Test report for the STEP AP242 Benchmark #3

*CAD test case – Short Report*

September 2020 – Version 1.0: released
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Abstract
The STEP AP242 Benchmark is an AFNeT and prostep ivip associations project with the support of several industry associations (GIFAS, PFA, VDA).

The objective of this benchmark is to provide a public status of STEP AP242 functionalities available for operational use, tested by the industry and to identify limitations of the tested PLM COTS AP242 applications.

The Benchmark #3 includes two work packages: CAD test cases and PDM test cases. This document is the test suite of the CAD benchmark and defines the CAD test cases.

The test results are documented for each implementation participating in the benchmark. The tests are based on the exchange of 3D PMI semantic representation linked to graphic presentation and 3D exact geometry, the correctness and conformity of the STEP files, the fulfilment of end-to-end assembly validation properties, and the end-user validation. Furthermore, the test results are derived to provide conclusions on the general maturity of STEP AP242 based implementations, related to the tested CAD functionalities.

Related websites
AP242 project:  http://www.ap242.org/
AP242 benchmarks:  http://benchmark.ap242.org/
PDM-IF:  http://www.pdm-if.org/
CAx-IF:  http://www.cax-if.org/

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1 Introduction

ISO 10303 STEP AP242 is available for the Automotive and Aerospace industries, as well as many other branches of the manufacturing industry, as a unique product standard for Managed model-based 3D engineering data interoperability. STEP AP242 has been released as "International Standard" (IS) in August 2014 and the edition 2 is published in April 2020. Multiple COTS applications have been tested by the CAx Implementor Forum and the PDM Implementor Forum based on the 2014 AP242 edition 1.

STEP AP242 applications become increasingly important for CAD and PDM interoperability in the manufacturing industries. This project allows our communities to reach a status of maturity for these applications. The benchmarking activities are needed to apply quality control to AP242 based implementations.

Therefore, AFNeT and prostep ivip decided to conduct the STEP AP242 Benchmarks and to support the user community represented by several industry associations (GIFAS, PFA, VDA) and manufacturers which drive the project, for getting an independent assessment of COTS STEP AP242 ed1 interfaces.

![Figure 1 – V cycle for STEP AP242 solutions](image)

The objective of this Benchmark is to provide a public status of STEP AP242 functionalities available for operational use, driven by the industry, and to identify limitations of the tested PLM COTS AP242 applications.

This project is composed of two work packages:

- CAD work package managed by AFNeT;
- PDM work package managed commonly by AFNeT and prostep ivip.

The organization of this benchmark is based on the following principles:

- business priorities defined by the industry stakeholders supporting the STEP AP242 Benchmark;
- AP242 interoperability functionalities already tested by the CAx-IF and PDM-IF;
- tests based on STEP AP242 COTS solutions available on the market or on their way to be shipped to the industry.
This document presents the test suite of the CAD test case which covers the tests of the following AP242 PDM functionalities:

- exchange of 3D PMI semantic representation linked to graphic presentation and 3D exact geometry;
- correctness and conformity of the STEP files;
- fulfilment of end-to-end assembly validation properties;
- and end-user validation.

Furthermore, the test results are derived to provide conclusions on the general maturity of STEP AP242 based implementations, related to the tested CAD functionalities.

Since PLM vendors and CAD integrators constantly enhance the functionalities and robustness of their STEP AP242 edition 1 interfaces, the results of this Benchmark provide a snapshot of the functionalities tested at a certain moment in time for a specific version of the vendors' solutions. New editions of this benchmark will be conducted, addressing additional software & functionalities.
2 References and terms

2.1 Reference documents

<table>
<thead>
<tr>
<th>Name</th>
<th>Status / version</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEP AP242 edition 1 AIM long-form EXPRESS schema</td>
<td>IS</td>
<td><a href="http://www.cax-if.org/documents/ap242_is_mim_if_v1.36.zip">http://www.cax-if.org/documents/ap242_is_mim_if_v1.36.zip</a></td>
</tr>
</tbody>
</table>

Table 1 – Reference documents

2.2 Abbreviations

AIM Application Interpreted Model  
CAD Computer-Aided Design  
CAx-IF CAx Interoperability Forum  
COTS Commercial off-the-shelf  
GIFAS Groupement des Industries Françaises Aéronautiques et Spatiales  
IS International Standard  
ISO International Standardization Organization  
PDF Portable Document Format (ISO 32000)  
3D PDF 3D viewer format defined by PDF/E (ISO 24517)  
PLM Product Life-cycle Management  
Part 21 ISO 10303-21  
P21 Part 21  
PFA Plateforme France Automobile  
PMI Product and Manufacturing Information  
SFA STEP File Analyzer  
STEP STandard for the Exchange of Product model data  
STEP AP242 STEP Application Protocol: Managed model-based 3D engineering (ISO10303-242)  
VDA Verband Der Automobilindustrie  
VP Validation Property
3 Test methodology

3.1 General testing instructions

The in-scope tested interface solutions are CAD applications, converters, connectors, and viewers. Before the test phase, a pre-test session has been performed by the vendors in order to define the right settings. The test model has been provided by the "Benchmark Technical Team" to the Vendors.

The native formats of this benchmark for the converters, connectors, and viewers are limited to the following one:

- CATIAv5;
- Creo;
- NX.

The selection of these native formats has been done in order to decrease the test phase workload according to the availability of the resources.
### 3.2 Test procedure

The test procedure is:
- first, the creation of STEP files from all the selected applications;
- then, the selection of the STEP files based on the syntax check and the loop tests (conversion from STEP to native with the same application used for the conversion from native to STEP);
- finally, the import of the selected STEP files into all in-scope applications.

The selection of the best STEP files has been done in order to decrease the test phase workload according to the availability of the resources. A systematic import of a STEP file in each application increases the workload, depending on the number of applications able to create the STEP files, and the quality issues of the STEP files.

![Diagram of test procedure](image)

**Figure 2 – Illustration of the CAD test procedure**

### 3.3 Rules of STEP file selection for phase 2

The general approach was to select a STEP file of good quality for each functionality tested in phase 2. The selection criteria that needed to be fulfilled are listed below:
- no major errors listed in the export log files;
- completeness of critical content;
- loop test successful (import into the exporting system using the same translator);
- no major errors in the validation properties;
- no major syntax errors in the STEP file;
- no major errors regarding conformity to the EXPRESS schema;
- conformance to relevant CAx-IF Recommended Practices. The “NIST STEP File Analyzer” has been used to verify the conformance.
4 Test case: PMI semantic representation linked to 3D exact geometry

4.1 Motivation

Product and Manufacturing Information (PMI) is required for several business use cases in the context of STEP data exchange. Among others, it is a pre-requisite for long-term data archiving. In addition, PMI can be used to drive downstream applications such as coordinate measuring and manufacturing.

Semantic PMI Representation relates to the capability to store PMI data in the STEP file in a computer-interpretable way, so that it can be used for model redesign or downstream applications. Though the definition of the data is complete, it is by itself not visible in the 3D model. Additional presentation capabilities are needed to display the data in a way that it is visible to the user in the 3D model.

4.2 Approach

The approach is to create STEP files containing the semantic representation linked to the graphic presentation. The import of the STEP file allows to check:

- the number of semantic PMI;
- the semantic of the PMI;
- the PMI validation properties.

The STEP files had to be created according to the CAX-IF recommended practices. And especially, the CAX-IF Recommended Practices for the Representation and Presentation of Product Manufacturing Information (PMI) (AP242) shall be applied.

4.3 Test model overview

The description of the test cases is available at https://pages.nist.gov/CAD-PMI-Testing/models.html
4.4 Test model configuration
The Native to STEP interfaces must export the geometry as exact geometry with:

- the graphic presentation of the PMI (tessellated or polyline);
- the semantic representation of the PMI.

The file shall be compliant to the STEP AP242 edition 1 AIM Long form express schema.

The encoding of the STEP shall be done according to ISO 10303-21.

The STEP file shall not be compressed.

The STEP file shall contain the PMI validation properties:
- number of annotations;
- affected Geometry.

4.5 Statistics
Statistics concerning the conversion (come from logs): PMI semantic (GD&T) and related validation properties are well converted (export and import).

Statistics concerning the end-user check: the fact that the imported PMI semantic is modifiable in the CAD system is verified.
### 4.6 Test criteria

The detailed test criteria are described in the table below. The following row names are the rows composing the result tables:

- Number of semantic PMI: Summary;
- Quality of the Semantic PMI: Summary;
- PMI VP: Summary.

<table>
<thead>
<tr>
<th>Criteria name</th>
<th>Test criteria description</th>
</tr>
</thead>
</table>
| **Source format**                          | • Phase 1: source CAD system  
   • Phase 2: = STEP                                                                                                                                                                                                       |
| **Target format**                          | • Phase 1: = STEP  
   • Phase 2: target CAD system                                                                                                                                                                                            |
| **Solution name**                          | Name of the tools used to perform the conversion                                                                                                                                                                              |
| **Number of log errors**                   | • Phase 1: Number of errors reported in the conversion log file during the native format to STEP conversion  
   • Phase 2: Number of errors reported in the conversion log file during STEP conversion (read or import)  
   The number are “type number” (if an error occurs several times it is count as 1)                                                                                                                                          |
| **Number of loop errors**                  | Number of errors reported in the conversion log file during the loop test (= imported with the same system)  
   Not relevant for phase 2  
   The number are “type number” (if an error occurs several times it is count as 1)                                                                                                                                      |
| **Number of SFA errors**                   | Number of errors reported by the NIST STEP file analyser  
   The number are “type number” (if an error occurs several times it is count as 1)                                                                                                                                       |
| **End-user validation of the number of**   | The end user tests that the Number of Semantic Dimensional Location and size in the target CAD system is the same as it in the native CAD System                                                                                       |
|   | semantic dimensions                        |                                                                                                                                                                                                                            |
| **End-user validation of the number**      | The end user tests that the Number of Semantic Geometric Tolerance in the target CAD system is the same as it is in the native CAD System                                                                                         |
|   | semantic tolerances                        |                                                                                                                                                                                                                            |
| **End-user validation of the number**      | The end user tests that the Number of Semantic Datum Feature in the target CAD application in the target CAD system is the same as it in the native CAD System                                                                     |
|   | semantic data                              |                                                                                                                                                                                                                            |
| **Number of semantic PMI:**                | The end user concludes on the global support level of the PMI VP.  
   This criteria is a row in the test result tables.  
   * See Table 4 – Criteria ratios for each criterion for the rules to conclude on the global support level.                                                                 | **Summary**                                                                 |
| **End-user validation of the semantic**    | The end user test of the Semantic Dimensional Location and size in the CAD application:  
   • The PMI shall not be corrupted  
   • The PMI shall be modifiable.  
   • The value shall be correct.                                                                                                                                            | dimensions                        |
| **End-user validation of the semantic**    | The end user test of the Semantic Geometric Tolerance in the CAD application:  
   • The PMI shall not be corrupted  
   • The PMI shall be modifiable.  
   • The value shall be correct.  
   • The datum system are correct (if applicable)  
   • The modifier are correct (if applicable)                                                                                                                                     | tolerances                        |
| **End-user validation of the semantic**    | The end user test of the Semantic Datums in the CAD application:  
   • The PMI shall not be corrupted  
   • The PMI shall be modifiable.  
   • The value shall be correct.                                                                                                                                            | data                              |
| **Quality of the Semantic PMI:**          | The end user concludes on the global support level of the PMI VP.  
   This criteria is a row in the test result tables.  
   See Table 4 – Criteria ratios for each criterion for the rules to conclude on the global support level.                                                                 | **Summary**                                                                 |
The following table contains the ratios between the test criteria used to compute the “% of success” of summarized results.

<table>
<thead>
<tr>
<th>Criteria name</th>
<th>Weight of each criteria to conclude on the summary rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-user validation of the number of semantic dimensions</td>
<td>33%</td>
</tr>
<tr>
<td>End-user validation of the number of semantic tolerances</td>
<td>33%</td>
</tr>
<tr>
<td>End-user validation of the number of semantic data</td>
<td>33%</td>
</tr>
<tr>
<td><strong>Number of semantic PMI:</strong></td>
<td><strong>Average</strong></td>
</tr>
<tr>
<td>End-user validation of the semantic dimensions</td>
<td>33%</td>
</tr>
<tr>
<td>End-user validation of the semantic tolerances</td>
<td>33%</td>
</tr>
<tr>
<td>End-user validation of the semantic data</td>
<td>33%</td>
</tr>
<tr>
<td><strong>Quality of the Semantic PMI:</strong></td>
<td><strong>Average</strong></td>
</tr>
<tr>
<td>Validation of the number of PMI VP during the export written in the STEP file</td>
<td>25%</td>
</tr>
<tr>
<td>Validation of the number of PMI VP during the import computed by the interface</td>
<td>25%</td>
</tr>
<tr>
<td>Validation of the functionality of the comparison of the number of PMI VP read and computed</td>
<td>25%</td>
</tr>
<tr>
<td>Validation of the functionality of the comparison of affected geometry VP read and computed</td>
<td>25%</td>
</tr>
</tbody>
</table>

*See Table 4 – Criteria ratios for each criterion for the summary of the long report.*
<table>
<thead>
<tr>
<th>Criteria name</th>
<th>Weight of each criteria to conclude on the summary rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of semantic PMI: Summary</td>
<td>33%</td>
</tr>
<tr>
<td>Quality of the Semantic PMI:</td>
<td>33%</td>
</tr>
<tr>
<td>Summary</td>
<td></td>
</tr>
<tr>
<td>PMI VP:</td>
<td>33%</td>
</tr>
<tr>
<td>Summary</td>
<td></td>
</tr>
<tr>
<td>Public Result</td>
<td>Average</td>
</tr>
<tr>
<td>Summary</td>
<td></td>
</tr>
</tbody>
</table>

*Table 5 – Criteria ratios for each criterion for the summary of the short report*
5 Tested solutions & test results

This chapter presents the following results:

Overview of all tests results

This part is presented using a table with summarized test criteria and tested solutions. The corresponding summary private table is fully detailed in the long report. The Table 5 – Criteria ratios for each criterion for the summary of the short report – specifies the ratios between the test criteria used to compute the “% of success” of summarized results.

Test results by functionalities and STEP conformity criteria

The intention of this Benchmark is not only to give an assessment of individual software tools, but also to derive a statement concerning the general maturity of STEP AP242 based implementations.

The test results are grouped by functionality. This helps the reader to answer general questions such as “how good does the transfer of relevant information work overall?”.

The results are grouped together so that it provides an overall assessment of the state of the art for STEP interfaces. It also enables to reflect the main criteria implementation maturity.

The test results are combined to provide a rating of STEP and EXPRESS conformity. This renders a rating of the quality of the implementation and the conformity of the exchanged dataset, rather than the quality of the data exchange.

NOTE Test results per solutions:

This part presents in detail the results for each participating interface solution. The related clauses per solution is not in the public report.

5.1 Tested solutions

<table>
<thead>
<tr>
<th>Company</th>
<th>Application name</th>
<th>Solution type</th>
<th>Tested conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT CoreTechnologie</td>
<td>3D_Evolution 4.3 SP1</td>
<td>Converter</td>
<td>CATIA V5 ⇔ STEP AP242&lt;br&gt;NX ⇔ STEP AP242&lt;br&gt;Creo ⇔ STEP AP242</td>
</tr>
<tr>
<td>Dassault Systèmes</td>
<td>CATIA V5-6R2020 SP1</td>
<td>CAD System</td>
<td>CATIA V5 ⇔ STEP AP242</td>
</tr>
<tr>
<td>Dassault Systèmes</td>
<td>3DEXPERIENCE R2020x FD01</td>
<td>CAD System</td>
<td>3DEXPERIENCE ⇔⇔⇔ STEP AP242</td>
</tr>
<tr>
<td>Datakit</td>
<td>CrossManager V2020.1</td>
<td>Converter</td>
<td>CATIA V5 ⇔ STEP AP242&lt;br&gt;NX ⇔ STEP AP242&lt;br&gt;Creo ⇔ STEP AP242</td>
</tr>
<tr>
<td>Elysium</td>
<td>ASFALIS EX8.2</td>
<td>Converter</td>
<td>CATIA V5 ⇔ STEP AP242&lt;br&gt;NX ⇔ STEP AP242&lt;br&gt;Creo ⇔ STEP AP242</td>
</tr>
</tbody>
</table>

* As considered for this benchmark.
5.2 Overview of the test results

This clause presents the Table 7 – Public short summary of the test results per applications and per targeted format and the meaning of the symbols is described in on Table 8 – Legend. The criteria results are based on Table 4 – Criteria ratios for each criterion and on Table 5 – Criteria ratios for each criterion for the summary of the short report.

<table>
<thead>
<tr>
<th>CoreTechnologie</th>
<th>Dassault Systèmes</th>
<th>Datakit</th>
<th>Elysium</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D_Evolution v4.3 SP1</td>
<td>CATIA V5R2020 SP1</td>
<td>3DEXPERIENCE R2020x FD01</td>
<td>CrossManager V2020.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NATIVE to STEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATIAv5</td>
</tr>
<tr>
<td>Creo</td>
</tr>
<tr>
<td>NX</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STEP to NATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATIAv5</td>
</tr>
<tr>
<td>Creo</td>
</tr>
<tr>
<td>NX</td>
</tr>
</tbody>
</table>

Table 7 – Public short summary of the test results per applications and per targeted format

<table>
<thead>
<tr>
<th>Test result</th>
<th>Symbol</th>
<th>% of success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success</td>
<td>●</td>
<td>100%</td>
</tr>
<tr>
<td>Partial success</td>
<td>●</td>
<td>&gt;66%</td>
</tr>
<tr>
<td>fail</td>
<td>●</td>
<td>&gt;33%</td>
</tr>
<tr>
<td>Total Fail</td>
<td>●</td>
<td>&lt;33%</td>
</tr>
<tr>
<td>Not supported</td>
<td>●</td>
<td>&lt;0%</td>
</tr>
<tr>
<td>Not applicable</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

Table 8 – Legend

NOTE  Dassault Systèmes’s CATIA v5-6 & 3DEXPERIENCE are considered CAD systems, thus the presented results are STEP export and STEP import instead of respectively NATIVE to STEP and STEP to NATIVE.
5.3 Test results by STEP AP242 functionalities and conformity criteria

Semantic PMI is a recent functionality and the related Recommended Practices are still evolving. But it has to be noted that semantic PMI STEP exports in interface solutions are more and more available and reliable, knowing that industries show strong needs for this STEP functionality.

Currently there are at least one native to STEP interface solutions for each source format, whereas there is a lack of STEP to native interface solutions. Only one solution provides an implementation to convert STEP dataset to NX format, and none for STEP to Creo. As a conclusion, the validation by this benchmark is done with the means available that does not allow to check the full semantic conformance of the PMI. Moreover, the scope of the benchmark is limited to a few numbers of PMI because of the recent covered implementations. And finally, the results assess the STEP interfaces maturity within use cases of CAD to CAM exchanges and of long-term archiving, and not CAD to CAD exchanges.

Regarding the type of Semantic PMI, Datum PMI are fully successfully converted, and geometric tolerance results also show a high success rate. Nevertheless, there is less success on repetitive and multiple features associated to a semantic PMI, and less success for semantic geometric dimension PMI as well. The Figure 4 below presents the expected semantic PMI matching in percentage for all types of PMI.

As a remark, the initial intent was to use a test case using ISO GPS (ISO 1101, etc.), but because of a lack of representative public test cases designed with this standard in each format, this Benchmark used the test case based on the ASME standard.

![Figure 4 - Expected Semantic PMI matching pie chart in percentage](image)
6 Summary

The objectives of the industry are reached only when COTS STEP AP242 applications are available and used by a broad community, with the appropriate level of functionalities and quality.

This Benchmark #3 provides a snapshot of STEP AP242 interoperability functionalities of priority one requested by the industries. It is focused on a specific scope of STEP AP242 edition 1 functionalities already assessed by the CAx-IF.

The following criteria were evaluated:
- syntax quality control of STEP files;
- validation of the conversion of the detailed content of the source information;
- end-to-end quality control of conversion based on STEP validation properties.

For STEP AP242 P21 Semantic PMI associated to P21 exact 3D geometry dataset, test results present a good and positive level of implementation despite of the recent publication of the related Recommended Practices.

Some findings of the AFNeT Benchmark will be communicated to the CAx-IF as an input for the update of the STEP AP242 Recommended Practices. In addition, other outcomes will be provided for the development and for requirements of the edition 3.

The use of international open standards for 3D Model Based interoperability is a key enabler to support global engineering and manufacturing of complex products within the extended enterprise. It also contributes to ensure a better independence regarding PLM Editor's proprietary formats, and long-term preservation of 3D Model Based design. The availability of COTS STEP AP242 solutions for PDM, CAD and 3D visualization data interoperability contributes to answer to this challenge.

The present Benchmark provides the status of COTS STEP AP242 CAD converters and viewers in early 2020. The versions of these applications, which will be released in late 2020, provide important enhancements. Their testing will be completed by next benchmark editions. Moreover, next benchmark editions will address additional software & functionalities, especially regarding the Edition 2 of AP242 published in early 2020, which includes enhancements and new capabilities.

7 Publications

The detailed documentation of the STEP AP242 Benchmarks of the PDM and CAD test cases is only available for the participating Vendors & Industrials, and is accessible from the following website:

Short Reports are publicly available on: http://benchmark.ap242.org

8 Acknowledgements

The AFNeT association acknowledges the support, help and participation of the Editors who provided their COTS applications for the benchmark testing, the installation, and for the analysis of the tests results.

The AFNeT association is grateful to the NIST for the STEP File Analyzer tool and the use of the public test cases, and to the CAx Interoperability Forum for the STEP Recommended Practices.

The AFNeT association particularly thanks the participating Vendors, GIFAS and PFA, for their funding, orientations, and for making this project feasible.