Following the Megatrends in Painting Technology

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SCANDINAVIAN COATING 2015
May, 20th
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- Mass personalization
  - Industry 4.0
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Systematic Approach

Integrated value added chain in coating technology at Fraunhofer IPA

- Lackrohstoffe
- Lack
- Lackiertechnik
- Beschichtung

- Bindemittel
- Pigmente
- Füllstoffe
- Additive
- Verdünner

- Rezeptur
- Dispergierung
- Rheologie
- Farbgebung

- Vorbehandlung
- Applikation
- Trocknung, Aushärtung
- Anlagenplanung
- Simulation

- Haftung
- Korrosionsschutz
- Beständigkeit
- Prüftechnik
- Optik
- Funktionalität

RESSOURCENEFFIZIENZ
Ultraefficient factory

- Effectivity x Efficiency = Ultraefficiency

Value Creation

- Material recycling
- Factory recycling
- Energy recycling

Dispositive factors / IT

- New recycling processes
- Product
- Usage

Material

Energy

Staff

Funds

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Energy transition in Germany

- Can growth be decoupled from resource consumption?
  - Usage of alternative sources
  - Decentralization of energy generation (Smart Grids)
  - Massive increase of energy efficiency

Bildquelle: BMWi (2011)
Coating is most energy consuming process in car body production

Paint booths are the biggest consumer (conditioning of cabin air)
Dry scrubbing simplifies air recirculation and thereby big energy savings for humidifying and heating.

- Scrubbing with limestone
  
  Source: Dürr Systems

- Electrostatic scrubbing
  
  Source: Eisenmann

- Separation by inertia
  
  Source: Dürr Systems
Energy efficiency by reduction of process temperature

Consider the process chain:

- Bake hardening of (aluminum) substrate
- Curing of adhesions
- Seam Sealing
- Pretreatment
- E-coat
- Primer / topcoat

⇒ Savings of 11% (using UV curing even 16%) possible

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Greenfield and Brownfield measures following the „energy on demand“ strategy

- Energy efficient cleaning of exhaust air
- Skid-free car body transport
- Controlled drying curve
Closed loops instead of downcycling

- Substitution
  ➔ Renewable

- Value creation in closed loops
  ➔ Technological
  ➔ Ecological

- Holistic design for the product life cycle
  ➔ Planning of usage cascades
  ➔ Extension of the usage phase

- Zero waste production
  ➔ 100 % of material to the product
  ➔ Short, hybrid process chains

1 Bildquelle: www.rittweger-team.de/
Resource efficiency – overspray free painting

- Atomizing generates broad droplet size distributions with turbulent air flow
- Generation of precise droplet sizes without air avoids overspray
Resource efficiency – overspray free painting

- Prototype in IPA lab
- Examples:
  - Pattern on hood
  - Images on plastic parts
Resource efficiency – overspray free painting
Resource efficiency – overspray free painting

- High viscous material for electric structures
- Project to develop new orthosis for rehabilitation after stroke

Source MOBILAB
Total energy efficiency management - transparency used to optimize energy consumption

- Systematic investigation of energy savings on production
  - Achieving and monitoring of Energy data
  - Design of energy value chains
  - Evaluation of measures simultaneous to running production

- Energy management systems
  - Energy monitoring in the painting process
Transition of „energy guide for painters“ and TEEM into an electronic tool (App)

- Specific to the user and his facility
- Fast and efficient finding of energy savings
- No deep process know how necessary
- Showing energy relevant processes and their parameters
- Determination of characteristic numbers to save energy
According to Yoram Koren: The Global Manufacturing Revolution; Bildquellen: Ford, beetleworld.net, bmw.de, dw.de
Industry 4.0 – industrial revolution reloaded?

1. Ind. Revolution (~1750)
- Machines enable industrialization and prevents hunger

2. Ind. Revolution (~1870)
- Wealth by mass production by electrical energy

3. Ind. Revolution (~1960)
- Electronics and IT enable automated efficiency and mass production of many variants

- Cyber-physical systems link with the internet of services and the human beings enables decoupling of growth and wastage
  - Shortage of resources and global competition
  - Cyber-physical product life cycle systems
  - Will "Post Carbon Society" come?

Sources: hannovermesse.de; ingenieur.de; blog.im-c.de
Industry 4.0

- **Sensors („transparent facility“)**
  Real time acquisition of process and quality data

- **IT („intelligent facility“)**
  Automated interpretation of data (incorporating complex interaction of process and material)

- **Connected processes and facilities („Decentralization“)**
  Connection of products, processes and customers with the goal of self organization

- **Automatic reactions („Smart Factory“)**
  Closing of control loops and automated reactions of customer demands and environment
Industry 4.0 – Expectations

- Flexibility and versatility
- Fine modularization and autonomy
- High productivity
- New business models
Industry 4.0 - Example: Robotic in logistics

- Mobil helper for „low Cost Jobs“
  - Mobile robot refills workplaces
  - Mobile robot moves through storage

Mobile manipulator (omnidirektional)

Loading space

onRobot

Gripper

3D recording of environment

Application without fences
I 4.0 in painting – Challenges

- Today's painting concepts
  - Central facilities
  - No flexibility
  - Long process times
  - Processes without value adding:
    - Time (e.g. Waiting and handling)
    - Equipment (e.g. transport)
    - Space (e.g. storage)
  - Open questions regarding tracing parts
Lot size 1: Automated Paint program generation

- High Diversity up to personalization
14.0 in Painting technology – modular product and painting concept

- Efficient painting concept for a modular multi-material car of the future

<table>
<thead>
<tr>
<th>Einsparpotenziale</th>
<th>Cost per Unit</th>
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<tbody>
<tr>
<td>Primärenergiereduzierung</td>
<td>231 kWh pro Karosserie</td>
</tr>
<tr>
<td>Cost per Unit</td>
<td>Reduktion um ca. 7 %</td>
</tr>
<tr>
<td>Primärenergiereduzierung bei Einsatz von UV-Technologie</td>
<td>315 kWh pro Karosserie</td>
</tr>
</tbody>
</table>

Decomposition of the car body to modules

Source: AUDI

Conzept layout

Source: Audi, Daimler, Dürr, Wörwag, IPA
4.0 in Painting technology – modular product and painting concept

Fraunhofer IPA

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I 4.0 in Painting technology – Numerical simulation as „missing Link“ between real world and cyber-physical system

- For complex processes the virtual and the real world can be connected by physical process models

- Automated generation of painting processes by simulations

Bildquelle: Dürr
New aspects in numerical simulations – Example atomization by water steam

- Calculation of gas velocity

- High Velocities in the area of atomization → improvement of atomization
- On substrate low air (resp. steam) velocity → low back pressure
New aspects in numerical simulations – Example droplet impingement

- Investigation of air bubbles
- Alignment of effect pigments
New aspects in numerical simulations – Example orange peel

Numerical description of the central influences for formation of paint film surface structures:

- Structure formation by superposition of paint droplets
- Leveling caused by surface tension driven flow
- Influence of gravity (horizontal/vertical)
- Flow-induced mapping of wavy substrate structures
- Structure formation due to film shrinkage
Summary

- Megatrends influence painting technology
  - Mass sustainability
  - Mass personalization

- Some examples:
  - Real time data acquisition (process and quality)
  - Energy monitoring
  - Numerical simulations on physical models
  - Self learning systems
  - Integration of painting into the production
  - Cross-Energy-Management
  - Smart usage e.g. simplified robot programming