Standards-Based Interoperability for Design to Manufacturing and Quality in the Supply Chain – Part 2

Asa Trainer
GPDIS2017
Phoenix, AZ
Sep 2017
Introduction

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- International TechneGroup Incorporated (ITI)
  - Private company headquartered in Cincinnati since 1983
  - Development offices in the United States, England, Israel and India
  - Engineering software and services
    - PLM system migration solutions
    - CAD interoperability solutions

- Asa Trainer
  - New England upbringing, military veteran
  - Engineering education (UMD, WSU, RPI) and university educator/researcher
  - Both aerospace and CAD industry experience
  - Interoperability solutions development
  - US and foreign patents in interoperability
  - International consortia team member
  - Interoperability product / process / program management
Acknowledgements

The work described here is funded by

- NIST Grant (CA) 70NANB14H314
  - Investigating the Impact of Standards-Based Interoperability for Design to Manufacturing and Quality in the Supply Chain
- NIST Grant (CA) 70NANB14H256
  - Validation for Downstream Computer Aided Manufacturing and Coordinate Metrology Processes
- DMDII-14-06-05
  - Digital Standards for the Advanced Manufacturing Enterprise “Operate, Orchestrate and Originate (O3)”
Building Blocks to a Stds-based MBE Process

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D2MIV 2
- Can we close upstream info gaps needed for downstream processes?
- Can we move downstream MBD back upstream as feedback via a Std?

D2MIV 1
- Can we validate downstream MBD data against its upstream source?
- Can we map the upstream MBD Std to the downstream MBD Std?

D2MI
- Can we move MBD data to downstream processes (CAM/CAI) via a Std?
- Is there a demonstrable ROI in taking the MBD downstream?

Conf/Val 2
- Can we extend the Test Cases to include more “real-world” elements?
- If we do, what impact will it have on the results?

Conf/Val 1
- Can we define meaningful MBD Test Cases and Model them in CAD?
- Can we Verify that the models accurately represent the test cases?
- Can we create MBD Std-based Derivatives and Validate them?

SFA
- Can we Validate STEP files for proper STEP syntax?
- Can we coax better STEP file translators out of CAD OEMs & vendors?

NIST Sponsored

Can we move MBD back upstream as feedback via a Std?
Can we close upstream info gaps needed for downstream processes?
Can we validate downstream MBD data against its upstream source?
Can we map the upstream MBD Std to the downstream MBD Std?
Can we move MBD data to downstream processes (CAM/CAI) via a Std?
Is there a demonstrable ROI in taking the MBD downstream?
Can we extend the Test Cases to include more “real-world” elements?
If we do, what impact will it have on the results?
Can we define meaningful MBD Test Cases and Model them in CAD?
Can we Verify that the models accurately represent the test cases?
Can we create MBD Std-based Derivatives and Validate them?
Can we Validate STEP files for proper STEP syntax?
Can we coax better STEP file translators out of CAD OEMs & vendors?
Can we provide near real-time design change to the downstream users? Can we provide rapid feedback to designers & planners during simulation or execution?

Is there a better way to control geometric quality than global tolerances? Can tolerance data in PMI be used to control variation in nominal geometry?

Can the NIST benchmark data and verification/validation processes be used to drive improvement in commercial MBD (interoperability) processes?

Can the NIST benchmark data be used to drive improvement in commercial MBD (interoperability) processes?

Can end-user companies leverage the NIST benchmark data and verification/validation processes?

Can CAx and Interoperability vendors leverage the NIST benchmark data and verification/validation processes?
Design to Manufacturing

D2MI
Data Exchange from CAD-to-CAM and CAD-to-CMM

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Supplier
(Geater M&M)

CAM
(CNC MasterCAM)

CMM
(Mitutoyo MiCAT)

PDELib (ITI)

ACIS Kernel

NX to STEP
(CTCore)

STEP to eACIS
(ITI)

OEM
(Rockwell Collins)

CAD w/ PMI (NX)

CAM
(CNC MasterCAM)

CMM
(Mitutoyo MiCAT)

PDELib (ITI)

ACIS Kernel

NX to STEP
(CTCore)

STEP to eACIS
(ITI)

OEM
(Rockwell Collins)

CAD w/ PMI (NX)
Test Models and Results Metrics

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- **CAD Model Creation Metrics**
  - Introducing MBD Process into Design Org had some ramp-up (CAD system MBD issues, training reqmnts, etc)
- **CAM Model Creation Metrics**
  - MBD approach had similar cost to 2D approach
- **CMM Model Creation Metrics**
  - 70% reduction in cost over traditional 2D exchange

*Please refer to Part 1 presentation, GPDIS 2016, for additional details*
Design to Metrology Validation
Data Exchange from CAD-to-CMM (STEP to eACIS) with Validation

Validation by PMI Category
- DFS – Datum Feature Symbol
- DTS – Datum Target Symbol
- DIM – Dimension
- FCF – Feature Control Frame
- Notes – Free Standing Notes

Results
D2MIV Results Summary

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- **RC Models**
  - Focused on Heat Sink model – validation 99% clean
  - Issues with Dims on Stand-off Model

- **NIST CTCs**
  - 25 models from 2 CAD systems, 5 vendors
  - Datum Targets were biggest issue (all systems, all vendors)
  - Success Rate – Avg - 80% (StdDev 15%)
    - One model bad (all systems, all vendors)

*Please refer to Part 1 presentation, GPDIS 2016, for additional details*
Validation of extended-ACIS PMI representation with Source STEP Model
Validation of extended-ACIS PMI representation with source STEP Model illustrating an anomaly

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Validation illustrating loss of Associated Geometry for a Datum Target Symbol in target ACIS model
Change to Feature Control Frame primary datum reference frame identifier

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- NIST CTC 05_asme - 05212.0_re_c041:rev_b.png
- nist_ctc_05_asme - 05210_re_c04:rev_b.png

Diagnostic Panel
Sort By: Level
Level
- 2. Basic Dimension 7 [4611]
- 4. Concentricity 1 [6088]
- 7. Geometrical Tolerance 1 [361]
- 10. Geometrical Tolerance 3 [2956]

Model Tree Panel
Property | Value
--- | ---
Different Annotation Part | 7. Geometrical Tolerance 1 [361]
Annotation Type | Feature Control Frame
Category | Different Entity Property
Coordinate | (0, 0, 0)
Entities | Geometrical Tolerance 1 [361]
FCF DFA 1 Identifier | A-B -> A
FCF Type | Circular Runout
Indep Entities | [Tag.17 [4991] (LUMP)]
Left Entities | Geometrical Tolerance 1 [4889]
Level | Annotation Semantic Changes
Overall Tolerance | 0.00137795 (in)
STEP-QIF Mapping Tables - Classes

- **PMI**
  - Dimension Types (19/21)
  - Dimension Tolerance Principle (2/2)
  - Dimension values (45/48)
  - Tolerance Types (15/18)
  - Tolerance Zone (13/18)
  - Tolerance Modifiers (17/21)
  - Unit based Tolerance (9/9)
  - Datum reference modifiers (25/32)
- **Shape**
  - Topology (8/8)
  - Surface Geometry (11/11)
  - Curve Geometry (10/10)

- **Links**
  - PMI <-> Brep (both)
  - PMI <-> Polyline presentation (both)

- **Miscellaneous**
  - Notes (both)
  - Flag Notes (QIF)
  - Surface Finish (QIF)
  - Tables (none)
  - Global or General Tolerances (none)
  - Views (both)

(# of STEP elements / # of QIF elements)

*Please refer to Part 1 presentation, GPDIS 2016, for additional details*
Results

- Successfully demonstrated transfer of MBD design models from OEM to Supplier and from CAD to CAM and CM systems
- Proved that, for metrology, savings for MBD transfer over traditional, non-MBD, was significant (70% reduction in overall process time)
- Validation was a valuable check on data quality
- STEP and QIF have similar coverage, ACIS had gaps
Design to Metrology
Filling in the Gaps

D2MIV 2
DMDII O3
MBE Processes

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Designer creates CAD design

CAD
With PMI

CAD2STEP

STEP AP242
with PMI

FAI Model

Stage Model

STEP2ACIS

AP242

eACIS with PMI

Mfg Engr may add
Mfg (In-Process) PMI

CAM Planning

Process Plan
AP238

CAM Sim/Execution

CAM
Sim/Execution

Metrology Sim/Execution

Metrology
Analysis

Feedback
CAD or CAM or
CM

As-Measured
Char. each with
status & value

As-Measured
Char. each with
status & value

Concat QIF
Char to STEP

CM Planner may
add Insp PMI

QIF 2.1
QIFResults
QIFStats

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Last Year’s Next Steps

Gaps in PMI support important for Mfg/Metrology
  • Surface Finish, Welds, Material
  • Inclusion of Precision
  • UOS Tolerance

Management of UUIDs for Traceability
  • Choice of UUID class
  • Insertion/Extraction of UUIDs on PMI

Demonstration of feedback from Metrology (QIF) to Design/Manufacturing (STEP)
  • Alternate Shape Representations
  • Alternate PMI elements
  • Status
The Team

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[Logos of STEP Tools, Inc., VIMANA System Insights, DMDII, ITI International TechneGroup, and Mitutoyo]
Demonstration Architecture

• More accurate, more timely and more automated on-machine measurement

CNC with Twin Models

1. AP242 Tolerances
   Gate 1: AP242 -> ACIS
   Gate 2: MTConnect -> CMM
   Gate 3: QIF -> AP242

CMM with Gateways

1. Share stage model with required tolerances between CNC and CMM
2. Machine part with results to CMM as touch points on features/characteristics
3. Evaluation of tolerance compliance with results back to CNC for any necessary action

Model 1: Stage model
Model 2: Tooling model
Model 3: Result model

1. MTConnect Measurements

3. QIF Inspection results
Virtual model of part machined in Mukilteo

Are the features in tolerance?
Measurement Process

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Design to CAM/CMM
- via AP242 MBD
- CAM to CNC Machine with Digital Twin
  - Playback via MTConnect and AP238 for setup
- OMP streams through MTC to CMM
  - Probe points in part space
- CMM Analysis verifies Quality
  - Results return QIF Results
- MBD Gateway appends Quality Results to AP242
  - As-Designed and As-Measured PMI (Characteristics) packaged together

1. Design
   - AP242 MBD

2. Engineering – CAM
   - CNC Machine with Digital Twin
     - MTC recording from Mukilteo w/AP238 setup

3. MTC Agent
   - MTC Adapter Data w/ Sim or live OMP

4. Verification/Quality - CMM
   - MTC Agent Data w/ Sim or Live OMP
   - Probe points in part space

5. MBD Gateway
   - QIF Results

1' Performed at Mukilteo (see https://www.youtube.com/watch?v=Mjzg5nku5Lg)

2' Performed at DMDII with a virtual CNC in NY and a virtual CMM in Chicago
Input: Tolerances and probe points in AP242
1. Planner*: Measurements from AP242

* MiCAT Planner 1.5 special version for DMDII O3 Investigation Only

Semantic Tolerance
Measurement point
2. Digital twin measurements using AP238

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http://swim.steptools.com:8080

Machining Twin

Touch Probe

Virtual Part from MTConnect recording
3. Measurement points in MTConnect agent

http://swim.stepools.com:5000/current

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Linear X

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4. MeasurLink* generating QIF Results

* MeasurLink v8.2.1 (released Dec 2016) and newer
5. Viewer showing QIF Results in AP242
Internal: UUID’s that relate all the data

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STEP Data

QIF Data

MTConnect Adapter Data
How?

• Planning
  • UUID assigned to each tolerance and characteristic in STEP
  • UUID translated into CMM server database

• Manufacturing
  • UUID of measured characteristic put into MTConnect stream
  • UUID of measured characteristic put into QIF results
  • UUID of corresponding tolerance put into QIF results
  • UUID of tolerance read by digital twin
Why? - Increased Productivity

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- Design requirements sent direct to planning and manufacturing
  - Automated planning to meet the tolerances
  - Automated detection and correction of anomalies
- Integration of CNC and CMM functions
  - Single setup
  - On demand measurement
- Tooling optimization
  - Feed speed optimization
  - Adaptive programming
D2MIV 2 and DMDII O3

- **Near-term Gaps**
  - Measurement Geometry – Taper Circle example (NIST FTC)
  - UOS Tolerance
  - Surface Roughness
  - Agreed upon list of assoc. features and characteristics
  - Criticality Attribute - safety or functional
  - Traceability - UUIDs/QPids
  - QIF Results back to Design and Manufacturing

- **Longer-term Gaps**
  - Authentication - security checksum
  - Extending Validation
  - Metadata – External to the model (who, what, where when and why)
  - Certification to Standards

*Demonstrated*
Design to Metrology - Vision

TBD
A Vision for Interop. between Design & Inspection

- **Characteristics linked to design features**
  - Brep w/PMI (CAD)

- **Characteristics linked to shape aspects**
  - Brep w/PMI (AP242)
  - Brep w/PMI (eACIS/QIF)

- **As-Measured Physical Part (COP)**

- **Validate**

- **Characteristics linked to QIF Features**
  - As-Measured Actuals (QIF)

- **FAI Planning**
  - SPC Planning

- **FAI Execution**
  - SPC Analysis

- **FAI Results**
  - SPC Results

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Next Steps

Gaps in PMI support important for Mfg/Metrology
  • Surface Finish, Welds, Material
  • Inclusion of Precision
  • UOS Tolerance

UUIDs for Traceability
  • Recommended Practice for Cax Testing

Demonstration of feedback from Metrology (QIF) to Design/Manufacturing (STEP)
  • Add Alternate Shape Representations
  • Add Alternate PMI elements
  • Add Status and RPN
In closing…

- The building blocks we are setting into place are now forming the foundation for a Standards-based MBE process
  - CAD companies, interop. vendors, end-users, and consortia are all engaged and benefiting from the results of early research
  - Engaging downstream vendors and consumers in the process will accelerate the momentum around MBE
  - Research is now beginning to deliver the promise of real benefits to downstream consumers of MBD data