MODERN PRODUCTION TECHNOLOGIES
FROM THE FRAUNHOFER IWS
LASER INTEGRATION IN PRODUCTION ENGINEERING

Flexibility is high on the wish list for the industrial application of modern laser technology. Laser technology is often the method of choice to optimize existing machine design and automated processes; it also leads to completely new applications. It is suitable for shorter, small batch manufacturing processes, where maximum adaptability is the goal, as well as for mass production, where costs optimization is a primary concern.

Laser hardening - integration in manufacturing allows for lean processes

An example of customized solutions is the hardening of machine or vehicle components made of steel or cast iron, a standard procedure, which increases the wear resistance and the strength of parts. In the conventional process, the components are hardened in an oven or with vacuum plasma equipment. If the entirety of the component is not to be hardened however, local hardening can be achieved with flame, induction, and (since very recently) lasers. That in the past ten years the laser hardening of locally stressed components has established itself, is attributable to the significant contribution of the IWS Dresden. The mold and tool manufacturing industry as well as the automotive industry have begun to increasingly rely on this technology.
Technology developments for the effective surface hardening of rotationally symmetrical parts

The more complex a component is, the more difficult it becomes to use conventional hardening methods. Components with rotationally symmetrical or other complicated shapes require procedures and beam forming units, which can harden them in a consistent and tempering-free manner. In addition to technical advantages, automotive and other industries expect a noticeable reduction in costs. A number of industrial applications demonstrate how the developments of the Fraunhofer IWS meet the diverse needs of manufacturers:

Example 1: Systems for the surface hardening of the turbocharger shaft for commercial vehicles

The temperature-controlled lasertronic® LompocPro (“LompocPro”), developed by the Fraunhofer IWS is employed at three plants of BorgWarner Turbo Systems GmbH in Kirchheimbolanden, Germany. There, the laser was integrated into a manufacturing cell where the turbocharger shafts are partially hardened at their bearing points. The systems are used in three phases with a cycle time of around 60 seconds.

Example 2: Hardening process integrated in lathes

In 2008, the Fraunhofer IWS, in cooperation with the lathe manufacturer Benzinger, delivered several lathes with integrated high-performance diode lasers to Bosch Rexroth AG in Lohr/Main for the production of hydraulic components. The cycle times of only three or four seconds speak for themselves, especially when compared to 75 seconds in the previously used mechanical process. In Lohr, a fiber-coupled high power diode laser operates three systems sequentially. Because the machine is a two-lathe system, work on the main lathe occurs almost constantly during the entire laser process.

The flow of material from raw rod material to completed valve was reduced from 20 hours to 20 minutes.
Example 3: Local Hardening of spherical caps for commercial vehicles

The IWS scientists developed a special flexible optics using a rotating mirror system with integrated temperature control for strongly curved, rotationally symmetrical convex or even concave component surfaces. An example of the industrial use of the IWS rotating mirror optics is the local hardening of the spherical cap components of chassis technology. The optimal laser process time is in the range of seconds, thus the process is suitable for mass production. “LompocPro” is used for process control. Temperature measurement is carried out with the “E-MAqS” camera system, developed by the IWS. The system generates significant savings in time, logistics, and costs.

Example 4: Process development for hardening systems for use in diesel-injectors

Collaboration between the SITEC Company and the Fraunhofer IWS found a solution for the hardening of diesel injectors. This involves the hardening of a highly precise rotationally symmetrical component (the wall of difficult-to-access hollow). The component must meet specific requirements after hardening because post processing is not possible. Due to this fact, lasers are used. Due to the precise spatial and temporal controls of the heat input, it is possible to process installation-ready parts. A 1kW diode laser from Rofin Sinar is used. Thanks to its compact size, this laser is fully integrated into the equipment. With the temperature-controlled power control LompocPro, quality control over the entire system is achieved. The use of a diode laser makes sense for both technical and economic reasons: Low initial costs, moderate operating costs, and a wavelength that is particularly suitable for surface finishing.

Through the use of this technology, five laser hardening systems have hardened 50 million components since the beginning of production in 2004.

1 Laser hardened turbocharger shaft
2 Lathe with integrated laser optics at Benzinger factory
3 Hardening system for the hardening of diesel injectors, manufactured by SITEC, with 1 kW diode lasers by Rofin Sinar and “LompocPro” of the Fraunhofer IWS
Process and system development for hardening and cladding in tool manufacturing

The most popular application of high-power diode laser for surface hardening is in large tool manufacturing. The laser allows the partial hardening of finished tools without the delay of reworking. It is therefore ready to use immediately after hardening. Numerous contractors, as well as the tool construction departments of car manufacturers, use this procedure. In connection with the project “Integrierte Härterei”, funded by the BMBF, a portal system was installed for demonstration purposes at BMW Fahrzeugtechnik GmbH in Eisenach. Later the production plant was optimized and has been in use ever since. Here, for the first time, a camera-based temperature monitoring system and a dynamic beam shaping for high-power diode lasers with a scanning mirror were used.

On behalf of ALOtec Dresden GmbH, the Fraunhofer IWS from 2004 to 2009 implemented robot-based systems for hardening and surfacing to Härterei Gerster AG in Egerkingen (Switzerland), C. F. Monsano (Italy), EMO in Celjie (Slovenia), STAV in Barberino (Italy) and an Indian Research Institute. The machines were equipped with system components for quality assurance of the temperature-controlled hardening, laser welding processes. The contractors, as well as the ALOtec Company itself use the facilities for the hardening of tools or manufacture tools as their core business.

Example: Tool making at Audi AG

In 2010 a robotic laser system for cutting and forming tools began production at Audi AG in Ingolstadt. This system was created in collaboration with the Fraunhofer IWS Dresden and KUKA Roboter GmbH. This system for the laser hardening and buildup welding is aimed at the repair and new manufacture of auto body tools. The Fraunhofer IWS supplied special system components for beam shaping, process control, and powder feed, as well as modules for the installation on the robot arm. In addition, the IWS delivered process parameters for different applications and coordinated the start-up of the process control systems. Following the success a plant with similar functionality was completed at the Volkswagen AG Wolfsburg site in 2012.
SYSTEM COMPONENTS FOR FLEXIBLE AND STABLE MANUFACTURING PROCESSES
COMPLICATED LASER PROCESSES
EASILY MONITORED AND CONTROLLED

It is well known that the Fraunhofer IWS is significantly involved in the development and distribution of laser hardening and buildup welding processes for industrial application; yet in addition that the IWS has developed the corresponding special systems. Thus, the most complex processes can be easily monitored, controlled or regulated and adapted to the requirements of each application. The components are constantly optimized and tailored to new customer requirements. With the IWS measuring and control systems, the users have the tools at hand to ensure the highest precision and modularity.

Dynamic beam shaping system “LASSY”

In order to harden different component geometries and still allow them to remain flexible, the Fraunhofer IWS Dresden has developed the dynamic beam shaping system “LASSY“ for industrial applications of high-performance diode lasers. This enables, for example, the creation of a uniform hardening depth despite locally different component thickness. The system is used with laser surface treatment processes such as laser hardening, melting and alloying.
Variable software control system lasertronic® “LompocPro”

The variable software control “LompocPro” (laser online monitoring power control program) forms the basis of the IWS measuring and control systems. Depending on the case, different temperature monitoring systems can be connected, allowing “LompocPro” to control temperature for a number of laser procedures, such as laser hardening, laser soldering, laser annealing and laser cladding. The Fraunhofer IWS control software is especially suitable for fast processes.

Easy operation and automation of complex heat treatment processes is ensured, inter alia by the following parameters:
- flexibility due to individual adjustment of control behavior
- graphical representation of all process data during the process,
- permanent backup of all parameters,
- »Profibus« communication to CNC
- user-defined interfaces to temperature measuring devices.

The first application was the system in ALOtec Dresden GmbH heat treatment plant in 1999. Since then “LompocPro” has been continuously developed and has been used in the process control, process monitoring, process data backup, and quality documentation of more than 80 chiefly industrial applications.

0 Operating status of a laser cladding system with integrated process control “LompocPro”
1 Laser hardening process on the head of a main drive spindle
2 Laser hardening of a steam turbine blade with dynamic beam forming unit “LASSY”
3 Heat vision picture of a hardening process
“LasMon” - analysis of shaped laser beams

The measuring system for beam analysis for large laser spots “LasMon” is the quality control of laser sources and laser optics. Traditional beam diagnostic devices are either not able to measure several square-millimeter-wide laser spots or incapable to do this with high power in the range of kW. With this device, it is possible to analyze scanned or otherwise shaped laser beams with a power up to 10 kW. Thus, a reliable process management and constant control of the laser is possible before or during the process. In addition to the analysis of laser sources and optics, “LasMon” can be used as an alignment aid for scanner drives and other beam formations to optimize the power density distribution of laser beams, as well as to determine the baseline for the simulation of heat conduction or laser processes.

Temperature measuring system “E-MAqS”

“E-MAqS” is a camera-based temperature measuring system used for demanding measurement applications. The IWS scientists developed it as a space, time, and money saving alternative to conventional thermal imaging systems. The “E-MAqS“ system is usually used in combination with the temperature control system LompocPro. Laser hardening is its chief application; however, “E-MAqS“ is also used for industrial laser welding. Since the signal and image analysis can be easily adapted to customer requirements, other applications for temperatures above 600 °C, such as heat conduction welding or soldering, are possible.
Fast temperature measurement with “E-FAQS”

The modular system of the Fraunhofer IWS offers the fast pyrometer for high speed processes “E-FAQS”. This device is able to record temperatures from about 160°C with sampling times of less than 30 µs. “E-MAqS” has been primarily used in laser hardening and cladding. The much faster “E-FAQS” system is more often used in industrial plants for laser soldering processes. “E-FAQS” is also suited to laser annealing and plastics welding. The entire measuring and control system is compact and suitable for industrial use in the machine body.

Example: laser soldering of solar cells

In close cooperation with the company teamtechnik Maschinen und Anlagen GmbH in Freiberg am Neckar, the Fraunhofer IWS has shown that the “E-FAQS” is suitable for the laser soldering of solar cells. Since 2008 it has been used in industrial mass production. A special feature of the laser solder machines of teamtechnik is that both standard as well back-side contact solar cells can be soldered. Also short cycle times of three or four seconds per cell are possible. The systems are modularly designed so that different solder processes and modules for solar cell processing can be integrated. This is important, as the dynamic developments in photovoltaics through new semiconductor materials or new layer structures require quick response capabilities from the equipment.

Through the process development of the Fraunhofer IWS a total of 30 “E-FAQS” systems were installed in 10 plants from 2007-2012. Worldwide more than 170 of the Fraunhofer IWS system components for process monitoring, process control, and quality control were successfully used in industrial plants.

1 Camera based temperature monitoring system “E-MAqS”
2 Fast measurement and control system “E-FAQS”
3 Laser soldering system of teamtechnik Maschinen und Anlagen GmbH in Freiberg a. N.