Current trends in laser beam welding in pipeline construction

Integrated 100 % inline testing with the EMAT process

By Georg Trensch, Hans-Jürgen Kocks and Steffen Keitel

The advantages owing to the low heat input involved in automated laser beam welding can be fully exploited if this process can be combined with appropriate testing. For the non-destructive testing of weld seams, ultrasonic testing is the ideal solution. A laser-welded seam is very similar to that produced by the high-frequency induction pressure welding process used in pipe production. Here, ultrasonic testing is state of the art and, in combination with an automated welding process, should also provide the desired testing function in the field.

Introduction

Electric arc welding is state of the art for joining pipes in pipeline construction. While manual welding is standard in the smaller nominal size range, automated welding processes are often used in the large nominal size range, especially for long distances. Irrespective of the welding process, the steps involved in the production of the pipe joint in the field – welding, testing and field coating – remain independent processes that are performed in succession and usually by different contractors in a staggered sequence and with logistical effort for project management (***Figure 1***).

Laser beam welding is a joining method that can be carried out in a much more focused manner with less heat than the conventional electric welding processes used today. Its low heat input could make it possible to merge the welding and testing steps into a single operation and thus significantly reduce the logistical effort in the field. Apart from the orbital welding equipment necessary for pipeline construction, other applications are of course also of interest – such as in the construction sector, where stationary equipment is used to produce welded joints.

Ultrasonic testing is suitable as a non-destructive testing method. According to the regulations, wall thicknesses from 6 mm can be tested with the manual methods commonly used in the field [1]. Automated processes require validation of these application limits. For the smaller diameter range of interest here, a wall thickness range from 3.6 mm to approx. 12 mm is thus suitable and can in principle cover all possible applications of an HFI-welded pipe with outside diameters up to approx. DN 600.

The advantage of automated testing would be the 100 % inline testing of all welds. In addition, further information from the welding process can be used for evaluation, such as recording the emissions from the laser process.

The story so far

The starting point for this automated laser beam welding project was a feasibility study carried out in 2009 to 2010 with the participation of Stadtwerke München GmbH and Gelsenwasser AG [2]. In connection with this study, a first prototype was developed that can be used for welding pipe joints

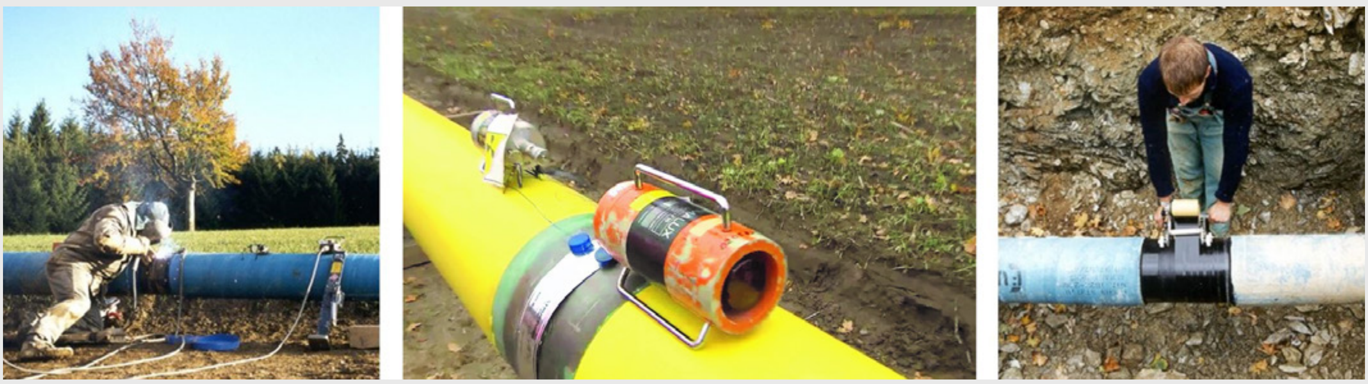

Figure 1: *Welding, testing and field coating*

in the wall thickness range up to 5 mm and in the diameter range of DN 80 to DN 150. Even with this first prototype, it is possible to achieve test results in line with the regulations. Automated ultrasonic testing is performed here without couplants. The probes are coupled via silicone rollers guided around the pipe at a fixed distance from the weld.

In the second part of the project, welding tests were carried out under field conditions with a prototype optimized for pipe diameters up to DN 400 on the premises of ONTRAS Gastransport GmbH in cooperation with Köster GmbH as the pipe installer. Different laying processes were simulated so as to fully exploit the scope of the welding process. Regarding automated weld testing, experience showed that the selected approach of silicone roller coupling has only limited suitability in the field. As the silicone rollers soon become soiled, the signals are seriously damped to the detriment of the informative value of weld evaluation. ***Figure 2*** shows a CAD model of the rotary design and the contamination of the silicone rollers used for coupling.

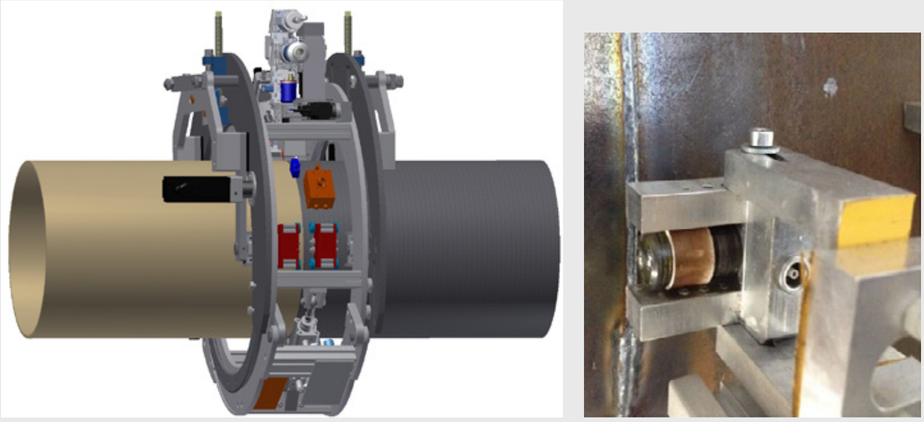

Figure 2: *CAD model of the prototype of the combination of laser beam welding and weld testing; and the soiled silicone rollers for coupling the ultrasonic probes*

In connection with a pipe-laying project of ONTRAS Gastransport GmbH, a first field test was performed near Greifswald without automated weld seam testing. The laser beam welding process with SLV Halle GmbH's prototype was successfully applied on the approximately 1,000 m long section of a high-pressure gas pipeline [3].

Within the scope of a third part of the project, the application of an alternative non-destructive testing method has now been investigated with EMAT. The potential of this technology is so compelling that the validation of the test method for laser-welded pipelines in a wall thickness range of 4 to 8 mm was completed in the context of this project.

The EMAT process

The term EMAT stands for ElectroMagnetic Acoustic Transducer and is a process that makes use of electromagnetically induced ultrasound. This method exploits electromagnetic interactions between the probe and workpiece to generate a high-frequency acousto-elastic vibration in the workpiece. The vibrations are comparable to those of classically applied ultrasound, transmitted to the workpiece via a piezo transducer, for example. The EMAT testing technology makes it possible to generate many different wave types directly in the test object. These can be either pure-mode or polarized. What is special about this is that there is no need for a couplant between the probe and test object. Due to the efficiency of ultrasound generation, the distance between the probe and the test object only needs to be a few tenths of a millimeter. A further prerequisite is the test object's electrical conductivity, since the lack of electromagnetic interaction prevents the generation of high-frequency acousto-elastic vibrations. The test system employed makes use of the pulse-echo method, in which a single probe is sufficient for sending and receiving

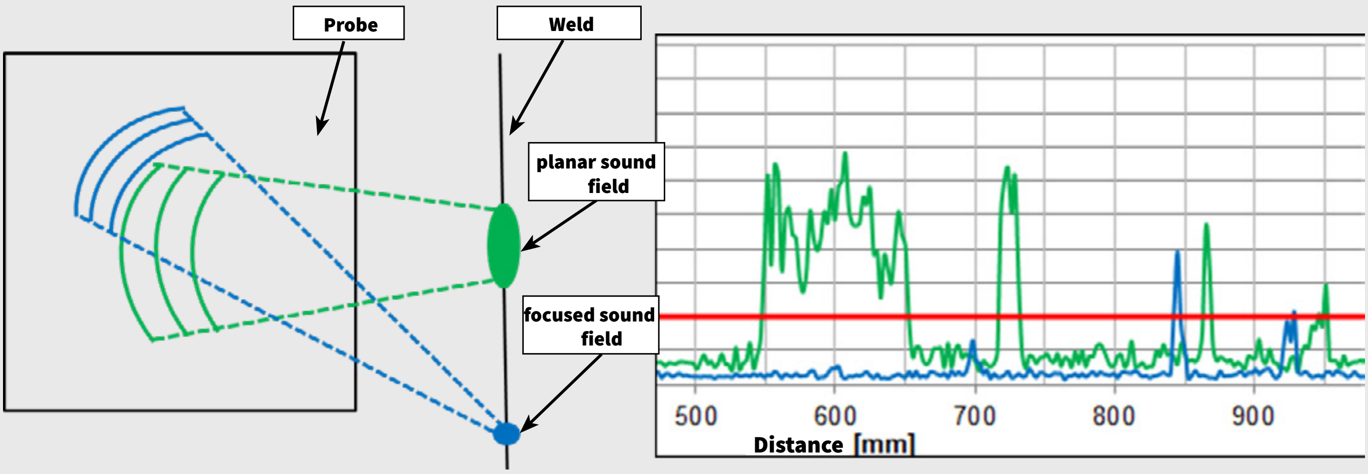

Figure 3: *Sketch of sound field orientation and detail of measurement result*

the measurement signal. As familiar from classical ultrasound, the signal is transmitted in the direction of the test object, in this case the weld, and may be reflected by imperfections in the weld. A small portion of the emitted ultrasound is reflected by the metallurgically related difference in homogeneity between the weld and the base material and recorded as background noise. If the weld is free of imperfections, only comparatively little background noise is recorded during the test. The probe is designed for the generation of two different sound fields. These are a focused, forward sound field and a planar sound field emitted parallel to the probe (***Figure 3***). This arrangement yields increased sensitivity to both one- and two-dimensional imperfections. A further step towards improved sensitivity is the choice of wave type. The present study uses a vertically polarized transverse wave with an angle of incidence of 35°.

Validation of the weld test

In the course of investigations, the EMAT testing technology was integrated into SLV Halle GmbH‘s clamp for orbital laser welding. Thanks to the high robustness of the probes and the experience gained from field testing, a strategy has been implemented that also permits large-scale operation. In cooperation with TÜV Nord Systems GmbH & Co. KG, there is now a testing strategy that covers wall thicknesses from 4.0 mm up to and including 8.0 mm. In this area, the testing system conforming to CEN/TR 14748 has been validated on steel pipes for pipeline construction for pipe diameters from DN 100 [4]. This validation thus confirms the suitability of EMAT technology as a couplant-free ultrasonic test for laser-welded steel pipes in conformity with the relevant guidelines and standards. To obtain a reliable assessment of the testing system‘s performance, a laboratory simulation was carried out at SLV Halle in connection with validation (***Figure 4***). More than 15 welds of different wall thicknesses were laser-welded and then subjected to partially automated EMAT.

The pipe joints were welded using a 6 kW fiber laser made by IPG Laser GmbH. Each EMAT test result was verified out by means of a downstream X-ray inspection.

The evaluation group „B“ of DIN EN ISO 13919-1:1996-09 serves as the evaluation standard for the introduced imperfections [5]. The EMAT test equipment is calibrated on specially produced pipe joints with wall-thickness-specific test error grooves of sensitivity classes U2 and U3 conforming to DIN EN ISO 10893-11:2011-07 [6]. The test system is able to reliably detect radial surface imperfections from a magnitude of 10 % of the wall thickness. This test error corresponds to incomplete edge fusion as can occur in beam welding. Due to the almost perpendicular edge angles of a laser weld, the real incomplete fusion can be simulated by means of a radial groove.

Conclusion and outlook

Based on the successful validation of the test system, the prototype for the combination of orbital laser beam welding and EMAT testing has been brought a big step closer to series maturity. The EMAT test system can be used for testing

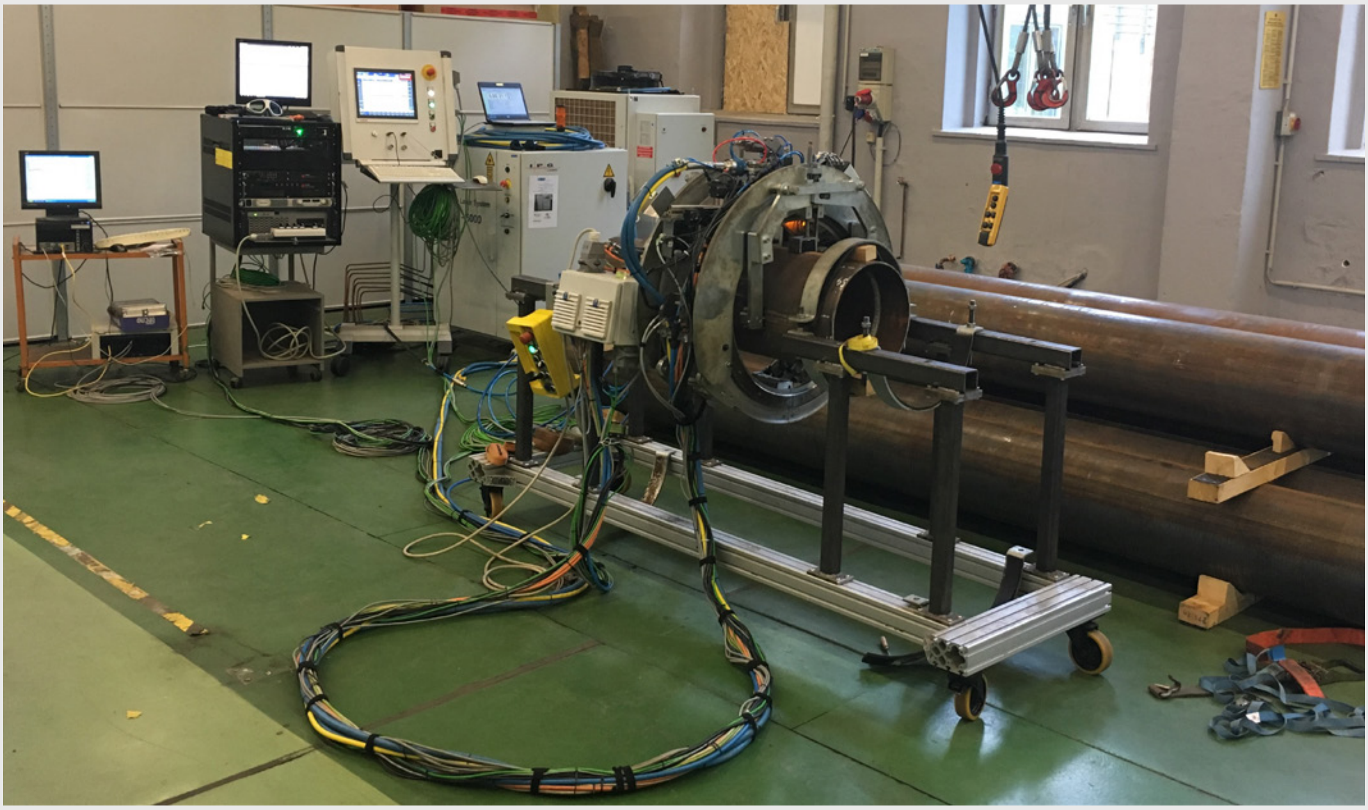

Figure 4*: Test pipe-laying site at SLV Halle GmbH for validation of the test system*

laser-welded steel pipes of the appropriate dimensions. Using this technology saves an enormous amount of time in the field, as the test results are available within 90 seconds. Also worth noting is that the system invariably tests 100 % of the welds. Furthermore, and unlike conventional non-destructive testing methods, the EMAT method does not require any special measures (radiation protection, couplant disposal, etc.).

Combining laser beam welding with EMAT testing reduces the pure production time of a girth weld in pipe diameters from DN 300 to DN 350, for example, to less than 5 minutes and, due to the low heat input, permits immediate field coating of the weld areas. Furthermore, the integration of optical measuring devices makes the programming of the welding path more precise and user-friendly and significantly reduces the time required for defining the welding process. The processing of all measured data on a central computer system also facilitates comprehensive process analysis, which can also be online if required. It is thus possible to keep a complete history of every single weld in a pipeline. This history contains all the laser welding parameters as well as the EMAT measurement results. This means it is possible to demonstrate at any time that the weld has been checked and executed free of imperfections.

The current state of development was on show at the 34th Oldenburg Pipeline Forum at the joint stand of Mannesmann Line Pipe GmbH and SLV Halle GmbH (***Figure 5***). In addition to a number of live demonstrations, interested trade visitors were introduced to the technology. The consistently positive feedback from visitors shows the industry‘s interest in this unique combination of technologies.

SLV Halle is currently working on an extension of the application and process limits so that pipes of larger dimensions can be welded and tested with this process combination. As consistent further development requires regular practical tests under real-life field conditions, SLV Halle is always looking for new possible applications in the real-life field environment.

Figure 5*: Joint stand of Mannesmann Line Pipe und SLV Halle at IRO 2020*

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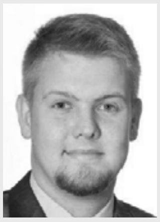

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