Laser machine enables coil joining in continuous strip processing lines

SYSTEM CAN INTEGRATE FIBER LASER SOURCE

CHRISTIAN DORNSCHEIDT, JENS ARTEL, AND CAESAR SASSE

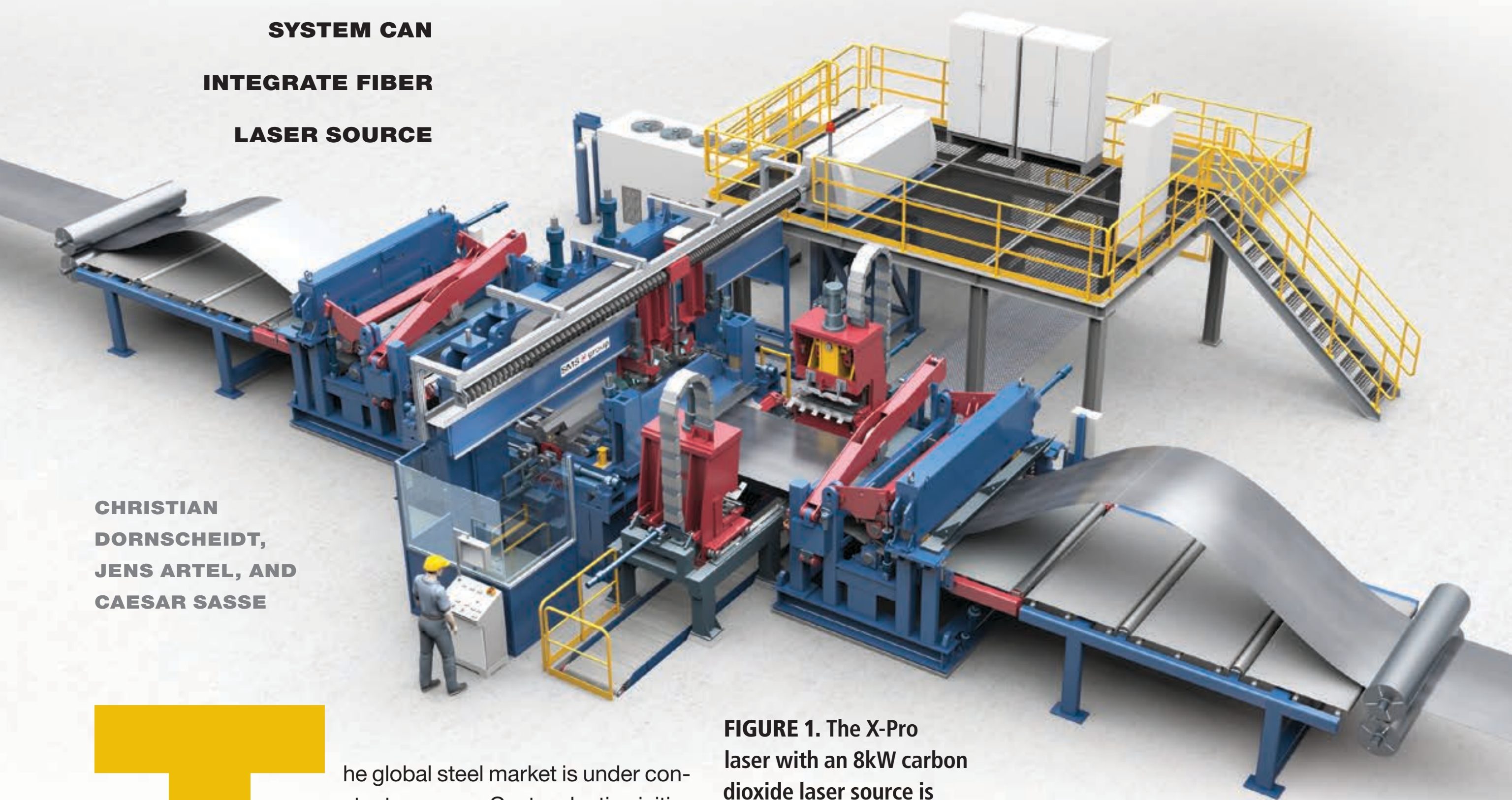


FIGURE 1. The X-Pro laser with an 8kW carbon dioxide laser source is the basis for a new order with a 10kW fiber laser to be integrated into SSAB's new entry section, which will provide high efficiency and availability as well as a safe, fast, and fully automated process, even for difficult-to-weld materials.

The global steel market is under constant pressure. Cost-reduction initiatives such as energy conservation, minimizing personnel, and spare-parts reduction come along with the need to increase the availability of equipment. Staying competitive comes with the necessity to offer a broad product portfolio, which focuses on modern steel grades.

Old flash butt welding machines or conventional laser welding machines are not able to weld modern steel grades in a reliable manner, as their high-alloying contents have an influence on the weldability of the materials. Furthermore, welding machines in existing lines need to be replaced as spare parts and in-house expertise availability dwindle.

In previous decades, more people were involved in operating and maintaining the equipment—but now, cost-control measures are reducing the number of involved personnel. Therefore, maintenance-friendly machines with high availabilities that operate automatically and adaptively with desired production results are required. SMS group reacted to this process change and on the worldwide impact of digitization with a newly developed welding machine.

The welding machine implements several digital solutions to operate in a simple manner. Its features allow for reduced operating and maintenance staff to perform preventive maintenance with long-time archives that record all relevant data. The machine's documentation is digitally available and interlinked.

Recently, SMS group received another order for its latest-generation X-Pro laser welder, as SSAB (Hämeenlinna, Finland) decided to revamp its pickling line to include a fiber laser welding machine (**FIGURE 1**). The company is

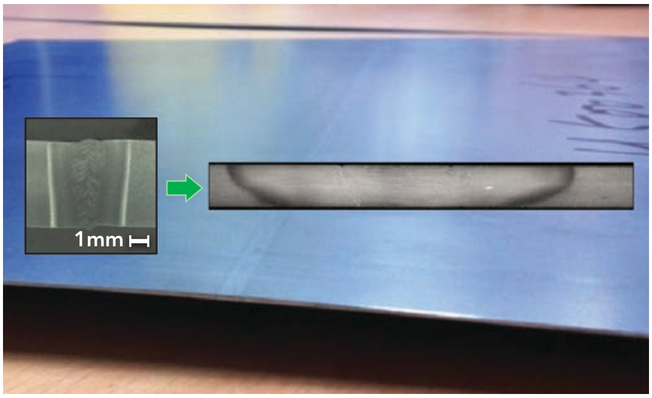


FIGURE 2. A metallographic cross-section of a laser-welded seam (martensitic steel with tensile strength of 1200MPa) from a notch sample after rolling; the weld seam was rolled full force with no mill relief during weld seam transit through 6 mill stands.

convinced on its pickling line's ability to weld high-strength materials within a short cycle time. Furthermore, its automatically controlled, reliable process and easy maintenance concept are beneficial features.

Requirements

The welding machine is not only a crucial technological piece of equipment in every strip processing line, but also an entry cycle time factor and one key component for utilized and maximized production. If coils are not joined properly, the whole process will stop: every strip break or machine stoppage has the potential to affect upstream and downstream operations, resulting in significant financial implications.

The weld seam is only utilized for a few minutes—at the very end of the line, it will often be cut out, but weld seam requirements and a reliable welding process are very high. The entire process is fully automated and the sequences to join both strip ends successfully are always the same. What changes is the material to be welded regarding steel quality, strip thickness, strip width, and thickness jump from one coil to the next.

The welding process takes place every 3 to 5 min. In a pickling line/tandem cold mill, the weld seam is bent numerous times with high tension (up to 65 tons), travels more than 1000m through the line at high speed (up to 1200m/min), and eventually gets rolled and significantly reduced in thickness with high forces in five mill stands (up to 1800 tons).

The rule, and not the exception, in a current steel plant is the production of modern high-strength grades with high contents of alloying elements. These grades tend to create extreme hardness increases in the weld seam area. Induction pre- and post-heat treatment, or even additional buffering wire during laser beam welding, are mandatory for these high-tech steel grades to improve the ductility of the weld to allow successful production without any weld seam breakages during a line run.

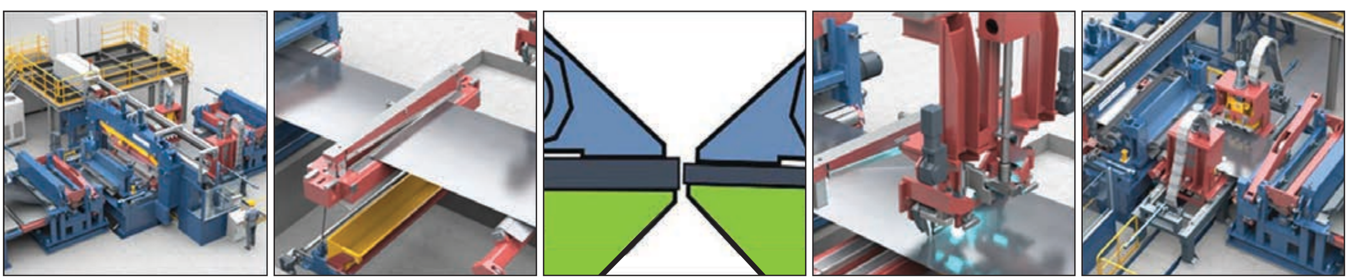
Another major requirement of the machine is a low cycle time. Since the lines are producing continuously, the needed stops for welding must be as short as possible.

Welding process

The process starts with tail-out threading of exiting coil and head-in threading of entering coil with two pinch roll units, which position both ends of the coils to be laser beam-welded into the welding machine. Strip centering devices located at the entry and exit side center-align both strip ends. During strip centering, the required welding parameters are calculated in the welder's programmable logic controller based on cast analysis and strip thickness coming from level 2 data. The strip thickness is verified during clamping of both strip ends.

A double cross-cut shear is used to cut both strip ends simultaneously to prepare the strip ends for welding. The cut scrap drops through the welder's shear onto a scrap discharge system, which is combined with the notcher scrap on a conveying belt. Test welds or notch samples can be conveyed to the operator side for inspection. In conjunction with the cutting process, a hole for the weld seam detection can be punched (**FIGURE 2**).

The prepared strip ends are aligned relative to each other in terms of width and thickness to achieve the desired welding joint geometry. Before the strip ends are welded together, the position and geometry of the welding joint are measured by a camera. The position-controlled welding head guarantees the seam to be exactly positioned on the joint. If there are any deviations in position or geometry because of wear or wrong alignment of machine components, the welding traversing unit adapts to the new conditions and automatically controls the welding head into the correct position. In this way, the weld seam is always positioned exactly on the joint, which prevents the weld seam from breaking. Furthermore, repairs can be postponed until the next scheduled maintenance shutdown, as certain misalignment can be compensated by the welding traversing unit.



Positioning Cutting Aligning Welding Notching

FIGURE 3. A principle representation of the welding process, which incorporates five main steps.

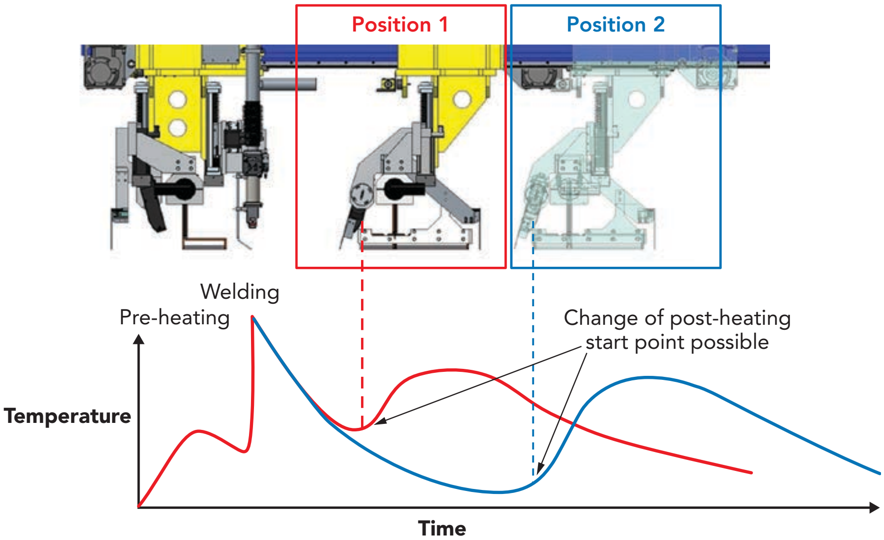


FIGURE 4. The system for pre- and post-heating of the weld seam with freely selectable start points and temperatures.

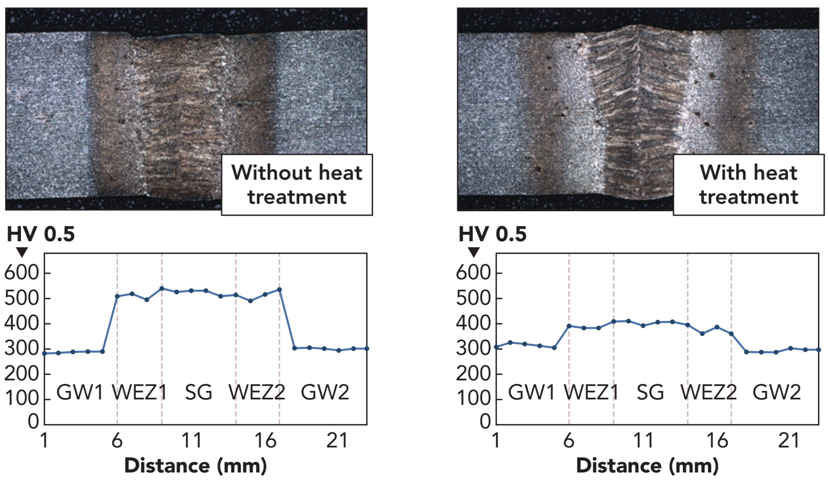


FIGURE 5. A reduced hardness profile by post-heating (right) improves ductility of a welded seam.

In case of hard-to-weld material, the weld seam is subjected to inductive heat treatment (pre- and post-treatment) to obtain a homogeneous hardness profile across the weld seam.

Upon completion of the welding process, the edges are removed with a side notcher to ensure reliable strip travel and to allow the edge trimming shear downstream in the line to move into the continuous strip. The material cut-offs can also be used for weld seam testing.

Welding machine capabilities

The main goal when developing the welding machine was a compact design with simple requirements to build a foundation for revamps and to replace old flash butt welding machines (**FIGURE 3**). The following paragraphs describe the machine's capabilities.

Heat treatment of the weld seam. One major advantage of the machine is its inductive pre- and post-heat-treatment of the weld seam (**FIGURE 4**). The machine allows an individual annealing process of the hardened weld seam. Since every material combination is different and the range of possible material combinations has significantly increased, the distances between the inductive heaters and the seam, as well as the power, are variable. This means that the treatment time and temperature are adjusted flexibly in the most suitable way for each seam.

The highly efficient deep heat treatment with medium-frequency induction allows thorough heating of the material in the shortest possible time, thus preventing a hardness increase on the weld seam and the consequent risk of strip breakage (**FIGURE 5**). The special inductor design considerably reduces the holding time compared to conventional systems. This allows welding of hard-to-weld materials like martensitic or high-carbon/silicon grades.

Weld seam quality assurance. An integrated, automated weld-seam quality assurance system with two cameras evaluates the entire process. The first camera positions the welding head on the middle of the joint, and the second camera checks and rates the quality of the welded seam. If everything passes inspection, the system automatically approves (**FIGURE 6**).

Calculation of welding parameters. The welder is adjusted by automatic adaptation of the welding parameters. With this system, new material pairings can be welded without extensive testing. It uses level 2 data for cast analysis and thickness to calculate carbon equivalents, and features a database with suitable welding parameters.

Thanks to automatic calculation of the welding parameters for every individual material combination, even strip combinations of unknown steel grades will be welded. The correct welding parameters for the combination to be welded are determined immediately and reliably without having to spend time on test welds and lengthy searching in databases. All it takes for the calculation are the geometric strip data and analysis of the steel melt of the two steel strips. These data are usually stored in the production computer and can be transferred to the computer of the welding machine. Therefore, test welds on the production plant or problems when welding new material combinations now are a thing of the past.

Low cycle time. Another desired feature of the machine is its <60s cycle time, thanks to its simplified design for the process. Most machine movements are performed linearly and are position-controlled, as encoders for all movements allow for safe and fast positioning of the machine.

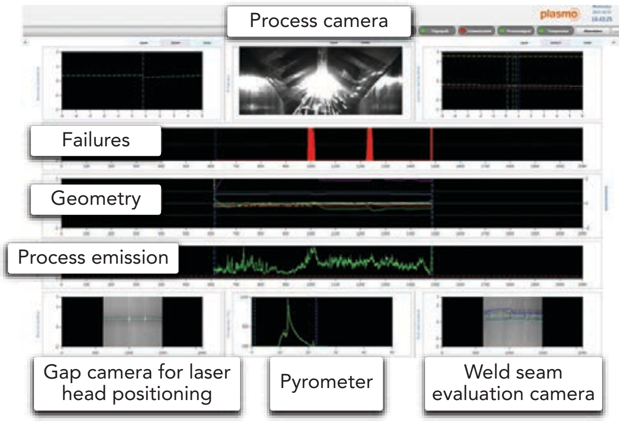


FIGURE 6. The welding machine's quality assurance system enables automatic weld release.

The exchanging time for the machine's top and bottom knife cassettes in the shear is extremely short—they can be changed in <20 min. This is a result of a smart machine design, with no additional equipment needed inside the machine to allow this quick-change procedure.

Selectable welding source. Thanks to the modular design of the welding machine and the consequent separation between weld seam preparation and the welding process itself, the welding source can be easily replaced. This allows use of a conventional carbon dioxide (CO_2) laser source or a solid-state laser source.

The weld seam preparation with alignment, fine cutting, and joining of the two strip ends is performed by separate machine modules. Subsequently, the welding source is moved with a welding traversing unit along the joint between the two strip ends. In doing so, the position and traversing speed of the welding source can be adjusted individually. This fulfills an important condition for enabling other welding sources to be used in the future. Furthermore, various welding procedures can be combined.

This extreme flexibility of the welding machine guarantees that, for example, hybrid laser beam welding for joining stainless steel strips can be used without having to carry out major revamps.

Solid-state laser

In former projects, SMS group installed multikilowatt CO_2 lasers—either 12kW (TRUMPF) or 8kW (Rofin-Sinar). For this latest project, the company will install a solid-state laser for the first time—a 10kW fiber laser (IPG Photonics). When compared to a conventional CO_2 laser, the laser beam is generated in a resonator with a laser-active fiber. Thanks to its high wall-plug efficiency and almost no power consumption in stand-by mode, operating costs will decrease up to 90%.

With a solid-state laser, it is possible to save or even avoid process gas (for example, helium), and reduce the maintenance effort. An excellent feature of the system is its simple modular structure, which is almost maintenance-free. What's more, solid-state lasers come with a compact design and small footprint with a flexible process laser fiber, enabling plant concepts to be kept simple.

The solid-state laser process is rougher and more turbulent in comparison to a conventional CO_2 laser source with process stability, especially on thicker grades above 3mm. The appearance of spatter due to a different plasma vapor plume is well known and often described in various literature references. Certain measures were implemented to avoid these spatter appearances on gauges thicker than 3mm to allow the solid-state application is suitable for the strip processing process.

Installations

The X-Pro laser welder for a new pickling line/tandem mill at Big River Steel (Osceola, AR) welds almost 1.5 million tons of steel strips per year (**FIGURE 7**). Commissioning took place in 2016. After the welding process, the material, including the welded joints, will not only be pickled, but also rolled in a five-stand, four-high tandem mill. This means the 1.4- to 5.0mm-thick strip will be reduced to a final gauge between 0.27 and 1.4mm. Even steels with high silicon will be produced on this line and, therefore, welded.

SSAB Europe has awarded SMS group an order covering the modernization of a continuous pickling line entry section in its Hämeenlinna, Finland plant. This modernization will significantly increase the line's availability and its output, as well as the degree of automation and safety.

With the installation of an X-Pro fiber laser welder and a high-performance tension leveler, it will be possible to produce modern, high-strength steel grades with high alloy contents. The conversion,

FIGURE 7. The X-Pro laser welder is integrated in the new pickling line/tandem cold mill at Big River Steel.

including modification of the complete electrical and automation equipment, will be accomplished in two phases, and is scheduled to be completed by the end of 2018. With the new equipment, the line will be able to process materials with yield points of up to 900MPa. Higher capacity at lower operating costs will be a further benefit.

An essential element of the modernization is the X-Pro laser welder with solid-state laser. In 2015, SSAB had sent difficult-to-weld, high-alloy plates from its own production to SMS group, which have been welded with the machine using a fiber laser source.

The line is designed for strips with thicknesses between 1.5 and 6.5mm and widths from 650 to 1650mm. In the processing section, the strips will be pickled in the turbulence pickling tanks at a speed up to 180m/min, whereas the maximum strip speed attainable in the entry section will be 400m/min.

Strip processing lines are facing several challenges when it comes to flexible, economical, and safe welding of modern steel grades. The X-Pro laser welder, which is easy to maintain and can easily be integrated in existing lines, is able to produce hard-to-weld strip materials.

The welding machine offers several beneficial features, including patented inductive heat treatment, automatic parameter calculation, a quality assurance system, low cycle time, and exchangeable laser sources. One special new feature is the integration of a modern solid-state welder, which decreases operational costs.

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X-Pro is a registered trademark of SMS group.

CHRISTIAN DORNSCHEIDT *(christian.dornscheidt@sms-group.com)*, **JENS ARTEL**, *and* **CAESAR SASSE** *are all with SMS group, Düsseldorf, Germany; www.sms-group.com.*