Klaus Krastel, Grzegorz Chrobak

New Production Tools for Energy-efficient Joining Technology in Automotive Manufacturing

Abstract: The LaserSeamStepper (laser welding gun), introduced by IPG, is a new laser welding tool which is comparable with a standard resistance spot welding gun. The components are initially pressed together and then welded by laser radiation. The integrated laser safety function greatly facilitates the use of the laser material processing and keeps down high investment costs. Manual guided laser welding and one-sided accessibility extends the range of applications and manufacturing processes. Overlap joints in the automotive industry (car body) as well as planking of space frame structures can be done very cost-effectively on a normal shop floor. A continuous improvement process has taken place since the beginning of car series production with the LSS, the result of close cooperation with different car manufacturers. This results in a highly reliable laser welding tool with an availability of 99.9 percent. Due to the high repeatability of the complete system (fiber laser and LSS module), a very high continuous production quality can be guaranteed without any rework at the manufactured part itself.

Keywords: laser welding, LaserSeamStepper, IPG, Automotive Manufacturing

Introduction

Laser welding technology has been for many decades an integral part of technical joining in the automotive and precision engineering industries. The laser could be used for the joining of precise pre-manufactured components in the powertrain and in the production of tailored blanks. In the body shop, the use of lasers, however, was difficult to achieve because an accurate clamping technology and flexible seam tracking was necessary. Furthermore, laser safe cabins are required, which does not facilitate the handling of complete car bodies in the current production line.

Higher CO_2-standards lead to weight reduction of the body shell. For this purpose, high-strength steel or aluminum materials are used while reducing flange widths at the same time.

This new tool, LaserSeamStepper (LSS), offers in this case an alternative to the standard laser welding processes such as laser remote welding and to standard resistance spot welding. The LSS-system combined with IPG's high efficiency fiber lasers is a step forward for saving energy and investment costs.

Laser Seam Stepper System

The laser welding gun, named as Laser Seam Stepper by IPG, provides a number of various advantages, which simplifies the use of lasers inside the car body shop.

Dr. Klaus Krastel – IPG Laser GmbH, Burbach, Germany; inż. Grzegorz Chrobak (Eng.) – IPG Photonics Ltd. Gliwice, Poland

At the LSS, the plates are placed between two clamping pieces and are pressed together with a controlled clamping force of up to 3 kN. After that, the parts are welded together within the integrated laser shielded housing. Up to 40 mm long weaved welding seams can be achieved. The weaving frequency, the welding speed and the weld length are programmable and can be adjusted from weld to weld. Normally, the resulting welding fumes inside the upper pressure element were suppressed by compressed air and sucked away near the welding position. For welding of stainless steel, aluminum or titanium, see figure 1, shielding gases can be used for keeping the surfaces clean and free of oxidation.

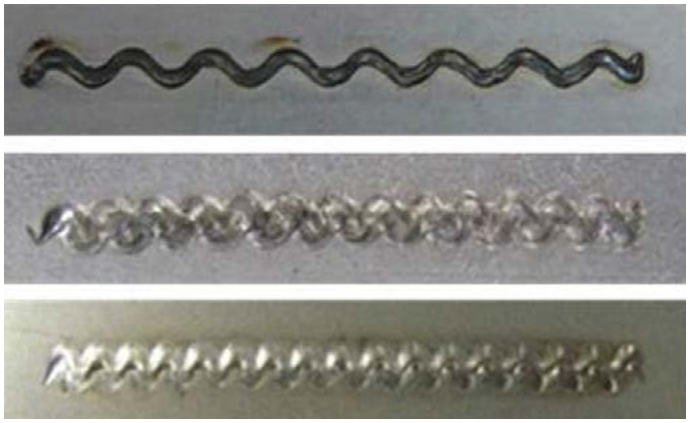

Fig. 1: 40mm weaved seam; upper: MnB-steel, middle: aluminum, lower: stainless steel

Installation in the car body shop

The implementation of press-hardened steels in modern car body designs and the increasing demand for higher stiffness and rigidity require much higher interfacing at the joining area which cannot be achieved by standard resistance spot welding in most cases. This is partly due to the recommended minimum distance between the resistance welded spots and the high heat input which negatively influence the material specifications.

For the car body of the Volkswagen Golf VII, joining technologies which can provide high joining interfaces will have great advantages. This is shown in Figure 2 at the triangle window at the A-pillar and at the cross connection of the B-pillar with the rocker panel.

While at the triangle window the increasing of the connection interfaces is important, also savings in the processing time can be achieved at the cross connection of the B-pillar with the rocker panel. 26 resistance spot welds were eliminated by 9 laser weld seams, at the roof application 10 RSW points were replaced by 4 weaved laser welded seams (see figure 3).

Further advantages of laser spot welding can be found in welding outer skin panels and hang-on parts. Here, the seam length is reduced and a fiber laser with a better beam quality is used. The required laser power can be less than 1kW. So called micro steps with a weld length of 12 mm were created (see figure 4) and can be placed near the cutting edges.

The micro-welding step only requires a flange width of 6mm and is especially important for

Fig. 2. Car body of Volkswagen Golf VII.
Triangle window is welded with LaserSeamStepper.

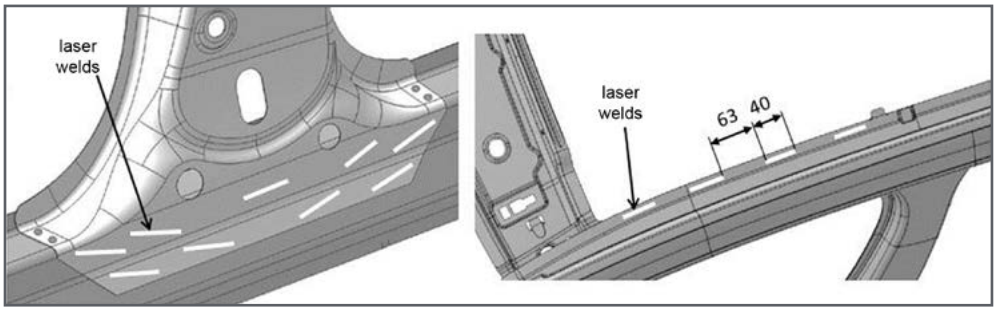

Fig. 3. Left: cross connection b-pillar to rocker panel; right: roof frame

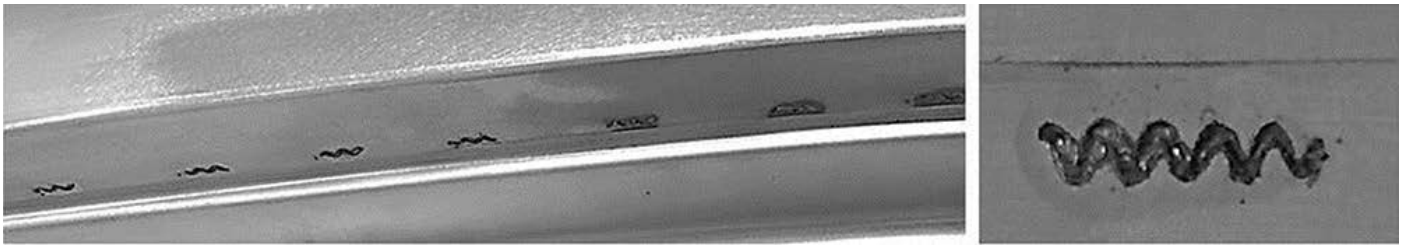

Fig. 4. LSS welded outer skin panel with micro-steps (length: 12mm) placed near the cutting edge

sensitive components such as shown in Figure 5 at the upper window frame. Contrary to resistance spot welding, the sheets at laser welding are fixed just before the welding process, and were not deformed during or after the process. The pressing of the electrodes into the material during the resistance spot welding leads to an elongation of the sheet in the area around the welding point and will lead to a distortion of the complete component. Here, especially the forceless laser beam welding holds a big advantage.

Fig. 5. Welding of 6mm flanges at door frame.

For components, which are welded only in small numbers or with high variability, the hand-held LSS-3 system is the right tool. In this case, the laser welding gun (weight: 38 kg) is installed at a balancer and articulating support and can be moved by an operator to the welding position (see figure 6). The operator starts the welding manually. The servo driven gun is closing and clamping the parts together. After that, the laser is triggered and selects the required laser power automatically for a complete penetration weld.

Single Side Access Applications

Shipyard Industry

In many technical designs, frame structures are planked with metal sheets, or sheet metal constructions are reinforced with steel profiles. Herein, technical solutions are necessary for joining the panels with highest reliability to the substructure without introducing deformations and distortions. This is where laser welding holds a big advantage due to its single side access. Figure 7 shows a robot-guided "picker" version of the LaserSeamStepper, welding omega-profiles onto another outer skin panel made of aluminium for reinforcement.

Fig. 6. Hand-held LaserSeamStepper LSS3 mounted at articulated arm and balancer with 4kW laser and controller in an all-in-one design

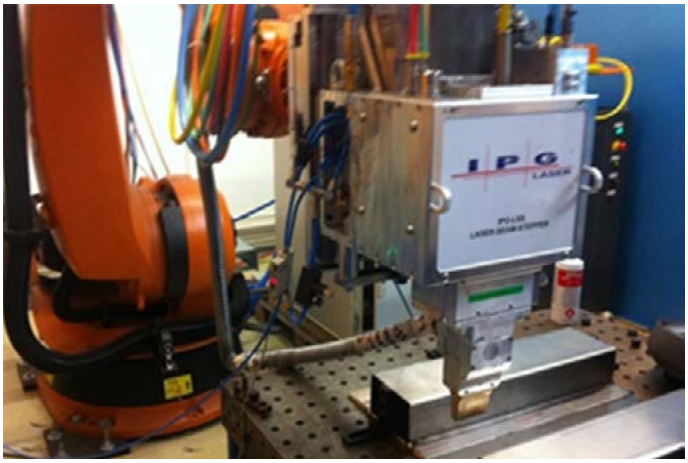

Fig. 7. LaserSeamStepper in picker version for single-side-access applications

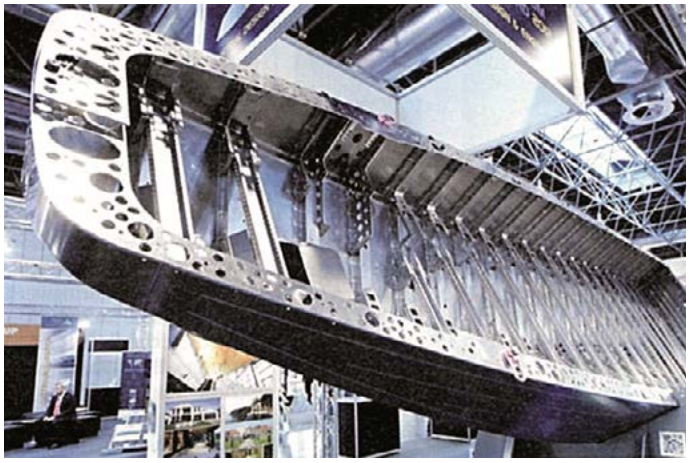

Fig. 8. Aluminum boat hull, welded with LaserSeamStepper in picker version

With a picker version boat hulls are made out of aluminum. Stiffening structures were welded from the inside to the outer skin panel. Figure 8 shows such a boat hull, wherein the outer skin has no distortion and no visible defects caused by the heat effected zone. This lack of distortions and defects reduces the rework and produces a product with much higher quality. The realized welds (see figure 9) are widened by the beam oscillating function of the LaserSeamStepper. The reinforcing stringers have a thickness of 3mm, the outer skin panel 8mm. The goal is to achieve a maximum of a cross section interface and a minimum of visible surface defects on the outer skin. To reach a welding speed of 6mm/min, a laser power of 3.5kW is required. The weld length is approximately 30mm; the width is 4mm; and the penetration measured from the top is 5mm.

Due to the implementation of the laser welding gun, the welding quality improved with less preparation work and less refinishing operations. Costly jigs are nearly eliminated. Therefore, this method is rated significantly better than MIG welding and is used instead.

Fig. 9. Large width aluminium weld by oscillated laser beam with LaserSeamStepper in Picker version. Top view (left) and cross section (right)

Railway Vehicle Manufacturing

In railway vehicle manufacturing, railway carriages are mostly designed of sheet panels with reinforcement profiles. Materials can be mild steel, stainless steel or aluminum. Today these reinforcement profiles are attached to the planking sheets by using the gas metal arc welding technology (GMAW), but with a clearly visible and significant distortion at the outer skin panels. An additional complex straightening process is necessary. Figure 10 shows a complete side panel which is laser welded by the LaserSeamStepper (picker version).

For this manufacturing process, the side panel is placed in a counterpart, and the reinforcement parts were aligned and fixed with a set of simple toggle clamps. The picker is supported by a gantry system and moves the welding device to the welding position. The picker then presses the reinforcement parts onto the skin panels and starts the welding process inside the light-tight pressure piece. The pressure piece serves as a hold-down device for minimizing the welding gap between the two parts and at the same time acts as a safety enclosure

for deflected the laser radiation. The design of the laser welding station for such huge parts does not need any laser safety cell with a complete enclosure. Easy loading by crane from top down is possible and high investment costs are extremely reduced.

Fig. 10. LaserSeamStepper (picker) welded side panel of a passenger train

Economic aspects

In cooperation with Inpro (an innovative company for advanced production systems in the automotive industry in Berlin; its cooperating partners are Daimler AG, Volkswagen AG, Siemens AG, ThyssenKrupp Technologies and Sabic Venture BV), the joining technology of resistance spot welding was compared with laser welding by the Laser-Seam-Stepper using a wobbled beam. Here, physical and technological features, behavior of the part itself and crash performance were taken into consideration, along with economic aspects.

Figure 11 illustrates the overall evaluation of the considered factors for laser welding by LSS (blue line) and resistance spot welding (red line). The line nearer to the middle for laser welding represents a better result than the one achieved by resistance spot welding. The overall technical result shows that the performance of the wobbled seam produced by the new welding module is comparable to or even better than resistance spot welding and can complete welding tasks in half the production time. The result of economic comparison shows a total cost reduction of 6 to 10 percent, assuming fully automated production of 800 units in three-shift operation.

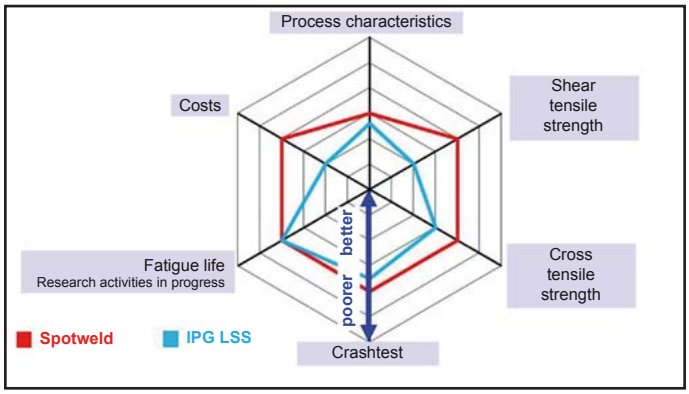

Fig. 11. Overall evaluation of the process comparison

Summary

Laser material processing is today one of the most important key technologies in modern production lines. Compared to competing conventional manufacturing technologies, the laser process has convinced planning and development engineers as well as designers due to its process advantages and high flexibility.

The high-volume production environment present in the automotive industry is one specific example where resistance spot welding and laser welding are well-established technologies. Both technologies have pros and cons. For laser welding, especially in the case of laser remote welding, the main advantage is the significant cycle-time reduction due to almost complete elimination of idle times and the advantages of laser-welded seams. For resistance spot welding, one of the pros, compared to laser welding, is the integrated clamping technology, which appears nearly for free.

Both advantages can be combined in a fast laser-welding production tool that provides robust, process-secure, integrated clamping of components: the Laser-Seam-Steppers in various designs (LSS1, LSS2, LSS3 and LSS5) from IPG Laser GmbH.

The new tool is a Class 1 laser device under specific restrictions. That means it can be used

on production lines without the need for additional laser-safety mechanisms. This is a distinct advantage over traditional laser welding, which typically takes place behind safety enclosures, adding cost and consuming valuable space. Modern laser welding has been used in auto body plants and in the production of sheet metal components with the following advantages:

– Higher process speeds (shorter cycle times),
– Increased component strength via longer seams and resulting higher torsional stiffness,
– Effort and cost comparability to today's resistance-welding systems,
– Realization of higher job safety requirements with reduced costs.

The new module deflects the preset laser beam via process fiber into X-Y coordinates. For safety, the laser beam is directed via a funnel-shaped small angled housing. To release the laser power, the housing has to contact the component to be welded.

Laser welding with or without the weaving function (± 1 mm) for increasing the welded interface can be effected within the range determined by the housing (standard = 40 mm). In cooperation with an innovative company for advanced production systems in the automotive industry, fundamental research was done for the joining technology resistance spot welding and laser welding with the LaserSeamStepper. Physical-technological properties, behavior of the part itself and crash performance were taken into consideration, along with economic aspects.

The overall better result for the LaserSeamStepper enabled installations in the world wide productions lines of the automotive, shipyard and railway industry as well as in production lines for home appliances.