HIGH PERFORMANCE LASER WELDING SYSTEMS FOR THE PRODUCTION OF INNOVATIVE LASER WELDED PRODUCTS

Marius Spoettl, Managing Director. WISCO Lasertechnik GmbH, Ravensburg, Germany

WISCO Lasertechnik GmbH is leading in the development and manufacture of laser welding applications for the steel and automotive industry. Based on our know-how in plant construction, our laser welding systems have been developed for the production with optimized piece costs. Our engineering performance in the laser welding area is carried out in close cooperation with our customers. It comprehends the constant further development of existing and field-tested system concepts and - using all the resources provided by the WISCO group companies - the new development of alternative system concepts. That is why our customers benefit from a closed experience chain with regard to the planning and realization of Tailored Blanks applications in the vehicle construction, but also in other applications like coil welding, manufacturing of rotation-symmetric parts and Laser cutting. With an experience since 1985, far more than 200 million blanks have been produced up to now by laser welding systems made by WISCO Lasertechnik.

With its famous **Conti Laser Welding Machine** for Tailored Blanks, WISCO Lasertechnik is still providing the production system with the highest productivity and cost efficiency worldwide for Tailored Blanks with linear seams. **Gantry Type Systems** for Tailored Blanks with non-linear seams complement the portfolio for Tailored Blanks production, which is also extended by the so called **Ablation Weld System,** a brand new concept which was developed to meet the challenges which arose due to the increased application of Hotform-Blanks in the automotive industry.
WISCO Lasertechnik is the first and up to now only supplier, who developed a series production system for longitudinal welding of Coils (Tailor Welded Coils) and released it to the market under the name **TWC.**
With its systems for **Orbital Welding**, WISCO Lasertechnik is covering applications of laser welded rotational symmetric parts, which are applied in the powertrain, exhaust systems and other automotive and non automotive components.
Beside the **Coil Joining Systems** for Coil processing lines, which will be described in this article in detail by the following case example, the portfolio of WISCO Lasertechnik is completed by the **ROBLAS** system, a laser cutting system which is designed to especially meet the demands of the cutting of hotformed components.
By WISCO Lasertechnik's **Laser Scratching (Scribing) Station** the core loss of grain-oriented magnetic steel flat products can be reduced. Customers realized a reduction of core loss of 12 to 17%. With an optical set-up with polygon-wheel scanner an irradiation by laser beam, perpendicular to the rolling direction, reduces the size of the magnetic domains, what is leading to the reduction of the total core loss.

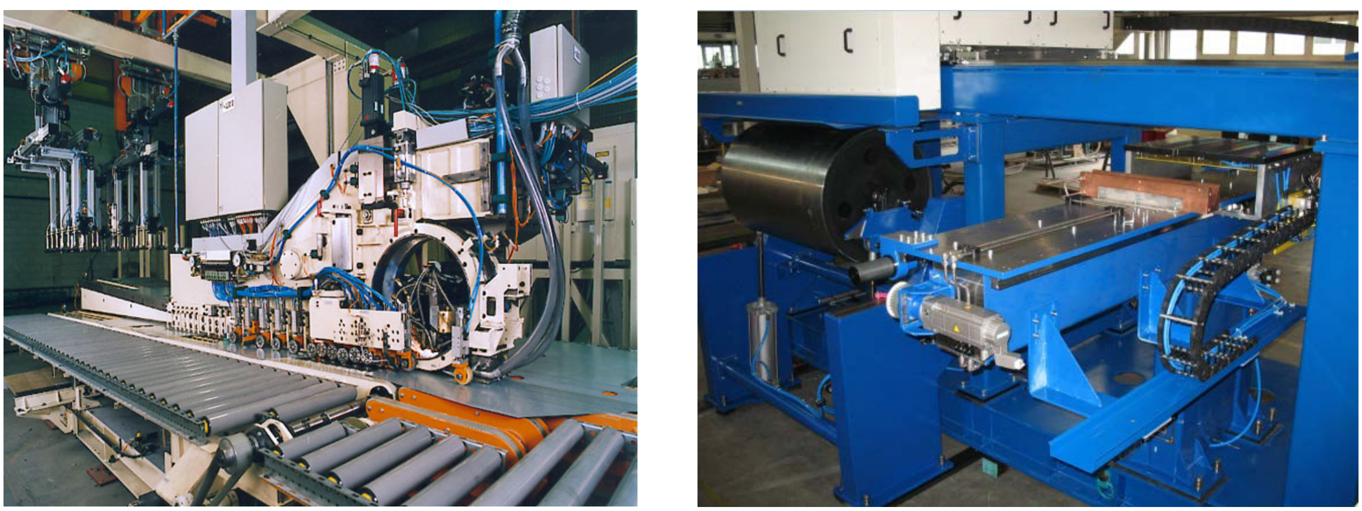

Figure 1: Tailored Blanks Production systems: Conti Laser Welding Machine (left); Laser Scratching System (right)

Case example: Coil Joining Systems for Coil processing lines – HDGL #7 at ThyssenKrupp Steel Europe:
(Main content is taken from [1])

The joining of AHSS increases the requirements to a welding machine considerably. Different steel types in various thicknesses and widths can securely be cut and welded with the Coil Joining System of WISCO Lasertechnik. The machine equipment allows the preparation of the coil ends by laser cutting. Hence the wear and tear of shearing knives is speared. In the article the successful implementation to TKSE No.7 HDGL is explained and the benefits concerning downtime, stability, flexibility and weld-quality are discussed against the challenges of maintenance and complexity of operation.

In recent years, high strength steels and the so-called Advanced High Strength Steels (AHSS) are becoming more and more important as the automotive industry is forced to reduce carbon dioxide emissions. These AHSS impose a significant challenge to production lines such as hot dip galvanizing lines (HDGLs), not only because of their wetting behavior, but also due to their poor weldability with compression welding machines. For the ThyssenKrupp Steel Europe (TKSE) HDGL No. 7, this meant that AHSS like, e.g., Transformation Induced Plasticity (TRIP) steels could not safely be welded together. To circumvent this problem, one had to use a so-called 'Zebra production', i.e., alternating production of AHSS and IF-steel, or needed to weld two meter long intermediate plates of IF-steel at the starting end of each TRIP coil during a maintenance shift. Neither of these methods is desirable, as they lead to poor flexibility or significant downtime.

When using a laser welding machine, these drawbacks can be avoided completely. The trend towards AHSS is, therefore, also a trend towards laser welding machines. However, the laser welding machines come with different challenges and demands. Most important is edge preparation, as the welding spot of a laser welding machine is extremely small (<1 mm) and laser welding machines usually use the butt welding principle. If the cutting edges are uneven and/or not rectangular, the weld seam is likely to suffer from underfilling or other geometric defects. This is a real challenge for laser welding machines using a mechanical cutting device, not only because of the large product mix which has to be cut precisely (HDGL No. 7: 0.5-2.7 mm soft IF-steel and AHSS), but also as the AHSS increase wear and tear of the hydraulic shears.

WISCO Lasertechnik GmbH has therefore developed a laser welding machine, where the laser is used not only for welding, but also for cutting, hole cutting (weld seam detection) and notching. Moreover, all process steps are done by a single laser head equipped with a multi-purpose nozzle. This makes the laser welding machine very unsusceptible to all issues related to the absolute position of the weld joint, which leads to very stable level of high quality weld seams and helps to reduce unscheduled downtime for maintenance and repair. In this article, the technical characteristics of the WISCO Coil Joining Machine (LWM) installed at ThyssenKrupp are being described, discussed and compared to conventional (laser) welding machines.

Figure 2: The WISCO Laser Welding Machine at ThyssenKrupp. The laser source, a 5 kW CO_2 laser, is mounted in a acrylic glass cage at the side of the line. Because of work safety (laser radiation, automatically moving machines) the entire laser welding machine is enclosed by an acrylic fence (optically thin for optical wavelength, optically thick for CO_2 laser radiation).

THE LASER CUTTING AND WELDING MACHINE

Technical details

This section deals with the technical details of the LWM of the HDGL No. 7 in Bochum, Germany. The relevant facts and figures of the HDGL No. 7 are shown in Table 1. The laser welding machine was commissioned in April 2009 during a 23 day maintenance downtime. Figure 2 shows a picture of the LWM.

Table I: Facts and figures of the hot dip galvanizing line No. 7

Capacity	45,000 to/month
Products	galvanized, galvannealed (incl. exposed parts)
Steel grades	IF-, BH-, DP-, TRIP steels
Strip thickness	0.47 – 2.7 mm
Strip width	800 – 1,650 mm
Entry looper	500m
Line speed	max. 180 m/min

The laser source is a 5 kW CO2 slab laser, which is mounted at a fixed position at the side of the line. Although this leads to an additional deflection mirror when compared to competitive laser welding machines, where the laser unit is usually mounted on the C-slide, this has considerable advantages. Firstly, the laser unit is enclosed in an acrylic cage with air conditioning and heating to ensure stable working conditions and secondly, this allows for a much larger movability of the laser head. As there have been no problems with the deflection mirrors so far (neither misalignment nor contamination), four and a half years experience of operating the LWM have not unearthed any drawbacks of this concept yet. The usage of a CO_2 laser also implicates the advantage that it is very easy to account for stray radiation. A simple acrylic fence around the machine is sufficient to shield the operators from stray radiation and from automatically moving parts, while still allowing the operator to see what is happening inside the laser welding machine.

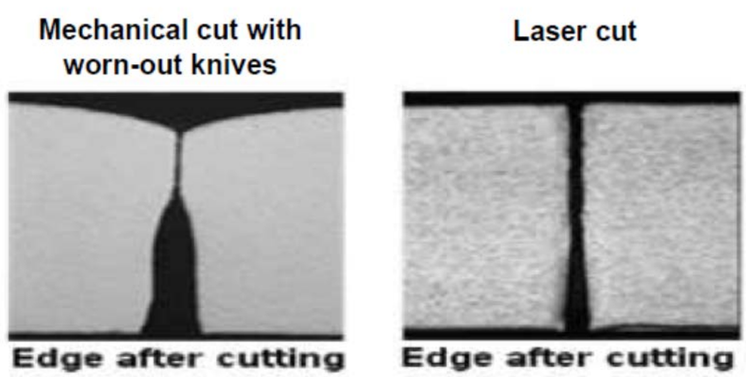

Figure 3: Mechanical cut with worn-out shearing knives (left) *vs*. laser cut (right).

As mentioned before, one of the characteristics of the TKSE LWM is that the edge preparation is done by a laser rather than hydraulic shears. This makes the costly replacement of shearing knives redundant and also leads to stable conditions over time – on the contrary to mechanical cutting devices where the cutting conditions will be poor just before the replacement of worn-out knives (see Figure 3). Cutting with a laser also enables one to prepare each edge with the optimum cut conditions rather than have to use a fixed cut gap and overlap to suit all steel types and thicknesses at once. However, laser cutting is neither new nor special. What is new is that the LWM at HDGL No. 7 uses a so-called multi-purpose nozzle with one optical system for the entire process, i.e., cutting, welding, hole cutting, and notching (see Figure 4)

Figure 4: The welding of two coils in detail. Cutting (top left), welding (top right), hole cutting (bottom left), and notching (bottom right) are all done with the same multi-purpose nozzle using the same optical system.

The joining of the two prepared ends is not done by a linear unit, which simply moves towards a predefined position, but by a pneumatic joining cylinder, which presses the ends together with a defined and adjustable pressure. The combination of the multi-purpose nozzle with the pneumatic joining cylinder greatly improves the stability of the weld seam quality of a laser welding machine. Firstly, gaps between the two ends will be closed automatically by the joining cylinder. Secondly, thermal expansion of the machine does not influence the process significantly. Lastly, this makes the laser welding machine unsusceptible against, e.g., mechanical offsets of the laser head by one mm perpendicular to the weld seam, as the cutting would be shifted by the same amount as the welding and the joining cylinder would make sure that there is no gap between the two ends.
Of course, laser cutting needs more time than conventional mechanical cutting (here: 13 sec. for a 1.2 x 1,200 mm strip and 20 sec. for a 2.0 x 1,200 mm strip)., but from the experience of the HDGL No. 7, there is no negative influence on the total cycle time compared to competitive machines.

Quality Control systems

The LWM at HDGL No. 7 is equipped with a so called Quality Control station (see Figure 5). In this station, which is accessible during production, several parameters important for the process can be monitored in a regular interval (theoretically after each weld, no influence on production). Firstly, the nozzle is cleaned with a rotating brush (marked with ‘1’), afterwards, the pressure of the proportional valves for the laser cutting are checked (‘2’). When notching the welded strip (because of different width or to check the weld seam), the LWM uses a distance sensor to keep a constant distance between nozzle and strip even in the case of ripples at the rim or different thicknesses of the welding partners. Due to temperature variations, this distance sensor has to be calibrated from time to time. This is done with the plate labeled with ‘3’ in Figure 5. In the fourth test, the absolute position of the multi-purpose nozzle is being checked by a 3D-needle (‘4’). During the last two tests, the position and intensity distribution of both the focused and the raw laser beam are measured (‘5’). The position of the focus is then compared with the position of the nozzle (i.e., to answer the question “Do these positions match with each other”).
Each of the performed tests has set reference values and limits and the operator will get a warning once a violation of the limits occurs. This regular quality control supports to get a good weld seam quality and enables one to notice if something is slowly drifting away

before the problem gets that large that it will hinder the production. Moreover, in the situation of a huge but unsolved problem, these measurements help to locate the root cause of the problem.

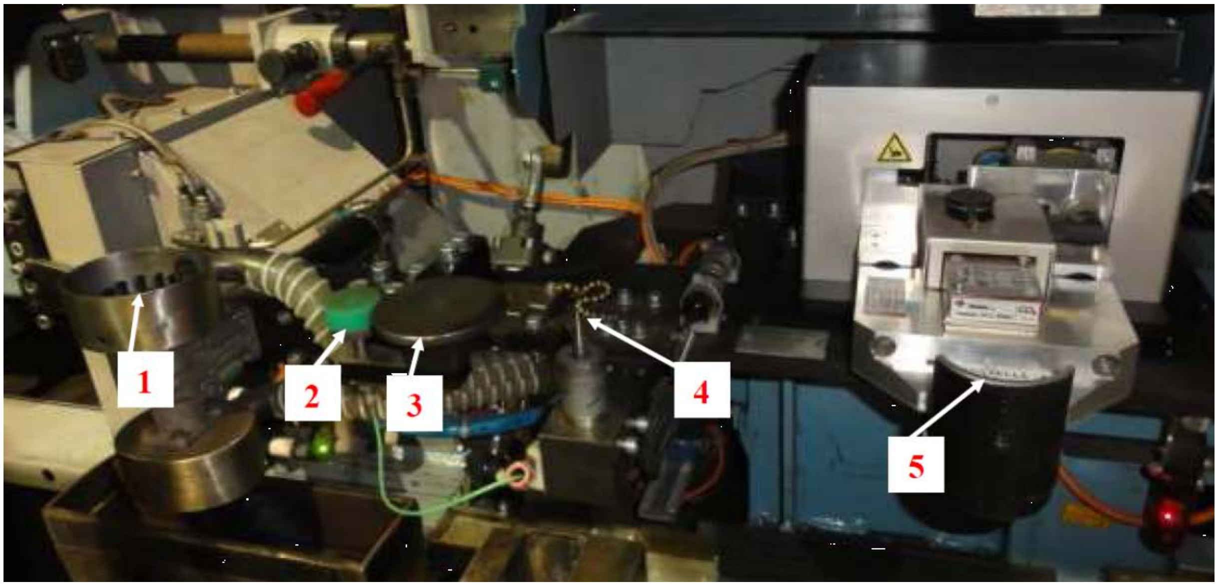

Figure 5: View of the Quality Control station. To ensure the best weld quality, the nozzle is cleaned (1), the pressure of the cutting gas is checked (2), the distance sensor is calibrated (3), the absolute position of the nozzle is measured in three dimensions (4) and the position and intensity distribution of the focused and raw laser beam are measured (5) on a regular basis during production.

Whereas the Quality Control station is used mainly to monitor mid- to long-term trends, the weld seam quality also has to be checked directly before sending the weld seam into the line. At HDGL No. 7, three sensors – two from the top side and one from the bottom side - are used. The main system consists of two sensors from the top side. One uses the laser triangulation principle to detect geometric defects of the weld seam like under- or overfilling or a height mismatch. The other sensor is a CCD detector and measures the intensity of the weld plasma, to judge whether there is a sufficient root fusion. The operator gets an image of the measured signals over the entire seam length (see Figure 6) together with the judgment of the quality system (ok/n.ok). Currently, no additional offline tests (like a bending test) are performed.
The weld seam in Figure 6 shows small regions with under filling at the first part of the weld seam, which in this case, however, are not large enough to reject the weld seam.

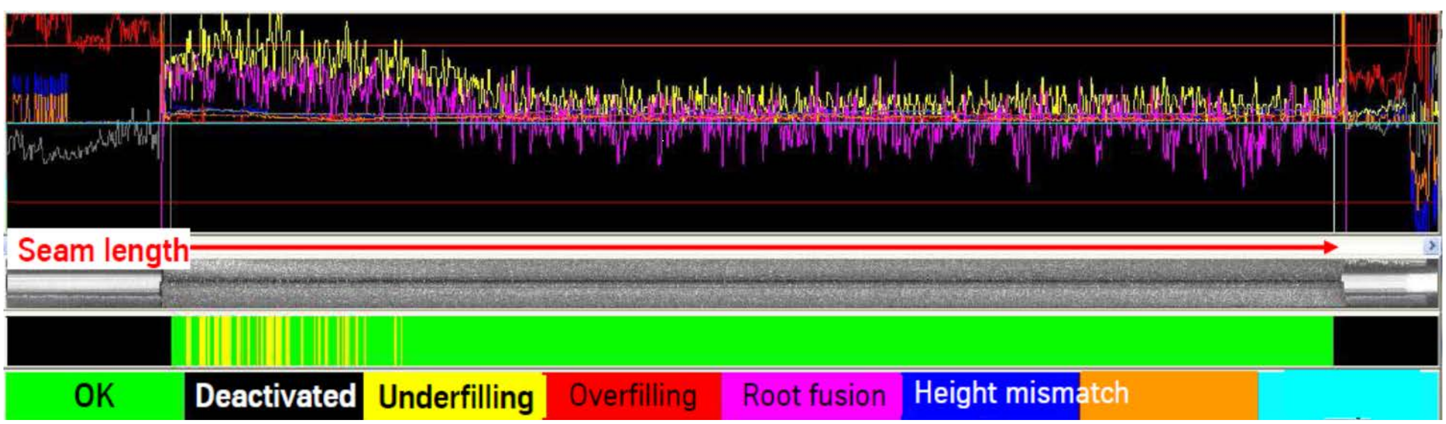

Figure 6: Picture of a weld seam monitored by the quality system. The left part of the weld seam shows some under filling.

In addition to the upper quality system, a so-called 'root broadness sensor' (RBS) is installed and detects the seam from the bottom side. This system also uses the laser triangulation principle and can detect a height mismatch and a root relapse and measures the width of the root.
Both systems run simultaneously and provide supplementary information of the top and bottom side of the weld seam.

Results

Weldability of different steels

Since commissioning of the LWM in April 2009, nearly 85,000 weld seams have been processed through HDGL No. 7, with a significant amount of AHSS. Other steel grades, which are considered problematic to weld like 3 mm cold rolled Bor-Mn steel for warm forming, austenitic high Mn alloyed X-IP® steel (with 23 wt.% of Mn) or unpickled hot rolled CP-steel have been welded in order to test their weldability. All tests done in the lab (tension test, metallographic analysis, hardness tests) show that every steel is weldable with any other steel, combination of steel grades or different thicknesses.

An important motivation for replacing an old compression welding machine by a laser welding machine is to minimize weld seam fractures, especially in the furnace of the HDGL and when producing thick and high strength material. In these cases the weld seam fractures can cause much more damage to the line then and it also takes much more time to get the line running again. As the weld seam – or more precisely, the heat affected zone of an IF-steel - usually represents the weakest spot of the entire strip (due to coarse grains which cause a dip in the hardness of the material, see Figure 7), the strip is most likely to rip at the weld seam. This is also in accordance with our lab tension tests of IF-steels. Higher alloyed steels, like TRIP steels do not show this dip in the hardness, making the weld seam the strongest part of the strip; the tension tests in the lab showed that the material rips far away from the weld seam. In the new LWM at HDGL No. 7, there has been no weld seam fractures caused by the laser welding so far.

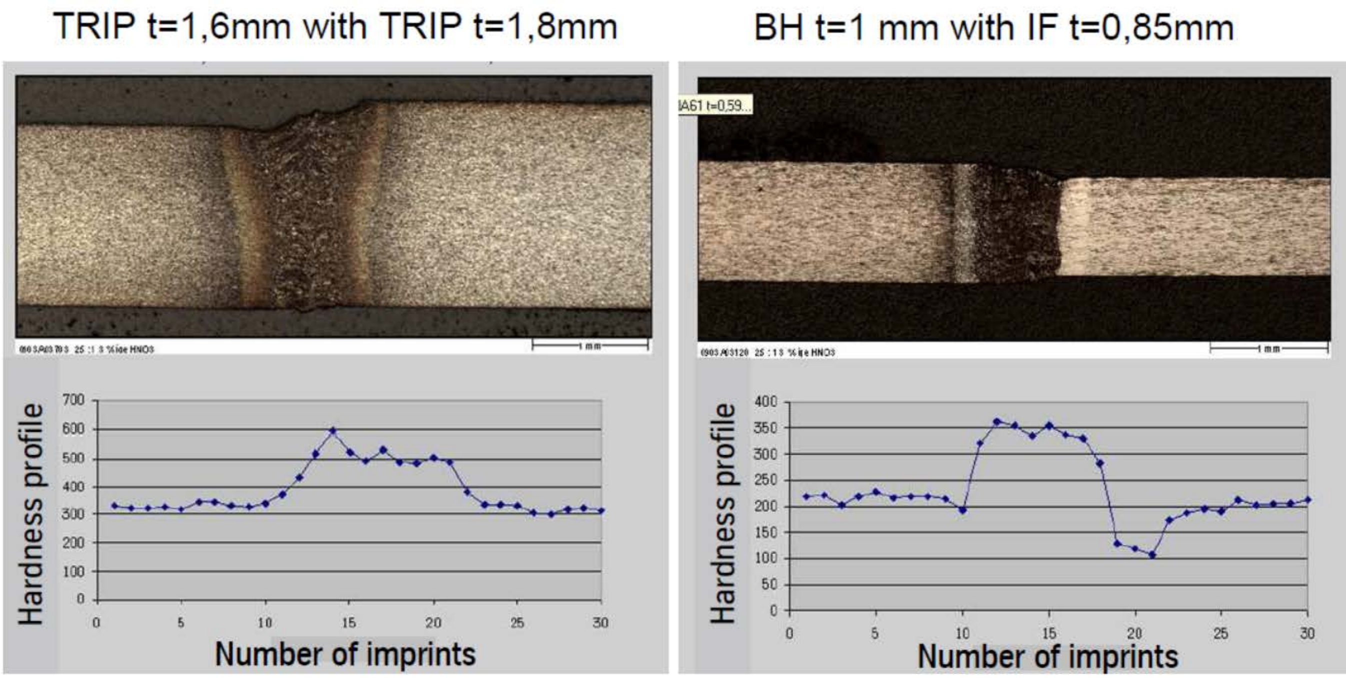

Figure 7: Hardness profile of welded material

Most problematic, however, are weld seam fractures in the furnace. With the new LWM, there also has been not a single weld seam fractures in the furnace of HDGL No. 7 so far, which demonstrates that the weld seam quality of the LWM is indeed excellent.

REFERENCES

1. Dr. rer. nat. Clemens Trachternach; ThyssenKrupp Steel Europe AG: „The new ThyssenKrupp-Laser-Welding-Machine at HDGL #7"