Flexible laser system technology for welding applications

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Abstract. Economic and ecologic trends led to significant changes in the construction of assemblies. There was an increasing interest in production-ready design, manufacturing in light-weight design while combining different materials and avoiding rework. The complexity of assemblies increasing, more single pieces had to be joined with a higher number of weld seams. To respond to rising demands of precision, welding the whole assembly in one single clamping became necessary. As weld seams are scattered all-over the construction, designing the clamping system to make all welding positions accessible is a challenge to the engineers. Ten years ago, simple robot cells (ERLASER® WELD ROBOT) using common welding optics were sufficient. Only through further development of system technology the permanently increasing quantities and demands for quality could be mastered. Primary processing times were significantly reduced when the laser scanner was introduced into welding applications, because of the fast positioning times of the laser beam. Various systems of the ERLASER® WELD SCAN were built. ERLAS is now presenting a future-oriented, modular system technology – ERLASER® UNIVERSAL – using a newly-developed scanner which is fully integrated into one system control, being flexible concerning production of different work pieces as well as using different technologies.

1. ERLAS Erlanger Lasertechnik GmbH – The company’s history
In 1987, the Bavarian Ministry of Economics established an application lab for laser technology at the University of Erlangen-Nuremberg. The purpose of this newly-founded institution was to transfer the comprehensive know-how acquired on laser-assisted manufacturing technologies, such as laser beam cutting, welding and hardening to industrial production. Under the direction of Dr. Peter Hoffmann it was transformed into a non-profit research institute, the BLZ Bayerisches Laserzentrum gGmbH in 1992. He was its managing director until 1998. Eventually these process and system technologies, which have been refined with a focus on technical and economic benefits, formed the basis for the foundation of a profit-oriented company in 1998, the ERLAS – Erlanger Lasertechnik GmbH.

This German company currently employs more than 100 employees and has an annual turnover of about 15 million Euros. ERLAS develops laser technologies, builds laser systems and produces series parts in two own facilities, at its headquarters in Erlangen, Germany and in Amurrio, Spain. Today, 20 years after its foundation, ERLAS has made a name for itself on the world-market with numerous projects especially by developing machines for suppliers of well-known automobile manufacturers. The company is proud of its unique history which brought along ever-new challenges enabling the firm to gain various experience in the world of laser technology. Therefore, ERLAS is now capable of predicting future tendencies of laser system technology for welding applications.
2. Motivation for new designs and trends for manufacturing of assemblies

Today, for economic and ecological reasons, there is a high motivation of keeping the amount of material used and the processing steps for manufacturing of a welding assembly at a minimum.

Companies in our field of work are striving towards producing assemblies in light-weight design, possibly sheet metal constructions with combined materials (e.g. sintered components, formed parts and sheet metal parts) which are adapted to machinability and functionality. Production should be rework-free to save manufacturing costs. Considering all these ideas, new designs of assemblies are inevitable. For assemblies, the following tendencies can be observed: increasing amount of single parts, increasing number of weld seams and weld seams can be found all-over the construction, which means a challenge to the construction of the clamping system concerning the accessibility of the welding position. In addition to that, manufacturing must be more and more precise because of decreasing tolerances of the whole assembly group.

3. Development of laser system technology for welding applications

In order to meet very high tolerance requirements, the welding process should be done in one single clamping. Therefore, the machine needs considerable degrees of freedom. A simple laser welding cell is built as follows: A standard industry robot acting as guiding machine for the laser working head will be placed on a massive base plate inside a laser safety cabin. A clamping system which can orientate
the clamped workpiece via rotating axes towards a simultaneously guided working head is placed on each side of a partition wall on a turn table.

These hybrid kinematics of the robot guided processing optics towards the turning workpiece guarantee the necessary degrees of freedom for machining in one single clamping and therefore the accessibility of the required production tolerances. During welding inside of the safety cabin, the worker removes a welded part of the outside clamping and feeds it with single parts for the next welding. The cycle time for manufacturing a shift fork (see figure 2) with this type of machine, called the ERLASER® WELD ROBOT is approximately 25 s, including turning of the table which is less than two seconds. The assembly group shift fork is produced in four variants. The current need of 6.4 million pieces per year is realized on seven machines altogether.

Figure 3. Laser welding cell ERLASER® WELD ROBOT

Since robot guided welding processes with common welding optics (e.g. Trumpf BEO D70) are comparably slow, it is no longer possible to respond adequately to the ever-increasing quantities of assemblies needed, especially in the automotive sector. Due to the significantly improved beam quality of fibre-guided laser beam sources, the laser scanner could be introduced for welding applications. Via the mirror axes in the scanner, the laser beam can be positioned and applied significantly faster. It is state of the art to mount laser scanners onto standard industrial robots to realize high numbers of work pieces. However, the disadvantages of this application are obvious. For larger work pieces, welding of seams outside of the relatively small work range of the scanner is only possible with new positioning of the scanner or by welding-on-the-fly. Programming of such processes is rather time-consuming, there are separate controls for scanner and robot. Considering that the axes of the scanner do not have any spatial reference, the scanner welding programmes can only be triggered by positioning of the robot. This is the reason why accessible accuracies hugely depend on the guiding behaviour of the robot. Butt and fillet welds are the preferred weld seams in laser compatible design. In a robot-scanner combination, these seams are difficultly or not at all realisable, therefore, there is a need for additional seam tracking devices.
For boosting the effectivity of welding with laser scanners, ERLAS started to develop kinematics which make positioning times caused by robots almost disappear. The laser scanner is mounted in a stationary position and the clamped workpiece is quickly orientated in the work range of the laser scanner towards the laser beam being the tool. This type of machine is called ERLASER® WELD SCAN and has proven effective in the practical field.
Welding in two steps
- Step 1: four single parts, 18 weld seams, welding time: 20 s
- Intermediate step: Mechanical machining (outside of plant)
- Step 2: four further single parts, eight further weld seams, welding time: 9 s
- Total cycle time: 54.5 s

The automobile manufacturers increasingly introduced modular construction systems to save weight and costs and enhance productivity at the assembly lines. They are targeting an increase in the number of identical parts of the entire vehicle fleet taking into account the equipment of different classes and types. Therefore, as many assemblies as possible are constructed and manufactured identically. The steering column bracket is one of these identical assemblies. There are four variants.
Figure 7. Steering column bracket – exploded view, welded and mounted assembly

The assembly group *steering column bracket* consists of eight metal parts, five plastic parts und is joined by 26 weld seams. The annual need is 9 million pieces! The accomplishment of this welding task is neither economic nor practical with the previously presented system technology. Roughly 50 ERLASER® WELD ROBOT systems would be needed to respond to the task. Secondary processing times, mainly caused by manual feeding, would be much too long in relation to the welding process (primary processing time).

Novel machine concept for high-speed remote laser welding

As a solution to the welding task *steering column bracket*, the following concept has proven effective: Laser welding of all parts is made in one single clamping. Feeding of parts happens simultaneously in several so-called *mobile workpiece carriers*. Additional rotary and tilting axes serve to reach each of these welding positions unimpededly [1, 2].

Figure 9 (top). Mobile workpiece carrier

Figure 8 (left). Illustration of possible degrees of freedom by additionally available axes
Using this concept, the welding time for 26 weld seams is minimized to 7.5 s. It is necessary to adjust the secondary processing times, especially the feeding of the workpiece carriers, to the duration of the welding process to maintain a constant flow of the production. For reaching a total cycle time of 9.5 s, the ERLASER® WELD SCAN AUTOMATION runs a circulation system with ten mobile workpiece carriers. These workpiece carriers are fed automatically. There are two neighbouring welding cells, where welding takes place in time intervals. There is one laser for two welding cells. While feeding the welding cell with a mobile workpiece carrier containing the single parts, the workpiece carrier with the welded assembly is simultaneously removed from the laser welding cell by means of a double gripper technology.
In the meantime, ERLAS has realized several plants for the Asian market which are also used to produce steering column brackets, the crucial distinction to the systems destined for European automotive suppliers lies in the way of feeding: the Asian plants are fed manually.

An industry robot removes a completely fed mobile workpiece carrier from the assembly station, which is taken to the welding cell, and, at the same time, delivers a workpiece carrier with a welded assembly from the welding cell. The worker removes the finished assembly, puts it onto a conveyor belt and feeds the mobile workpiece carrier with single parts for the next welding process.

- Considerable lower production costs and therefore lower selling price
- Flexible in application
- Different types of welding assemblies (e.g. shift fork/gear shift controller) producible simultaneously
- Cycle time depending on product (steering column bracket: 15 s)
- Productivity depending on number of workers

Despite the impressive productivity of this type of laser welding plant, there are still limitations in application. These are due to the separated controls of system technology (motion control) and laser scanner (scanner control). Although being quick as a lightening, the laser can only be put in operation after the motion control has positioned the workpiece in the working range of the scanner via numerous axes and has given the release for the next welding process via a superordinate control. In short: fast positioning - welding - fast positioning - welding and so on.

The next generation

The Erlangen experts have developed a revolutionary type of machine called ERLASER® UNIVERSAL [3]. This machine enables the application of different technologies as well as various ways of feeding. The components to be processed can be fed via a turntable (Figure 13). Due to the gantry system, an integration of the plant into production lines is also possible. Theoretically, the system is infinitely expandable.
A stiff Cartesian XYZ portal moves a scanner and a telescope, two additional rotation axes can tilt and rotate the clamped workpiece. The scanner mirrors are hereby moved by NC-drives. By means of complex mathematical models (reverse transformation), all axes of scanner and gantry are fully integrated into one common numerical control. The plant therefore disposes of eight numerical axes which can be combined alternately for an interpolation of up to five axes within the CNC high-performance control. The NC-controlled telescope is a further specialty of the ERLASER® UNIVERSAL. Additionally, a highly dynamic linear motor can adjust the focal position within a range of 150 millimetres. For the first time, a “real time welding on-the-fly” is possible. The system is destined for fibre guided lasers up to 4 kW laser power.

**Figure 15. ERLASER® UNIVERSAL – Programmable axes**
• Hybrid kinematics
• Fast orientation of workpiece by rotating and tilting axes
• Cartesian guiding machine for scanner movement
• Novel 3D scanner: - no f-theta optics, adaptive telescope integrated in sleeve of z-axis,
  - servo drives
• Common numerical control for scanner and gantry
• Easily programmable

4. Conclusion
There is a tendency of welding tasks getting more complex, which necessitates new machine concepts. Since welding with the laser scanner remarkably reduces primary processing times, new concepts for feeding with single parts and the removal of finished assemblies are needed. Due to shortened product lifecycles, system technology should be flexible for the manufacturing of different products. This should be achievable with low effort e.g. by changing a clamping device and changing and simple reprogramming. Therefore, future-oriented laser system technology for welding applications is characterized by user-friendliness as well as by flexibility in possible applications for other technologies and products.
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