Innovative Laser-based Manufacturing Concepts for Automotive Steel Processing

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Abstract: Laser welding has been used for a large variety of applications over the last two decades due to its attractive properties such as low heat input, high precision and speed as well as versatile and automatic handling. The exploitation of the full application potential of laser welding requires an appropriate manufacturing concept and the corresponding technology. The integration of laser welding and cutting into larger manufacturing processes or into stand-alone systems will be demonstrated using examples of WISCO Lasertechnik's experience of over 20 years in this field. More specifically the modular setup of such manufacturing concepts and the different level of automation will be indicated to offer individual solutions for different needs and budgets of small & medium sized as well as large enterprises. The demonstrated applications range from flat sheet, profiles, tubes to rods made from carbon steel or stainless steel.

1. Production Concepts for Tailored Welded Blanks

For laser welded blank production various manufacturing concepts are used in the industry. These are the result of different production strategies and also of rapid parallel development of technology by different players in the market. A production concept is basically characterized by the way of achieving a relative displacement of laser beam and sheet material as well as by the manner of managing the material flow through the process. The driving forces behind any welding machine concepts are maximization of the utilization of the laser welding equipment, the optimization of production flexibility and the reduction of cost.

Fixed-optics laser welding systems are characterized by a stationary welding head while the sheet assembly to be welded is passing underneath (Fig.1). This procedure allows producing straight weld seams of various lengths. Moving optics systems represent the opposite approach where the sheets to be welded are at rest while the laser welding head is executing the desired 2-dimensional trajectory (Fig.2). In this way weld seams of nearly arbitrary shape can be made.

1.1 Continuous welding system

For the production of single straight welded assemblies, machines equipped with fixed optics are clearly the method of choice. Each additional straight weld in a blank design requires a corresponding additional pass through the machine since only one weld seam can be manufactured at the time. This results in extra handling and machine set-up whereas a moving optics system finishes even complex multi-weld assemblies within one machine cycle. Therefore, a detailed analysis of the manufacturing cycle time is required to decide which of the two machine concepts is to be preferred.

Fig.1 Fixed-optics welding machine with continuous material feed (arrow = feed direction)

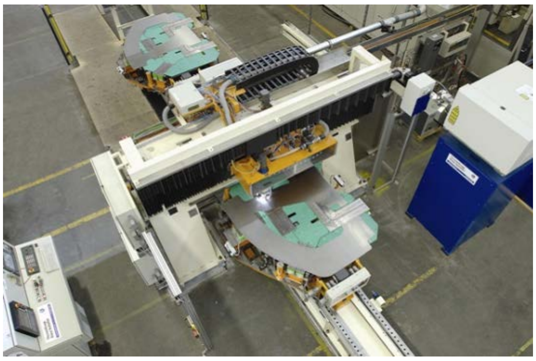

Fig.2 Moving-optics welding machine for 2-D welding with discontinuous material feed

Table 1 Cycle time and batch production time for continuous and discontinuous material feeding (assumptions: 1 m weld length, 50 mm spacing, 8 m/min weld speed, 3 blanks per load cycle for discontinuous feeding).

Feeding system	Process time per welded part (s)				Job change-over time (s)	Production time per batch (min)		
	Welding	Travelling	Reloading	Total cycle		2,000 parts	5,000 parts	10,000 parts
Continuous	7.5	0.4	0.0	7.9	300	268	667	1,325
Discontinuous	7.5	0.4	3.3	11.2	3600	433	993	1,927

The challenge to the material-handling concept is to offer a new batch of non-welded sheets to the weld process as soon as the welding cycle of the previous is finished. This scenario allows a maximum utilization of the capital-intensive welding equipment and thus leads to minimization of the welding cost. The ideal solution in case of a fixed-optics welding machine is a continuous material flow through the welding machine. In this case the welding speed represents the speed of conveying material into and out of the welding machine. Consecutive sheet batches are separated by a minimum intersection to keep the beam-off time as short as possible. In particular cases, accelerated material flow in between weld sections helps to reduce the beam-off time. Since welding cycles can be as short as a few seconds, appropriate buffer zones have to be foreseen at the beginning and the end of the continuous conveying system. The continuous material flow system is based on the conveyor principle where the individual blanks are loaded and while moving onwards being positioned automatically. Naturally this method does not allow static clamping of the sheet pair during welding. Clamping is occurring by inclined friction rolls pushing the two mating blanks against each other and simultaneously moving them forward at welding speed. To avoid any risk of increased gap opening due to heat distortion especially towards the end of longer weld seams, WISCO Lasertechnik has developed a very effective countermeasure. By specific temperature management in the already welded hot zone a closure of the butt gap in the area yet to be welded is induced. This technique supports the action of the inclined friction rolls driving the blank pair forward and towards each other. In a reversing feeding system a shuttle takes a batch of non-welded blanks that are clamped statically. Then the shuttle is passed through the welding machine. After unloading the welded blanks at the end of the welding pass, the shuttle is returning empty to the loading position. The return and refill periods define an additional unavoidable beam-off time so that the overall productivity is inferior to that of a continuous feed system. The continuous material feeding process offers the shortest possible handling time and thus represents the optimum solution. The machine availability is determined by planned and unplanned maintenance as well as by the changeover time from one production job to the next. Hence low maintenance and reduced changeover time are desired machine features. Maintenance is reduced by robust machine design building on the manufacturers experience. The changeover time is related to the material handling system. The continuous feeding system does not involve any part specific tooling that would need to be changed. The conveyor system taking care of the material flow adjusts itself to a new production job by a simple software command. Machines based on discontinuous feeding systems require a tooling change so that the setup time is usually in the order of 30 to 60 minutes. The impact of this setup time becomes the more severe the smaller the production batches are. Table 1 demonstrates the advantage of the continuous feeding system. Already the base cycle time per part is 30% shorter as compared to discontinuous feeding. Taking into account the changeover time and various batch sizes, the productivity of the continuous feeding line can be up to 40% higher.

1.2 Modular production concepts

The continuous welding line core module can be equipped with various handling facilities at the entry and exit of the line. The respective setup has influence on the investment cost and on the line productivity. The local conditions in a specific market may require an individual contemplation to find the optimum line configuration.

The simplest configuration is to load and unload the blanks by manual labor. This means at the entry of the core module two workers place blanks on the conveyor. At the exit of the line one or two workers, depending on the size, unload the welded blank from the conveyor. Naturally such a mode of operation is favorable in countries where labor cost is cheap. Also the flexibility of changing between different orders is high since no hardware or tooling changes are required. Hence, this condition is very suitable for developing markets where batch sizes are small and/or product variety is high. In markets where labor cost is higher and/or larger order volumes are to be produced, manual labor can be replaced by mechanized material handling such as 6-axis robots equipped with a suitable handling attachment or handling gantries in case of very high volume production. Other features like automatic blank dimpling to balance the stack height of the welded blanks and flip-over of welded blanks can be integrated as well in the exit section of the line. All features can be added ad hoc allowing the core concept to grow towards higher productivity as the market demand is developing.

2. Tailored Strip Production

For some manufacturing processes it is interesting to have the tailored product on coil rather than individual blanks. Tailored strip technology provides this possibility by downcoiling 2 or 3 individual slit coils and joining them along the strip edge to become a tailor welded coil (Fig.3). Such tailored steel coils are suitable for further processing in progressive dies or roll forming operations directly from the coil. The so-called Turbo-Conti principle was developed by WISCO Lasertechnik based on the experiences with the continuous welding system for tailored blank production described in §1.1. It allows exceptionally high welding speed of up to 20 m/min. Further developments are in progress at WISCO Lasertechnik with the goal to realize welding speeds of up to 50 m/min. This represents a considerable advantage in terms of productivity as compared to conventional tailored blank production. Furthermore, the costly die blanking process becomes obsolete. Thus tailored strip is economically viable in applications where conventional tailored blanks would be too expensive. A typical application making use of tailored strip is the exhaust line component shown in Fig.3. In this case ferritic stainless steel grades of different gages are joined. The optimized gage variation not only reduces the component weight but also considerably lowers the material cost. Tailored strip technology is applicable to profiles, rail and frame parts and for many other applications also outside the automotive industry.

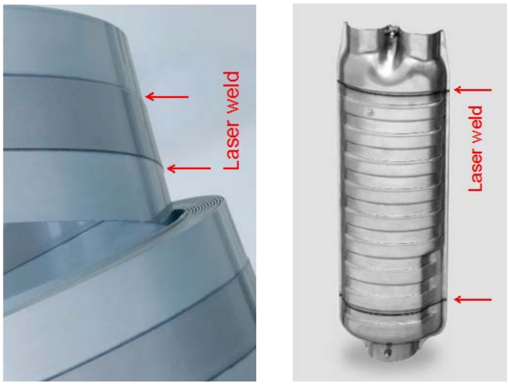

Fig.3 Coiled tailored strips and exhaust component produced from stainless tailored strip

3. Manufacturing of rotational-symmetric laser welded components

Until recently, rotational symmetric automobile components have usually been produced from initial materials such as tube, wire or bar. Tailored orbitals are composite semi-products being fabricated from combinations of materials of different thicknesses or grades, or with different coatings. These tailored products can generate added value, similar to tailor welded blanks in car body applications, thanks to features such as lower weight, improved function and a possible reduction in cost. The advantages are feasible even for highly dynamically stressed components. Further applications can be expected in the areas of chassis, engine, transmission, power train and steering system. The engineering steels used in these applications are much higher alloyed than steels for body components. Consequently, any optimization of material utilization using tailored orbitals technology has a comparably bigger cost saving effect.

Laser-welded components offer great functional potential in shock absorber construction (Fig.4). The low heat input into the welded components associated with this joining process facilitates the manufacture of parts that are fitted with thermally sensitive components such as electromagnets and shock-absorbing elastomers like piston rods for active shock absorbers. The requirements for this component, which is important for safety (wheel guidance in the McPherson front suspension), are a controlled production process and a low heat input so that an elastomer component fitted into the piston rod, as used in the Mercedes A- and B-Class, suffers no damage. These requirements for the A- and B-Class gave rise to various approaches. Welding was the optimal process from the viewpoint of process reliability. The next step was to carry out benchmarking of the various welding processes in close coordination with the end customer Mercedes-Benz. Various processes such as capacitor discharge welding, electron beam welding, MAG (Metal Active Gas) welding and plasmatron welding were available and were all put to the test. From the point of view of process reliability and heat input, capacitor discharge welding, MAG and plasmatron welding processes were rejected after the initial trials. Because the pilot project Mercedes-Benz A-/B-Class represents mass production of 1.4 million units/year, the process has to be attractive from the viewpoint of the cycle time and the cost of production over and above the requirements mentioned earlier. Laser welding was thus the process of choice. The development of laser-welded piston rods for the A- and B-Class was carried out in close collaboration with the end customer.

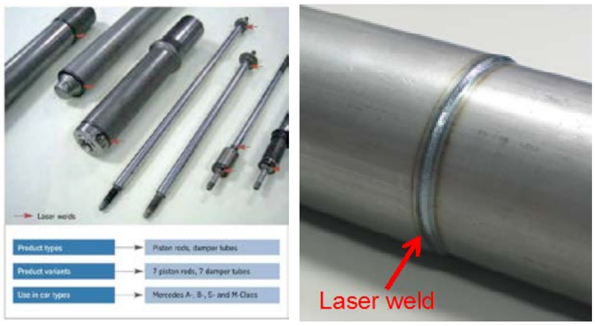

Fig.4 Tailored Orbitals for shock absorber components (left) and exhaust pipe (right)

The technology of orbital welding has recently been extended to manufacture stainless steel exhaust tubes. In this process, tube segments are place vertically on top of each other. The gravitational force by the weight of the tube segments is sufficient to allow orbital butt-welding. For that reason the process is called Gravrolas. Robots are handling the material feed. Laser welding is done using a fixed welding head with the tube assembly rotating along the head. The technology is used to combine different tube gages and stainless steel grades to a composite exhaust line, thus optimizing weight, properties and cost. Up to 5 tube segments can be joined in this machine. The very low heat input by laser welding limits the grain coarsening in ferritic stainless steel to a minimum, which is of advantage when the weld is subjected to a subsequent forming operation.

4. Conclusions

Laser welding is a key technology in the production of materials and semi-products for modern automobile construction. Tailor welded blanks are the most established products of that kind. WISCO Lasertechnik is the leading supplier and innovator of respective laser welding equipment offering custom made technology. The productivity of the continuous laser welding system is unsurpassed by any competing technology. The combination of laser cutting and welding using the same head offers additional flexibility and economical efficiency even for lower production volumes. Tailored strip production allows further reducing manufacturing cost due to its high welding speed and efficient handling. It hence creates weight reduction opportunities that were hitherto considered to be too costly. Orbital welding technology opens a whole range of new possibilities for the processing of engineering steel component and tubes enabling weight reduction and selective cost-optimized material use. Depending on the specific challenge WISCO Lasertechnik is ready to develop customer-made solutions for existing as well as new applications.