Digital Factories and Digital Manufacturing

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Outline

• Digital factory and Digital manufacturing
  – Definitions and purpose
• Digital factory
  – Information to represent
  – Standards
• Digital manufacturing – Virtual manufacturing
  – Information to represent
  – Applications
• Manufacturing feed-back for continuous improvement
  – Correction, prevention and elimination of disturbances
• Modifying the model based on experience
Digital factory and Digital manufacturing

• Digital Factory
  – Definition: A technology to capture and represent information to model manufacturing systems and available processes in a factory

• Digital Manufacturing
  – Definition: A technology to process information to verify and optimise the manufacturing of products.
Digital Factory - Purpose

• The digital factory should mirror a factory and its available processes
• It will represent all relevant information about the resources in the factory and their processes.
  – Machine-tools
  – Fixtures
  – Tools
  – Conveyers
  – Buffer stores
• The factory model should be the resource model for:
  – Process planning
  – Factory design
  – Layout and material flow design and analysis
  – Design for manufacturing
Digital Manufacturing - Purpose

- Digital manufacturing should mirror manufacturing in the real factory
- Digital manufacturing are all applications for:
  - Verifying product manufacturability and process plans
    - Simulation, Analysis (DFMA)
  - Verifying the performance of the manufacturing system
    - Flow simulation, geometric simulation, machine tool performance
  - Generating manufacturing system control information
Product, process, and resource information, their requirements and interdependencies
The Digital Plant

- Tool selection & procurement
- Off Line Programming
- Ergonomic Planning & Sim
- NC Control Sim/Gen
- NC Process Sim
- Product Features

MDM

Education Knowledge

Johan Nielsen and Olof Nyqvist

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Building the Digital factory

• How to capture information to represent
  – Resource models and
  – Process models
• in the factory

• We want to capture the information from the source and get:
  – The relevant Information
  – At the right detailing level and in
  – A usable format
To deliver the real as well as the Digital plant

Gordon Sjöqvist / ABB Body in White
Neutral Communication

Product data AP214 → Share-A-space → Manufacturing Resource data AP214

Internal Systems

Project Setup

Internal Systems

ABB

SCANIA

VRL
Digital Model and Real World

ABB

Scania / Pär Mårtenson

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Manufacturing Resources
Cutting Tool and Machine-tool

Information to be captured into the digital Factory:
The Cutting Tool interfaces

Information interface:
ISO 13399

Hardware interface:
ISO, HSK, Capto, KM,...
One tool with multiple functions

“Mini-turret” with multi-tool function

Table of data

<table>
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<tr>
<th>Turning</th>
<th>Threading</th>
<th>Grooving</th>
<th>Milling</th>
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One tool replaces many tools = many tool definitions
Standardized information models

- Needs to be generic in order to avoid “Standardization pitfall”
- Needs to have explicit concepts and rigorous definitions
- Are these requirements contradictory?
Differences in approach

- Our approach:
  - “This is the way in which you describe any cutting tool.”
  - Provides generic support for cutting tool information.

- Old approach:
  - “These are the cutting tools that exist, and these are their attributes.”
  - Provides a description of the current state of cutting tools.
Categories of items

- Workpiece side
  - Cutting item
  - Tool item
  - Adaptive item
  - Adaptive item
  - Adaptive item

- Machine side
  - Adaptive item
  - Adaptive item
  - Tool item
  - Tool item
  - Tool item

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Overview of information types
Different id in different contexts

Factory A

ABC123

Factory B

XYZ789
Reference Data

• Supports a generic information model
• Definition source references from
  – Properties
  – Classifications

• A solution in which progress is anticipated
ISO 13584 – Parts Library

- Hierarchical
- Component catalogue
- Simple inheritance
- Freely available software tool
- Easy to use
Example of machine-tool representation in AP214

- **"Spindle"**
  - Name
  - Associated item
  - Item version
  - Single-instance
  - Next higher assembly

- **"Tool changer"**
  - Name
  - Associated item
  - Item version
  - Single-instance
  - Next higher assembly

- **"Fixture"**
  - Name
  - Associated item
  - Item version
  - Single-instance
  - Next higher assembly

- **"Table"**
  - Name
  - Associated item
  - Item version
  - Single-instance
  - Next higher assembly

- **"Movement area"**
  - General property
  - Definition
  - Property value representation
  - Specified value

- **"Number of revolutions"**
  - String value
  - Value specification

- **"Number of axes"**
  - String value
  - Value specification

- **"Machining center"**
  - Item
  - Associated item
  - Item version
  - Single-instance
  - Next higher assembly

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PDTnet schema XML format

- <Item id="xml_43">
  <Id>33231</Id>
  <Name>Machining center</Name>
  + <Item_version id="xml_44"/>
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## Standards of interest

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AP 203, AP 219, +++

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The Manufacturing development process and Information Backbone

Product models

Process planning

Machine investment

Factory development

Operations and improvement

Models in UGS, Delfoi etc.

Material

Process

Tool

Fixture

Machine-tool

Layout

Physical part

Coordination

Integration Platform,
Standards – STEP AP: 13399, 214, 238, 239, 240

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Production Investment PILot - PIL
Example of an information driven work process

- Generic work process
  - A common work flow to support collaboration
  - Contents adapted to user and needs

- Modeling principles
  - Modular activity model with defined purpose and interface (gate criteria) – configurable according to needs
  - Information in relation to activities: Inputs, outputs, control and mechanisms
  - Information in documents and models:
    - Requirements, product and equipment models, administrative documents

- Implementation
  - XML-based web application
  - Interface for industrial usability
Activities of different actors
PIL ProduktionInvesteringar - Lotsen

Förstudie

INITIERING

- Indikation av behov
- Uppdragssdirektiv

FÖRSTUDIE

- Projektdefinition
- Insamling av information och förankring

Initiering

Syfte

Huvudsyftet är att samla och sammanställa fakta samt att identifiera typ av behov som kan leda till ett investeringsprojekt.

Dokument för arkivering

- Uppdragsdirektiv

Övergångskriterier

- Uppdragssdirektivet färdigt.
- Beslut fattat om man ska gå vidare och genomföra en förstudie
Digital manufacturing

- A technology to process information to verify and optimise the manufacturing of products
  - Verifying product manufacturability, process plans, NC verification and code generation etc
    - Simulation, Analysis (DFMA)
  - Verifying the performance of the manufacturing system
    - Flow simulation, geometric simulation, machine tool performance
  - Generating manufacturing system control information
Digital Manufacturing
Precision manufacturing

- Enhancement of the precision in machining
- Increasing Efficiency

Geometric and Kinematical Accuracy
Temperature Distorsions
Static Flexibility
Dynamic Flexibility

Accuracy in Machining System
**Definitions**

1) **Machining System:** Functional connection between ES and CP

![Diagram](image)

- **ES** - Elastic Structure
- **CP** - Cutting Process

2) **Stiffness:** Capacity of a mechanical system to sustain loads without excessive changes of its geometry (deformations)

3) **Damping:** Capacity of a mechanical system to reduce the intensity of a vibratory process
Machining System
Closed-loop System

Elastic structure of machining system

Machining process

Machine tool  Cutting tool  Work fixture

Tool Geometry/ Tool Material  Cutting Parameters

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Body in white manufacturing

- Verify manufacturability by simulation
- Generation of control code
Possibilities

• Digital Factories
  • Today a new product is generally not possible to manufacture in existing manufacturing equipment and processes without change!

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Verification
Case study

- Body-in-White assembly line
- Handles two car models
- Ex. cell: Weld a plate on the side of the “floor”
- On each side: 2 robots, 1 fixture, 1 turntable...
Product – Joint A
  - Join
  - Strength X

Resource – Robot A
  - Move weld gun
  - Position weld gun

Resource – Jig A
  - Hold
  - Position

Resource – WGun A
  - Weld
  - Press
Method

- Identify information necessary to develop PLC code
- Make model based on ISO10303 (STEP)
- Purpose: Enable a reusable description of process and resource information
- Viewpoint: PLC programmer
Identified information types

- **Products**
  - Input and output to the cell (different car models)

- **Resources**
  - Robots, fixtures, racks, turntables...

- **Process**
  - Operations, relations between operations (start sequence, substitution, exclusiveness, simultaneous)
  - Transition conditions (criteria for an operation to start)
Information types

- Transition conditions, e.g.
  - Predecessors (which operations must be executed and finished before an operation)
  - States (what states of the resources are required for the operations)
  - Periodic operations (tip dressing of welding electrodes)
Using ISO 10303

- Process structure using AP214
Modelling results

- Process operation list with relations
- Different operations can be executed depending on triggers
Using ISO 10303

- Transition conditions:
  - Attempt to combine process information (AP214) with required resource states (AP239)
Modelling results

- Process information with assigned resources and their required states
Total view on improvement work

CoPE; Correction, Prevention and Elimination of disturbances

- **Strategic level**: Eliminate disturbances in new systems.
- **Tactical level**: Prevent disturbances in current system.
- **Operational level**: Correction of disturbances in current system.
Systematic use of manufacturing feedback

- **Operational level**
  - “Action ⇒ measure ⇒ evaluate ⇒ action”
  - Visualization of occurred events in the manufacturing system
  - Systematic acquisition and reuse of human observations and experiences (cause and action), language independent for global implementation
  - Condition based maintenance

- **Tactical level**
  - Optimization of bottleneck operations for synchronous flow by using acquired manufacturing data
  - Simulation of improvement actions based on occurred events, focus on line level

- **Strategic level**
  - Simulated operation of future manufacturing systems based on current manufacturing data
Robust capability handling

- Model of purchased manufacturing system
- Updated model of the manufacturing system
- Database for operational data
- Instant model of the manufacturing system
Tactic level:
Disturbance analysis using flow simulation (Scania D16 block line)
Tactic level: Disturbance analysis using flow simulation (Scania D12 block line)

Simulation D12
Simplan
June 2005
Arne Ingemansson
Skövde Högskola
Manufacturing system development and upgrading

We must be able to verify and optimize a manufacturing system being developed for existing and new products from early on in development and all the way through the development –How? Benefits?

Benefits?
- Shorten the development time 30%
- Reduce no of late corrections 10%
- Increase manuf. productivity 10%
- Reduce time for eduction 30%
- Decrease cost through OEE 15%

How?
From early on be able to:
- Verify manufacturability
- Verify that quality can be achieved
- Verify that through put and lead time can be achieved
- Verify that ramp up can be short enough
- Verify that the manuf. Sys will be safe
- Optimize product adaption to manufacturing
Information integration

Human Interaction
Interactive Stereo-Table

Model-Information Platform
Domain Structures

Real Manufacturing System

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Conclusions

- Apply a model based approach for digital factory and digital manufacturing
- Reuse information about manufacturing resources and processes
- Take advantage of available Standards
- Select the appropriate one’s
- Go for a modularized frame work which can be step-wise enhanced with new modules
- Take advantage of a data dictionary to manage concepts and terms
- Take care of manufacturing feed back to
  - improve manufacturing and
  - to improve the information about the factory
The End

Thank You

Questions?