Data mining as a method to industrialize and qualify automotive high-volume composite manufacturing.

Symposium on the occasion of the 5th anniversary of the Institute for Carbon Composites.

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Data mining as a method to industrialize and qualify automotive high-volume composite manufacturing.
Requirements to high-volume composite manufacturing.

- Reduction of material costs
- Reduction of cycle-times
- Machinery
- Capable Process Control Systems

Automotive: „high-volume“

Aerospace: „low-volume“

Motorsports: „manufacture“

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# Challenges to high-Volume Composite Manufacturing.

<table>
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<tr>
<th>Problem</th>
<th>Consequence</th>
<th>Needs</th>
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<td>Highly interacting processing parameters</td>
<td>Sensitive process → spontaneously occurring failures</td>
<td>Capable process control system</td>
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<tr>
<td>Sequenced process chain (RTM-Process) carries defect parts through the process</td>
<td>Extensive quality controls after every process step (early failure detection necessary) → high costs</td>
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<td>Relation between processing parameters and final part properties not entirely resolved</td>
<td>Time consuming fault-removal process → high idle time → high costs</td>
<td>Process knowledge and transparency</td>
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Handling of interactions.

Schematic view of a 2-parametric interaction:

Example part: (●): parameter A ↑ ∧ parameter B ↓ → reworking issue

Example: Support Vector Machine (SVM)

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Knowledge Discovery in Databases and Data Mining.

**Traditional approach:**
manual acquisition, analysis and interpretation of data by experts

**Problems:**
rising complexity of manufacturing processes + dramatically increasing volume of data to handle → Traditional approaches are stretched to their limits

**Problem-Solving-Approach:**

**Knowledge Discovery in Databases**
KDD is a structured process with the aim of identifying valid, new, useful and interpretable information within huge data collections

**Data Mining**
Data mining is a part of the KDD process in which methods from different fields (statistics, artificial intelligence, machine learning, …) are applied on the current data

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Modeling of the process chain.

Input Variables:
- Material
- Layers
- Fabrics
  - Type
  - Areal-Weight
- Non-Crimp-Fabrics
  - Type
  - Areal-Weight
- Binder
- VA-Mesh
- Core

Disturbance Variables:
- Material
- Measurement Errors
- Control Variable Tolerances
  - Temperature, applied Pressure
- Environment
  - Humidity, Temperature

Control Variables:
- Temperatures
- Heating System
- Tool-Temperature
- Pressure
  - Stamp Pressure
- …
- Time
  - Cycle Time
  - Heating System
  - Cycle Time
  - Preform Press

Target Values:
- Properties
  - Geometry
  - Weight
  - Stability
- Quality Issues
  - Type of Defect
  - Location of Defect
- Process Issues
  - Cycle Time
  - Material Requirements
  - Waste
  - Defect Rate

Control Variables:
- Temperatures
- Resin / Hardener
- Tool-Temperature
- Pressure
  - Stamp Pressure
  - Injection Pressure
- …
- Time
  - Injection Time
  - Demoulding Time

Target Values:
- Properties
  - Fiber-Volume Fraction
  - Geometry
  - Weight
- …
- Quality Issues
  - Type of Defect
  - Location of Defect
- Process Issues
  - Cycle Time
  - Material Requirements
  - Waste
  - Defect Rate

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Concept and setup of the data mining system.

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Capabilities of a data mining environment.

**Manufacturing process** → **Data (Data-Warehouse)**

**Reporting**
- Visualization of all relevant information
  → Continuous transparency

**Analytics**
- Evaluation of the process data
  - Using methods from the fields of statistics, and data mining
  → Continuous Improvement

**Predictive Analytics**
- Prediction of failures and reworking issues using trained data mining models
Reporting example: causes of defects.

Browser based reporting tool with combined information of process and quality data

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Analytics example: CHAID-Decision tree.

Automatically generated decision tree
Reworking issue: surface ripples at the BMW M3 Coupé CFRP roof

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Predictive analytics example: failure detection system.

Integrated Quality System for the detection of failures and reworking issues.

**Advantages:**
- Online monitoring of all processing parameters
- Visualization of the predicted results ➔ support of the machine operator
- Early detection of defect parts allow early removal from the supply chain ➔ increase of the net-benefit
Further possibilities: Support of the ramp-up management

Faster identification of the optimal process-window in new processes by the use of data mining (\( \Delta t \downarrow \)).
Benefits and conclusion.

**Reporting:**
- Increased availability of all relevant data
- Accelerated visualisation and analysis
- Support of the problem solving process
- Faster diagnosis → minimization of idle times

**Analytics:**
- extended and automated analytical methods by the use of data mining
- Quantifiable influence of control variable to dependent variable
- Description and handling of multidimensional interactions possible

**Predictive Analytics:**
- Promising results from a pilot study at the M3 Coupé CFRP-roof
- Early removal of scrap parts from the process chain to increase cost efficiency
- Reduced test cycles of the parts

**Conclusion:**
Data mining offers a variety of new possibilities to the high-volume manufacturing of composite parts and is able to contribute to the industrialization of the carbon-fiber in automotive industry.
Thank you for you attention.

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