A traceability information model for CNC manufacturing

AP 238 Traceability Approach

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Valencia

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1. Traceability.
   - Traceability.
   - Traceability Principles & problems.
   - Traceability & e-Manufacturing. NC Systems.

2. Traceability Model.
   - Traceability Data Model & Step-NC
   - Features & Tolerances: Characteristics.

3. Work Done.
   - .......
   - .......
   - .......
Traceability & Characteristics

**What is traceability (1)?**

- Is a set of practices to make available all essential information about a product.
- Achieved within each product, by registering characteristics & product manufacturing information like:

  - **with what** (raw materials)
  - **who** (employees, personnel)
  - **when** (manufacturing timings)
  - **how** machines & tools
  - **where** (handling, store, transport)
  - **How well** (characteristics)
  - **other data** (additional data, resources)

“the ability to trace the history, application or location of what it is under consideration”

ISO 8402:1994
ISO 9000:2000

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[Image of a manufacturing process]

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[Image of a manufacturing process]
SC4 Additional STEP requirements and traceability issues.

- Multiple Application support
  - Conceptual Design & Product Planning
  - Engineering Analysis
  - ...........
  - Logistics
  - Packaging
  - Manufacturing
  - Quality
  - Support & Maintenance

Traceability is about this, but is more than this.
Traceability & Characteristics

What is traceability (2)?

- Traceability Principles:
  - Identification
  - Data Capture & Recording
  - Communication
  - Links Management.

[Diagram showing barcode and part with links]
Traceability & Characteristics

What is traceability (2)?

- **Traceability Principles:**
  - Identification
  - **Data Capture & Recording**
  - Communication
  - Links Management.

- **with what** (raw materials)
- **who** (employees, personnel)
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- **other data** (additional data, resources)
Traceability & Characteristics

What is traceability (2)?

- Traceability Principles:
  - Identification
  - Data Capture & Recording
  - Communication
  - Links Management.
Traceability & Characteristics

**problems (1)**

**traceability is a complex process**

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<th>traceability in complex &amp; highly dynamic environments (e-Manufacturing, CNC) has complex problems:</th>
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Traceability & Characteristics

problems (1)

- Traceability in Dynamic, Complex and Heterogeneous systems.

In complex Products, traceability data could be difficult to understand.
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Traceability in Dynamic, Complexity and Heterogeneous systems.

- **Complex product**: several different suppliers or providers
- **Dynamic relations**: Supply chain is not static

In complex products, traceability data could be difficult to understand.
Traceability & Characteristics problems (1)

- Traceability in Dynamic, Complex and Heterogeneous systems.
  - Complex product: several different suppliers or providers
  - Traceability databases: data availability & disgregation
  - Dynamic relations: Supply chain is not static

In complex products, traceability data could be difficult to understand.

- Data Unavailable
- Data Unreachable
- Provider Change
- Provider Disappears
Characteristics (explanation)

- (¿ to fill by Martin ?)
- ... slide from GE about product characteristics problems ...
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   - ........
   - ........
STEP – EXPRESS (ISO 10303) information data model for tracing manufacturing operations, features & characteristics (AP238) and assembled products (AP 203).

Ap238/AP203 compatible (linked).

- assure traceability data will be understandable and available whenever required.
  - no matter the product or the manufacturing process complexity.
  - even if the subcontractor that made the product no longer has a relationship with the contractor.

- the main feature of the model is the definition of an explicit link between the traceability data and the CAM product data.
  - allows users to electronically browse the data and understand the relationships between the CAD/CAM data and the executed process.

- Input (configuration/requirements) and output (traceability data) are ISO 10303-21 files
STEP NC & Traceability Model (1)

- Simple CNC machining Scenario.
  - CAD/CAM Design + traceability configuration
  - 1 File Per design
    - Traceability Configuration File (Pat 21)
    - AP-238 File

- CNC Manufacturing + traceability recording
  - Manufacturing
  - Inspection (Characteristics)
  - Data Audit & Storage
    - 1 File Per Product Manufactured
      - Trace Data Files P21

- Manufacturing Data Audit & Storage
  - Trace Data Files P21
**Traceability & Characteristics.**

**Step-NC Approach + Traceability**

- **Customer**
  - AP-203/224/240
  - CAD/CAM System
    - + traceability configuration
  - CAD/CAM Translator
- **Shop**
  - Machine Independent CNC Control file
  - CNC System
    - + traceability
  - AP-238 File
  - Manufacturing
- **Traceability Configuration File (Pat 21)**
  - Common Objects Reference
  - Same traceability structure
- **Finished Parts**
  - Trace Data Files P21

**Machine Independent traceability configuration file**
What is traced? (1).

Traceability Model Header

Ap238

Workpiece
product / product definition
formation / product definition

product definition
shape

shape definition representation

The Trace Project
Tr_project

(link to Ap238 file/document) through Document_Reference

other aspects describing Traceability project Configuration (PDM)

tr_identification_relationship

tr_Manufacturing Operations_relationship

tr_Caracteristic_relationship

traced_Operations L[0:?]

traced_Characteristics L[0:?]

physical product ref.

WorkingStep traceability data

Features & tolerances data
Traceability Project File header

- Traceability Project Identification:
  - link between Step File & its traceability File.

- Traceability Project Structure:
  - Additional WorkPiece PDM (product Data Management), to be define & harmonized.
    - Authorization, approval data, ... (10303-1015 & 1012)
    - Traceability Data Definitions.
  - Traced Operations List (through traced_operations)
  - Traced Characteristics List (through traced_operations)
What is traced? (1).

**WorkingSteps. Operations**

The Trace Project
Trproject

other aspects describing Traceability project Configuration (PDM)

(link to Ap238 file/document) through Document_Reference

Workpiece product / product definition formation / product definition

product definition shape

shape definition representation

tr_identification_relationship

product

tr_manufacturing_operations_relationship

tr_caracteristic_relationship

tr_Manufacturing Operations_L[0:?]

tr_Caracteristic

Features & tolerances data

traced_Operations_L[0:?]

traced_Characteristics_L[0:?]

physical product ref.

Ap238

What is traced? (1).

WorkingSteps. Operations
What is traced? (2).
WorkingSteps. Operations

At the heart of the STEP-NC model
- Workplans containing a sequence of workingsteps.
- Each workingstep associates an operation with a feature on the workpiece.

Traceability data associated with each workingStep executed within the physical manufacturing of any feature.
What is traced? (3).

Working Steps: Operations

• Operation traceability data. STEP-NC model
  - Tool usage, identification & timings
  - Raw Materials identification & logistic data.
  - Employees, Machine Operators ...
  - Model is Open to new Data

[Diagram]

- Product Identification
- Trace Manufacturing Operation Type
- Tr_Persons
- Tr_Raw_Materials
- Tr_Tools
- Raw Materials Data
- Tools Data
- Operators L[0:∞]
- Used materials L[0:∞]
- Used tools L[0:∞]
- Other PDM Operation data
What is traced? (4).

GD&T. Characteristics.
What is traced? (5).
GD&T. Characteristics.

- **STEP-NC model supports GD&T. Tolerances**
  - Characteristics could be a wider concept.
  - Each Entity/object, can support, have, requirements specified by hundreds of different characteristics.
  - Characteristics should be defined, registered, stored, audited, validated ...

**feature:**
round hole

**Ap238 File**
- Tolerance (dim) #1175
- Tolerance (size) #1256
- Tolerance (pos) #1298
- Tolerance (ang) #1417

**Traceability File**
- tr_Characteristic_Relationship
  - trace_characteristic #1256
  - trace_characteristic #1298
  - trace_characteristic #1417

**Traceability data associated with each characteristic traced for any particular feature or tolerance requirement.**
What is traced? (6).
GD&T. Characteristics.

Characteristic traceability Data. STEP-NC model
- Characteristic Identification: Implicit or Explicit (Repository)
- Validation, Verification, Auditing, Comprobation, Control.
- Characteristics are heterogeneous
- Model is Open to new Data or Redefinition

```
tr_identification

characteristic_identification
(id, name, description)
```

```
tr_Persons

Operators L[0:?]
```

```
tr_timeStamp

time
```

```
Measure_Representation_Item

measure
```

```
Trace_Characteristic
```

```
tr_Characteristic_relationship
```

```
Timing data
```
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3. Work Done.
   Bla 1
   Bla 2.
Traceability & Characteristics.  
Step-NC Approach + Traceability

Customer
AP-203/224/240

CAD/CAM System

+ traceability configuration

CAD/CAM Translator

AP-238 File

CNC System

+ traceability

Machine Independent
CNC Control file

Manufacturing

Common Objects Reference

Traceability Configuration File (Pat 21)

Same traceability structure

Finished Parts + traceability

Trace Data Files P21

Shop

Machine Independent traceability configuration file
Traceability & Characteristics.

**Step-NC Explorer (1)**

- Setting Traceability Requirements on a WorkingStep. (Tracing Operations)
Setting Traceability requirements on a tolerance. (tracing Characteristics).
ISO-10303-21;
HEADER;
DATA;

FILE_SCHEMA ("TRACEABILITY_SCHEMA", "INTEGRATED_CNC_SCHEMA");
ENDSEC;

DATA;
#10=TR_TIMESTAMP(#56, #57);
#11=TR_TIMESTAMP(#58, #59);
#12=TR_TIMESTAMP(#60, #61);
#13=TR_TIMESTAMP(#62, #63);

#65=DOCUMENT_TYPE();
#66=DOCUMENT("D:\data\tolerance_part.stp", 'AP238 Base Document - Configured for Traceability', #65);
#67=DOCUMENT_REFERENCE(#66, "\data\tolerance_part.stp");
#68=TR_PROJECT(#67, #69, (#71, #72, #73, #74, #75, #76, #77, #78), #69);
#69=TR_IDENTIFICATION_RELATIONSHIP(#75, #76);
#70=TR_IDENTIFICATION("\", " LOT");
#71=TR_CHARACTERISTIC(0, location #45, 'Characteristic Applied to (Plus Minus Tolerance)-> location dimension tolerance', #30, #10, ());
#72=TR_CHARACTERISTIC(0, Feature - Hole #56, 'Characteristic Applied to (Feature)-> #31, #11, ());
#73=TR_CHARACTERISTIC(0, Position #53, 'Characteristic Applied to (Geometric Tolerance)-> position', #32, #12, ());
#74=TR_CHARACTERISTIC(0, Dimension #45, 'Characteristic Applied to (Plus Minus Tolerance)-> size dimension tolerance', #33, #13, ());
#75=TR_CHARACTERISTIC_RELATIONSHIP(21, #74);
#76=TR_CHARACTERISTIC_RELATIONSHIP(3683, #72);
#77=TR_CHARACTERISTIC_RELATIONSHIP(31, #72);
#78=TR_CHARACTERISTIC_RELATIONSHIP(205, #74);
ENDSEC;
END-ISO-10303-21;
Traceability & Characteristics.

Step-NC Approach + Traceability

Customer
AP-203/224/240

CAD/CAM System

+ traceability configuration

CAD/CAM Translator

AP-238 File

CNC System

+ traceability

Machine Independent CNC Control file

Common Objects Reference

Traceability Configuration File (Pat 21)

Finished Parts + traceability

Same traceability structure

TraceDataFiles P21

Machine Independent traceability configuration file

Manufacturing

Finished Parts + traceability

Trace Data Files P21
Traceability & Characteristics.

Step-NC Explorer (3)

- Inspecting Traceability data on a Feature. (NC-Explorer Update) (traced Characteristics & timings resume).
Traceability & Characteristics.

Step-NC Explorer (2) - Auditing

- Fast Auditing Traceability data for defined characteristics.

Hundreds of characteristic and traceability requirements per product, operation, feature or file.

Characteristic data is recorded on traceability data files.

Some data could be erroneous, out of range or even not available.
Traceability & Characteristics

CONCLUSIONS (1)

**traceability is a complex process**

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Automation of traceability is an important task

**Traceability in complex & highly dynamic environments (e-Manufacturing, CNC) solution & proposals:**

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**CONCLUSIONS (1)**

1. the product or the manufacturing process is, itself complex:
   - **traceability data linked to CAD/CAM data.**
2. multiple, and “eventual” contractor-subcontractor relationships.
   - **traceability data delivered with the product.**
3. traceability databases are not interconnected (internal traceability systems).
   - **traceability data as a standard part of PDE (product data exchange)**
4. products can have 100s of different and heterogeneous characteristics defined.
   - **generic definition of characteristics data fields.**
Related & Future Work.

**Ap 203** (1)

- Traceability Model is also AP 203.
- Samples of Configuration, Auditing & Visualization of trace requirements over StepViewer
Related & Future Work.

Ap 203 (2)

- Traceability Model is also AP 203.
- Samples of Configuration, Auditing & Visualization of trace requirements over StepViewer.
Traceability & Characteristics.

The BIG QUESTION (1)

- A new STEP Standard Information model for traceability?

**STEP NC Data Model**

- Feature data Model
- Operation data Model
- WorkingStep data Model
- Project data Model
- Core STEP Geometry
- Profile data Model
- WorkPlan data Model
- NC_parameters data Model
- WorkPlan data Model

**EXPRESSION data model for traceability**