Industrial Inkjet for Coating and Decoration of Automotive Surfaces

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Director – Advanced R&D
Disclaimer

Global Inkjet Systems supplies inkjet technology and components to 130+ original equipment manufacturers world-wide. As a matter of policy, we do not disclose our customer relationships.

The following slides contain images chosen to illustrate the range of inkjet print systems which are available in the market. The presence, or absence, of any manufacturer’s products in these images does not in any way imply a commercial relationship between that manufacturer and GIS.
Agenda

• Brief Introduction to Global Inkjet Systems (GIS)

• Industrial Inkjet
  • Busting the myths!
  • What inkjet can really achieve in production environments

• Challenges of Automotive Surfaces

• Printing or Coating Complex Curved Surfaces
  • Like a dashboard or a wing mirror...or even a complete car?
Global Inkjet Systems Ltd

• **Leading independent developer of inkjet technology**
  • Supply inkjet capability to OEM system builders, specialist integrators and end users
  • Support a broad range of inkjet printheads in wide range of applications and industries

• **Based in Cambridge, UK**
  • 12 years of growth & technology innovation
  • 70 employees
  • 130+ customers world-wide
  • Support offices in UK, Japan and China
Inkjet Technology

- **Industrial inkjet printheads**
  - Dominant technology: Drop on demand
  - Drop sizes: 2 – 200 picoLitres
  - Firing rates: 10 – 220kHz
  - Highly integrated: 100s – 1000s of nozzles per head
  - Printheads and variants for many applications
Inkjet Strengths

- Non contact
- Additive process
- Subtractive process
- Broad fluid capability
  - UV curable inks, resists & adhesives
  - Conductive fluids
  - Jettable polymers & dielectrics
  - Jettable active & passive electronics
  - Acid resist
- Precise drop formation
  - Small drops for small features
  - Large drops for coatings/area fill

- Precise drop location
- Conserves expensive materials
- Reduces cost
- High drop production rate capability
- Long printhead life
  - Heavy duty cycle capability
- Proven reliability in production environments
- Inkjet as a partial or complete solution
- Integrated into standalone & hybrid manufacturing systems
- Highly integrated, modular technology
GIS provides key technology to industrial inkjet systems builders, specialist integrators and large end users.

From pixels to droplets: we supply technology for the whole data pipeline – from image to print.
Inkjet in Production

Not this ...

Image source: HP
Inkjet in Production – Big Presses

Image source: Inca Digital, HP, KBA, KHS
Inkjet – Think Graphics – and Beyond Graphics

Direct Functional Printing

Direct printing

Pre processing
(Sample preparation)

Print Process
(Ink / printhead / surface interaction)

Result
(Finished product)

2D

3D

~30 μm

Homogeneous layers

Pre processing
(Sample preparation)

Print Process
(Ink / printhead / surface interaction)

Result
(Finished product)

~ 20 nm

Image source: Meyer Burger
Inkjet Markets – Coding and Marking

Non-impact gave inkjet a market breakthrough

Now key technology in Track & Trace

Image source: Domino, Codemark, Pryor Technology, Planet Group
Inkjet Markets - Ceramics

Inkjet now dominates ceramic tile production

That floor looks like stone - but it isn’t

Image Source: System Italy
Digital print for textiles has reduced minimum viable print run lengths and shortened turnaround times
Inkjet Markets – Automotive Textiles

Image Sources: Mimaki, Seiren
Inkjet Markets - Décor

Graphics and textures for all kinds of decorative products: wall coverings, edge banding, flooring, doors, window frames, furniture...

Image Sources: Hymmen, Cefla, Interprint
Inkjet Markets – Texturing

- **Tactile effects**
  - Additive
    - High laydown effects
  - Subtractive
    - Ink-jetted acid resist

Image source: Ikonics, Kuei, Komfi
Inkjet Markets – Printed Electronics

- Display
  - LCD colour filters
  - OLED
    - Depositing light emitting layer
    - Encapsulation layers
- Photovoltaics
- Other
  - Jetting conductive tracks
  - Solder mask

Increasingly moving towards flexibles

Image source: Kateeva, Meyer Burger
Inkjet Markets – 3D

• **Inkjet one of many 3D technologies**
  • Concept & functional prototypes and Industrial use
    • Automotive
    • Aerospace
    • Pump & Heavy Industry
    • Art & Design
    • Film & Museum

• **Production example - Binderjet**
  • Powder can be
    • Sand for industrial casting moulds
    • Metal, subsequently sintered
    • Ceramics: silicon carbide or aluminium oxide

Image source: Voxeljet, Stratasys, Hoganas, Schunk
Inkjet Markets – Direct to Shape

- Tubes, cones, tubs
- Tubes – now well established technology
  - Many systems – low & high production
  - Glass, plastics, aluminium
- Cones & tubs – require correction in software

Image source: GIS software, SMT Digital, KHS, Till, Martinenghi
More Complex Shapes

• Many complex shapes have eluded inkjet printing & coating
• Analogue technologies dominate - even when some processes are inefficient and wasteful of materials
• Inkjet moving from partial to full coverage printing of any object
Inkjet & Automotive Surfaces – so far

Some examples:-

Image Source: Momentive, Borbet, Ritzi, Nakan, Seiren, Ikonics
# Inkjet for Automotive Surfaces

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
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</thead>
<tbody>
<tr>
<td>Precise drop formation and placement</td>
<td>High transfer efficiency</td>
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<tr>
<td>Digital control</td>
<td>Fluid cost savings</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Drop on demand technology</td>
<td>No overspray</td>
</tr>
<tr>
<td>Digital control</td>
<td>Precision coatings</td>
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<tr>
<td></td>
<td>Environmental management cost savings</td>
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<td></td>
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<tr>
<td>Digital control</td>
<td>Graphic painting/coating without physical masking</td>
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<tr>
<td></td>
<td>Short run customisation</td>
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<tr>
<td></td>
<td>Labour cost savings</td>
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<tr>
<td>Highly integrated, modular technology</td>
<td>Fluid changes by switching print module</td>
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<tr>
<td></td>
<td>Support wider range of colours for decorative applications</td>
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</table>
Inkjet Productivity

Coating application:
• Depositing 80µm layer onto a flat surface
• Medium density head: 1000 nozzles @ 600dpi
• Firing large 160 picoLitre drops @ 20kHz
• Allow 10% for curing shrinkage

Surface coverage for a single head:
• Head width: 42.3mm
• Print speed: 846mm/s

Area covered by single printhead: 129 m²/hour
Inkjet Challenges

- We also have some challenges
  - Jettability
    - What fluids can we handle?
  - Throw Distances
    - Where can we jet them?
  - Complex Curved Surfaces
    - How do we adapt?
  - Navigation & Motion control
    - Where are we?
Inkjet Challenges - Jettability

• Viscosity
  • Most drop on demand printheads require fluids with viscosities in the range 7-15 centipoise (cps) at jetting temperature
    • Higher viscosity fluids can be heated to reduce viscosity to be jettable
    • Some new printhead developments will enable higher viscosities
  • Automotive paints – viscosity challenging for inkjet
  • Automotive hardcoats – can be as low as 10cps
    • E.g. Momentive SilFORT
  • Opportunities for inkjet to add efficiency and precision drop placement
Inkjet Challenges - Jettability

- **Particulates**
  - Some visual effects in automotive paints are achieved using large particles, which would probably cause problems blocking nozzles
  - These effects could be achieved instead using digitally controlled patterns
- **Inkjet provides different way of producing optical effects**
  - Currently lot of activity in commercial print & packaging – same techniques could be applied in automotive coatings

Image Source: Scodix
Inkjet Challenges – Throw Distances

- **Inkjet printers are typically designed to throw ink drops a distance of 1 – 2mm to the surface**
  - This produces sharp, detailed graphics and text – down to 2pt @ 1200dpi
  - And works well even when the head or surface are moving at up to 5m/s relative speed
  - But has created a perception that greater throw distances are a problem
- **In fact, nozzle drop velocities are in the range 5-8m/s**
  - Medium to large drops will travel over 20mm
  - Placement accuracy does degrade with range, so a trade-off must be found
    - Fine detail can be achieved on near-flat surfaces with shorter throw distances
    - Coating coverage can be achieved even in concavities up to ~25mm depth

Image Source: ImageXpert
# Inkjet Challenges – Complex Curved Surfaces

<table>
<thead>
<tr>
<th></th>
<th>Flat Surfaces</th>
<th>Curved Surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density Correction</td>
<td><img src="image1" alt="Density Correction" /></td>
<td><img src="image2" alt="Density Correction" /></td>
</tr>
<tr>
<td>Throw Distance &amp; Flight Time</td>
<td><img src="image3" alt="Throw Distance &amp; Flight Time" /></td>
<td><img src="image4" alt="Throw Distance &amp; Flight Time" /></td>
</tr>
<tr>
<td>Nozzle Alignment &amp; Interleaving</td>
<td><img src="image5" alt="Nozzle Alignment &amp; Interleaving" /></td>
<td><img src="image6" alt="Nozzle Alignment &amp; Interleaving" /></td>
</tr>
<tr>
<td>Screening</td>
<td><img src="image7" alt="Screening" /></td>
<td><img src="image8" alt="Screening" /></td>
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# Inkjet Challenges – Navigation & Motion Control

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<th>Curved Surfaces</th>
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<tbody>
<tr>
<td><strong>Geometry</strong></td>
<td>2 Dimensions&lt;br&gt;2 Degrees of Freedom</td>
<td>3 Dimensions&lt;br&gt;6 Degrees of Freedom</td>
</tr>
<tr>
<td><strong>Print Path</strong></td>
<td><img src="image1" alt="Flat Surface Print Path" /></td>
<td><img src="image2" alt="Curved Surface Print Path" /></td>
</tr>
<tr>
<td><strong>Shape Data</strong></td>
<td><img src="image3" alt="Flat Surface Shape Data" /></td>
<td><img src="image4" alt="Curved Surface Shape Data" /></td>
</tr>
<tr>
<td><strong>Motion Control</strong></td>
<td><img src="image5" alt="Flat Surface Motion Control" /></td>
<td><img src="image6" alt="Curved Surface Motion Control" /></td>
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</table>
From Concept To Reality – Sphere Printer

- Starting with a sphere
- Using a robot to position the shape under the printheads
- We built a test print rig

Image source: GIS
Sphere Printer – Mesh & Texture

- Many tools available for wrapping
  - Well established technologies from gaming, augmented reality industries, etc.
  - Many different ways to wrap, edit directly on to 3D surfaces
  - Result is expressed as a texture map

Image source: GIS
Sphere Printer – Print Path

- **Design a print path**
  - Taking into account the constraints of the object to be printed, inkjet printhead, capability of the robot
  - Currently we do this manually, which is appropriate for most manufacturing applications, but there is research towards automation

**Image source: GIS**
Sphere Printer – Print Geometry

At printhead scale and below: convex or near-convex shapes

Convex
\[ r \geq w \]

Near-convex
\[ h < h_{\text{max}} \]
Sphere Printer – Print Geometry

At printhead scale and below: convex or near-convex shapes

- Convex: $r \geq w$
- Near-convex: $h < h_{\text{max}}$
Sphere Printer – Positioning Accuracy

Industrial robots have sufficient accuracy for many industrial applications ...

... but printing requirements are tight
- Typical industrial robots can achieve absolute pose accuracy with calibration of 200-500 µm
- Inkjet printing requirements for graphics are typically 5-10x finer, not so precise for coating
- Robot repeatability is better than absolute accuracy, so further calibration is possible
All manufactured objects have tolerances

- E.g. Polypropylene sphere
- Inexpensive consumer product

**Nominal: 75 mm radius**

**Structural errors**
Assembly of two hemispheres

1.5 mm

**Precision errors**
Limitations of process

~0.25 mm

Image source: GIS
Sphere Printer - Stitching

• **Stitching is a key area where inaccuracies will show**
  • Positioning errors cause gaps or overlaps, familiar from 2D printing

[Images of stitching examples]

• **Careful control is required of multiple factors:**
  • Accuracy of transport, especially robots near to singularities
  • Print synchronisation
  • Variation of the target shape from nominal dimensions
Sphere Printer – Shape Variation Compensation

• **Measure the target shape accurately**
  • Mechanical profile gauges
    • Adequate, but rather slow
    • Contact with target shape may be a problem
  • Laser triangulation sensors
    • Resolutions down to ~1 µm, sample rates 1-100kHz
    • Non-contact

• **Apply measurements as corrections to the mesh model**
  • For per unit variations this can be done as a late stage correction
  • Output adjusted swathe data
Sphere Printer – Apply the Workflow

Creation Tools
- Import Mesh & Texture
  - Colour Separation
    - Density Correction & Screening
  - Unwrap
- Swathe Decomposition
- Swathe paths
  - Measure & Correct
  - Print Control
- Transport Control

Image source: GIS
Result: a printed polypropylene spheroid

- CMYK 1200 dpi
- Latitude swathes, 18° high, covering the top hemisphere
- 300dpi native; x 4 interleave
Simulated Print Sequence
Simulated Print Sequence
Simulated Print Sequence
Simulated Print Sequence
Simulated Print Sequence
Implications & Opportunities

- Inkjet already being used in automotive production
  - Decorative & functional
- Advances in printhead technologies, software and fluids
- No longer constrained to flat surfaces
- Some highly viscous fluids remain a challenge
  - Thinking differently can provide solutions
- Great potential for further usage
Thank you – Any Questions?

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