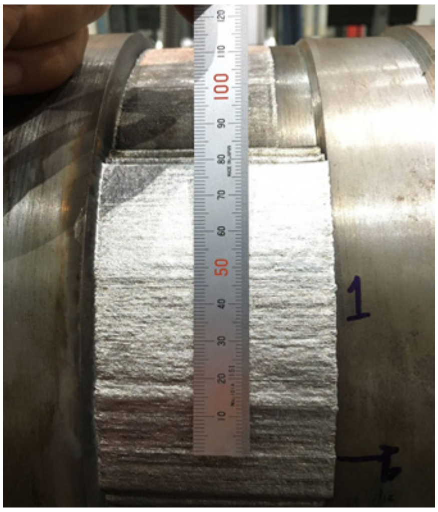

Fig. 6 • Layer structure of the pulsed laser beam repair welding.

certified according to the internal training guideline ”SLV-H-LS01” developed by DVS SLV Hannover. In addition to the DSI (Thailand) internal welders, laser beam welders are also trained by customers at the academy and qualified and certified by the DVS SLV Hannover.

Preparation of the surfaces to be welded (rotor shaft ends)

After cleaning, the machining surfaces were machined to a depth of 2 mm in the crack area over a width of 332 or 340 mm and an additional 5 mm deep in the direct crack area over a width of 100 mm **(Fig. 3)**.

Fig. 7 • The finished pulsed laser beam weld during the final stress check.

Welding technology

In order to determine possible component stresses, a stress test was carried out using the ”Residual Stress Measurement” method based on the “X-Ray-Diffraction” technique, in each case before, in intermediate steps during and after welding **(Fig. 4)**. The welding on the turbine rotor on site in Thailand is shown in **Fig. 5**.

The thickness of the seam applied in each layer was about 1 mm. In the direct crack area of the shaft (100 mm wide) there were approx. five to six circumferential layers, on the surface (332 or 340 mm) there were three layers.

From an economic/temporal point of view, this wide-area and large-volume repair welding was only possible by using two 900 W fibre lasers, which were used to weld simultaneously at both shaft ends. An interlayer result is shown in **Fig. 6**. In addition to the final stress tests and visual inspections (VT), the finished welds **(Fig. 7)** were also tested by means of dye penetrant testing (PT), magnetic particle testing (MT) and ultrasonic testing (UT). After the successful tests, the welded surfaces at the rotor shaft ends were machined on a head lathe to the original dimensions and tolerances determined for their use.

Result

Since recommissioning in spring 2019, the steam turbine has been operating without any problems.

Prof. Dr. Gerd Kuscher,
GSI – Gesellschaft für Schweißtechnik International, Subsidiary SLV Hannover, Hanover/Germany
and Stephan Thiemonds,
DSI Laser Service (Thailand) Co., Ltd., Chonburi/Thailand

In use around the world: Container suction unit constructed for extreme conditions

A container with something very special inside was recently sent on its way to India: It was equipped by the international manufacturer of suction units, Teka GmbH from Velen/Germany (https://en.teka.eu/), with suction and filter technology that had been specially adapted to the dimensions of the maritime freight container and the demands of extreme weather conditions.

“Our engineers repeatedly tested every aspect of this unit, which was specially developed for this very unusual order. It took only eight weeks from clarifying the necessary parameters through to implementing the project. The solution has now been sent on its way to India, where the container suction unit will be used for approximately six months during grinding

The “ZPF” suction and filter system is able to extract and clean large volumes of contaminated air: Two sets of pipework – one for welding fumes and the other for dust from grinding work – extract the contaminated air and guide it via the pre-separators to the filter unit.