Laser material processing at Bosch: trends, challenges and perspectives

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Outline

» Application review
  • Laser in the Bosch production
  • Successfully implemented applications

» Trends in focus topics
  • Laser welding & joining
  • Laser micro processing

» Challenges & Perspective

» Summary
Lasers have been used successfully at Bosch for more than 35 years.
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Lasers in current Bosch applications

Laser for metal welding applications
- Number of lasers increased by a factor of 15 between 1996 and 2011
- CAGR over the last 15 years ~20%
- More than 90% of all welds are carried out with solid state lasers with an average power $P_{av} < 1$ kW

Laser for micro processing applications
- Number of lasers (only picosecond-pulse duration) increased by a factor of 4 between 2009 and 2012
- CACR expected for next years ~ 40%
- Strongest growing laser field

CAGR = compound annual growth rate  $P_{av} = $ average laser power
Laser welding in typical Bosch products

- Direct gasoline pressure pump: 7 laser welds
- Direct gasoline piezo injection valve: 19 laser welds
- Direct gasoline injection valve: 7 laser welds
- Intake-manifold injection valve: 6 laser welds
- Transmission control unit: more than 50 laser welds
- ABS8/ESP8: more than 39 laser welds
Laser micro processing in typical Bosch products

- Broad band lambda Probe
- Diesel injector 1800 bar
- Direct gasoline injection valve
- Trimming structures
- Drainage groove
- Spray holes
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Global trends

Trends in products

- Volatility of markets
  - Dynamics in variants
  - Dynamics in demands
  - Dynamics in product live cycle
- Function increase
  - Miniaturization
  - Lightweight
- Digital product development

Trends in production

- Flexible production
  - Modularization concepts
  - Individualization at end of process chain
  - Scalable production
- Material & precision
  - Multi-material mix
  - Functionalized materials
  - Precision requirements
- Simulation Tools
The IIW White Paper – R&D needs

Basic research should provide the means to resolve key issues of welding science by transforming the welding and joining technology from “empirical-based” to “physical-based” process to cover the entire life-cycle of the welded product. This requires parallel knowledge building in the physical, chemical, materials sciences, mechanical and mechanics areas to tackle challenges of welding science.

A creation of a knowledge-based “virtual factory” requires better understanding of the relationships between “3Ps”, Process-Property-Performance of welded products and modelling of these stages as an integral system. To achieve that goal, it is essential to ensure that welding process and welding mechanics specialists are included in product/project design teams and that welding, and joining as well as service performance aspects of products fully integrate themselves with processes of fabrication excellence. Therefore, one of the major scientific challenges is to integrate welding & joining processes with the knowledge of welding mechanics into the design process to ensure high performance welded structures.

Complex and ever increasing requirements of welded products include energy saving both in material use and fabrication while providing long and safe service life with almost no inspection and repair. This situation will require to use significantly more dissimilar materials (in combination with a multi-material design approach) to make innovative products. Breakthroughs in the technology for joining dissimilar materials could lead to new manufacturing strategies that could reduce costs, improve productivity, and open up new markets for welded structures and components.
The mechanisation and automation of joining processes will still have a high development potential and still be required in order to maintain production in high-wage countries too.

With the increasing demand for sustainability and for the conservation of energy and resources, joining technology will become ever more significant as a manufacturing process.

Particular significance will continue to be attached to the qualification of the required personnel and to the international standardisation in all the fields of joining and welding technology.

Joining technology must be directly geared to product development, utilisation and exploitation and must therefore be developed and applied in an optimised way for materials, structures and processes. In this respect, robust joining technology processes must be made available and usable all over the world. In order to attain these objectives, research, technology and education in joining technology must be interlinked consistently on the national and international levels.
Trends: laser micro processing

Production System

Customer individualization at end of process chain by **flexible ablative laser processes** in finishing process

**Customer individualization in process chain by joined modular components**

CPE: Cyber Physical Engineering // CPS: Cyber Physical System
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Challenges in welding & joining

Push factors:
- Miniaturisation
- Higher local loads
- Function integration
- Lightweight
- Power electronics
- E-mobility
- E-drive efficiency

Materials:
- High strength steels
- Fiber reinforced plastics
- Aluminium (Al)
- Copper (Cu)
- Magnetic materials

Combinations:
- High strength steels
- Composites (GFR*) - steel
- Composites (GFR*) - Al
- Al - Steel
- Al - Al
- Al - Cu
- Cu - Cu
- Electrical sheets

Structure Simulation
Enabler for fast development

* GFR: Glass fiber reinforced plastics
Challenges in laser micro processing

Average power of ultra short pulsed laser systems

[Nolte et. al.; “Faserlaserkonzepte für UKP-Strahlquellen” ; UKP-Workshop (2011)]

Strong increase of laser power (by a factor 10 in 5 years)

Productivity increase lower than increase of laser power

Main Limitations:
- system technology (e.g. scanner speed for pulse repetition rates)
- thermal load on workpiece

Target: Productivity increase by factor 50
Photonics 21 - WG2

Main development needs

1) **Reduction of invest costs** - Laser systems & optical system technology (scanner, heads, security equipment, ....)

2) **Simulation tools** - Structure simulation (FEM) & material (synthetic material data) & process (usable tools based on standard solver)

3) **Quality assurance** - monitored processes → close-loop controlled processes
   - “Intelligent optics” for close-loop control (or measurement) of
     - Focus position related to workpiece (including thermal shift; ~ 0,5 zR)
     - Power at workpiece (including debris on protective glass; ± 3% RMS)
     - Intensity distribution at workpiece (differences > 10%)

4) **Productivity & usability in laser micro processing** - scanner / beam steering technologies & ultra short pulsed laser systems > 300 W – transport fibers

5) **Increase of wall-plug-efficiency** - especially for brilliant lasers (BBP ≤ 4 mm·mrad)
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Laser material processing will be a „hot topic“ in the future

Invest costs of laser equipment is the highest barrier (and in most cases showstopper for laser processes)

Simulation tools (structure, material, process) are necessary for shorten time to market and enabling full potential of laser processes

Pictures: wikipedia.org; Erwin Wodicka - wodicka@aon.at
Thank you 
for your attention

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