

# Laser beam pipeline welding in the Greifswald region

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Since 2012, the combination of laser beam welding and girth weld testing in a single process has been the subject of several partial projects under the management of SLV Halle. Within the framework of a pilot project, laser beam welding has been successfully tested under tough field conditions. The construction of a high-pressure gas pipeline near Greifswald in Germany by ONTRAS Gastransport GmbH presented itself as a golden opportunity for this pilot project, with the welded joints being tested under stresses resembling those involved in the operation of a high-pressure gas pipeline. This article reports about the experience gained along the 1,000 m test section. The project marked the commissioning and start-up of the world's first ever laser beam welded high-pressure gas pipeline.

Welded joints are easily the most important type of connection between two structural steel elements. This applies particularly to the joining of pipes for conveying energy sources such as gas or district heat, but also for the transportation of mineral oil and related secondary products as well as aqueous media. The welding of joints between pipes is essentially a manual operation. Only in individual cases involving larger pipe dimensions in project business is automated orbital welding equipment employed. Depending on the application, the necessary testing may pose considerable logistics challenges that should not be underestimated. Such a test is, moreover, required prior to the application of any corrosion protection. Given the heat development in manual welding, it is obvious that welding, testing, and field coating must be timed consecutively and at adequate intervals. In addition, these jobs are usually assigned to different specialists. An automated process, in which welding and testing are combined, is used for plastic

pipes where the welding parameters and/or the weld itself are automatically recorded. A similar procedure would be highly desirable for steel pipes as well. Meantime, with laser beam welding, a technology is available that, thanks to the low heat input involved, enables this combination of welding and testing in a single process. Laser beam welding offers significant advantages in terms of reduced weld volumes and thus fewer passes, plus deep and narrower penetration profiles, enabling joints to be welded using special mechanized equipment in an orbital pass. Encouraging the trend are developments in laser beam sources, notably in the area of solid-state lasers. The fiber laser system is particularly suited for mobile on-site applications due to its technological advantages, such as high output coupled with excellent beam quality and efficiency, as well as its compact design. With properties like these, the system is ideal for pipeline construction in either conventional or trenchless projects.



Figure 1: Pipe-laying



Figure 2: Pulling in a DN 500 water pipe string





Figure 3: Test set-up for the pipe-laying simulation test

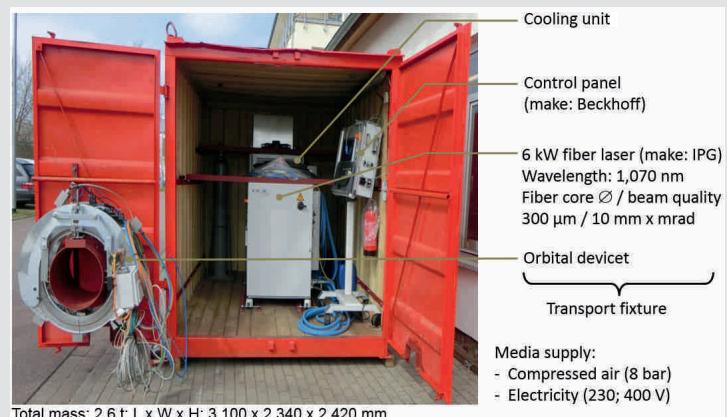


Figure 4: Mobile unit

Summing up, there are a host of technical features and benefits including:

- » Less physical exertion for the welders (overhead position, lying position in the pipe trench).
- » The welding process is less sensitive to weather conditions.
- » Lower flow resistance in the pipe as there is no root sag in laser beam welding.
- » In the case of cable conduits, reduced risk of damage to the cable, as there is no root sagging.
- » Automatic weld documentation.
- » 100 % weld testing.
- » Potential design advantages due to reduced heat input (pipe end design, field coating systems).
- » Problems of manpower shortage – especially skilled welders – are avoided.
- » Since this is an automated welding process, no welders are required but only operators for the welding equipment.
- » The weld properties are independent of the welding position.
- » Fast pipe-laying progress thanks to shorter welding times and improved on-site logistics.
- » Advantages in trenchless projects: The high welding speed allows for the use of shorter pipe lengths. Pipe stringing takes place in line with the drill rod dismantling cycle.
- » No interruption in pipe string pulling, since there are no waiting times for pipe joint testing.
- » In combination with automated field coating, the pipe string can be pulled into the bore as it is made up.

The implementation of a combined welding/testing system has been the subject of several partial projects since 2012. From that time onwards, laser beam welding has been expressly mentioned in DVGW Worksheet GW 350 among the welding processes. According to AGFW Worksheet FW 446 for district heat, other welding processes are generally approved, possibly including laser beam welding. The framework conditions then have to be defined jointly between the pipe-layer and the customer [2], [3].

With his option laid down in the regulations, it was possible to implement a further step in pipe-laying practice. In October 2016, the laser beam welding process was tested for the first time under field conditions during a project for laying a DN 300 high-pressure gas pipeline near Greifswald in Germany.

### Project description

Between September 2013 and August 2015, SLV Halle conducted a research project on "Pipe welding using the laser beam process under field conditions", which was funded by the German Federal Ministry for Economic Affairs and Energy (BMWi).

The objective was to develop a prototype device for operation under field conditions, to explore the possibilities of a new combined welding and testing technology and to demonstrate device and technology to potential users. At the center of this work are pipe-laying simulations in which the results of the development and optimization steps are tested, analyzed and demonstrated (see **Figure 3**).

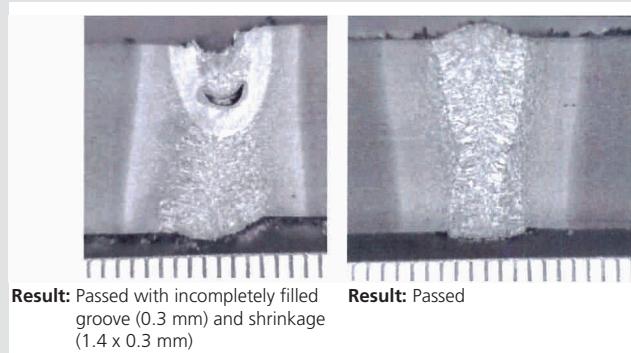
In the context of the research project, a solution was sought for the transportation and storage of the laser equipment. Eventually, the use of a container proved to be the most efficient option for both transportation and protection (see **Figure 4**).

In April 2015, SLV Halle GmbH and Köster GmbH set up a test construction site for various pipe-laying methods on the premises of ONTRAS Gastransport GmbH.

The variant with prior pipe string alignment and tack-welding and subsequent joint welding proved preferable. Summing up, the experience gained on this test construction site revealed that, given appropriate joint preparation, the laser beam welding process could be directly transferred from laboratory to field conditions with all previously determined parameters. In addition, the mechanical-technological characteristics as well as the internal and external quality of the field welds met all the requirements laid down in DIN EN ISO 15614-11, DIN EN ISO 13919-1 Evaluation Group B (except for edge offset) and DVGW GW 350.



**Figure 5:** Construction site set-up



**Figure 6:** Macrosections

Based on these results, the next step was to verify the suitability of the process for actual field conditions and compliance with the relevant requirements on pipelines.

### Project realization

The opportunity arose in October 2016 during the revamp of gas pipeline 98. It was decided to use the orbital laser welding process on an approximately 1,100 m long section south of Greifswald. The project was planned together with ONTRAS Gastransport GmbH, PPS Pipeline Systems GmbH and Salzgitter Mannesmann Line Pipe GmbH, with TÜV SÜD Industrie Service GmbH acting as the supervisory body.

However, before the project could start, certain formalities had to be dealt with such as registering at the state office for the application of non-ionizing radiation, creating a preliminary Welding Procedure Specification (pWPS), and conducting a welding procedure test.

The latter had to comply with the following specifications and standards:

» AD 2000 Bulletin HP 2/1/ [6]

» VdTÜV Bulletin 1052 [7]

» DVGW Worksheet GW 350 [2]

» DIN EN ISO 15614-11 [4]

» DIN EN ISO 13919-1 Evaluation Group B [5]

The fact that orbital laser welding was new in pipeline construction gave rise to additional requirements. Thus, the welding procedure test had to be carried out using the same pipes, the same equipment and even the same personnel employed on the construction site (see **Figure 5**).

The site equipment included a side boom (pipe-laying vehicle), a crawler-mounted vehicle with a crane and power supply, the welding tent with the orbital laser unit, a trailer with a container for the laser equipment and control, as well as a compressor.

The pipes for the pipe string had the following characteristics:

» Longitudinally welded

» Base material: L245NE (EN ISO 3183, Appendix M)

**Table 1:** Destructive testing

Test type	Number of test specimens	Characteristic values (average)	Result
Tensile test	2 (transverse, RT)	$R_m = 468 \text{ MPa}$	Passed (target value: 415 MPa)
Bending test	4 (2 x D; 2 x W)	Bending angle: 180 °	Passed (target value: 180 °)
Notched-bar impact bending test	6 (3 x HAZ; 3 x weld metal) at -20 °C	Weld metal: 119 J HAZ: 218 J	Passed (target value: 27 J)
Hardness test HV1	2 (6 x base material; 6 x HAZ; 3 x weld metal)	Base material: 135 HV1 HAZ: 159 HV1 Weld metal: 183 HV1 HAZ: 163 HV1 Base material: 140 HV1	Met
Microstructural examination	Metallographic macrosection and microsection		Defect-free weld build-up and root fusion, no cracks, flawless microstructure

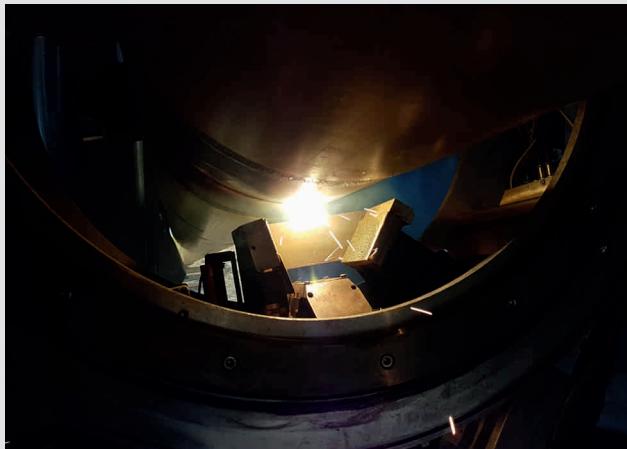


Figure 7: Welding



Figure 8: Dusty laser optics

- » DN 300 (OD = 323.9 mm)
- » Nominal wall thickness: 6.3 mm
- » Length: 18 m
- » Weld preparation: butt-welding joint (ex works)
- » Plastic coating (cut back approx. 150 mm)

The pipe welded on the construction site complied with all the requirements of the procedure test (see **Table 1** and **Figure 6**).

With the procedure test successfully passed, the welding operations on the construction site could start immediately. The working sequence was the same for every pipe: aligning followed by internal and external centering to keep the pipes in position and avoid impermissible edge offsets. Then the pipes were fixed in position by means of four tack-welds using the TIG welding process without any fillers, and the orbital laser unit was placed on the welding point.

Once the welding line was programmed, a laser weld was carried out as a tack weld around the pipe circumference at a constant output of 1,000 W and a speed of 0.65 m/min. The actual joint or orbital girth weld was produced with constant parameters:

- »  $P = 3,700 \text{ W}$ ;  $v = 0.65 \text{ m/min}$
- » Working distance  $160 + 2 \text{ mm}$
- » Free beam length 78 mm

(See **Figure 7**).

All the welds were subjected to visual inspection, ultrasonic testing and radiographic examination. In all, three flaws were detected and successfully repaired by TIG-welding. On completion, the repair work was duly examined and found to comply with requirements.

Besides the "normal" challenges of a construction site, the weather did its best to provide "optimal" conditions for verification that the process could actually stand up to field conditions. It is safe to assume that conditions of this nature have hardly ever been encountered in laser technology.

During the three weeks spent working on the construction site, gale-force winds of over 130 km/h were measured,

with rain belting down continuously on the parched soil. As a result, the complete mechanical equipment as well as the laser optics were coated in dust (see **Figure 8**). In the subsequent weeks, the wind was followed by temperatures just above freezing point (4 °C) in combination with a sodden and muddy terrain (see **Figure 9** and **Figure 10**). These weather conditions had no severe impact on the welding results and the equipment. All the necessary adjustments and repairs were done directly on the construction site.

### Summary

Within twelve working days, a total of 60 welds were completed on a pipe string of 1,152 m in length. The average time per welded joint was 57 minutes, subdivided among the following operating steps:

» Alignment	25 min
» Positioning of device	15 min
» Programming	15 min
» Tack-welding	70 s
» Welding	70 s

Summing up, the test operations have proved that reproducible welding results can be transferred from the laboratory to actual pipeline construction projects.

In addition, it was established that the welding process is unaffected to weather conditions and that laser beam welding is partly even superior to conventional processes (inert gas welding must be stopped in the event of gale-force winds). The field test also proved that the laser equipment and process are robust and impervious to external influences, and conventional tools can be used for aligning the pipes prior to laser beam welding. Furthermore, evidence was provided that standard pipes manufactured using state-of-the-art technology can be joined by laser beam welding. The pipeline section manufactured during the field test has successfully passed all customary function checks and has meantime been put into operation.

Regarding any weak points it has to be said that the prototype is not yet engineered for continuous service, and the



**Figure 9:** Construction equipment struggling with the mud



**Figure 10:** Fiber optic hose package in soggy soil

finishing touches need to be applied to the time-consuming programming process.

In the interest of economic optimization, further improvement is required on the orbital laser unit itself and on the interaction between conventional pipe-laying and orbital laser welding. The laser beam process has reduced the welding time to less than 10 % of that previously required. The heat input is significantly lower as are, as a result of this, the stresses generated during welding. The geometry of the welds is flush to the pipe surface.

The objective of future work is to adapt alignment and testing methods to the laser beam welding process and thus reduce the time required for pipeline projects to 50 % of today's. And finally, besides the introduction of a new welding process, the success of the project is mainly attributable to the excellent cooperation among our partners. Our special thanks therefore go to Salzgitter Mannesmann Line Pipe GmbH, ONTRAS Gastransport GmbH and the pipeline construction company PPS Pipeline Systems GmbH.

## References

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