STEP AP242 Benchmark

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.

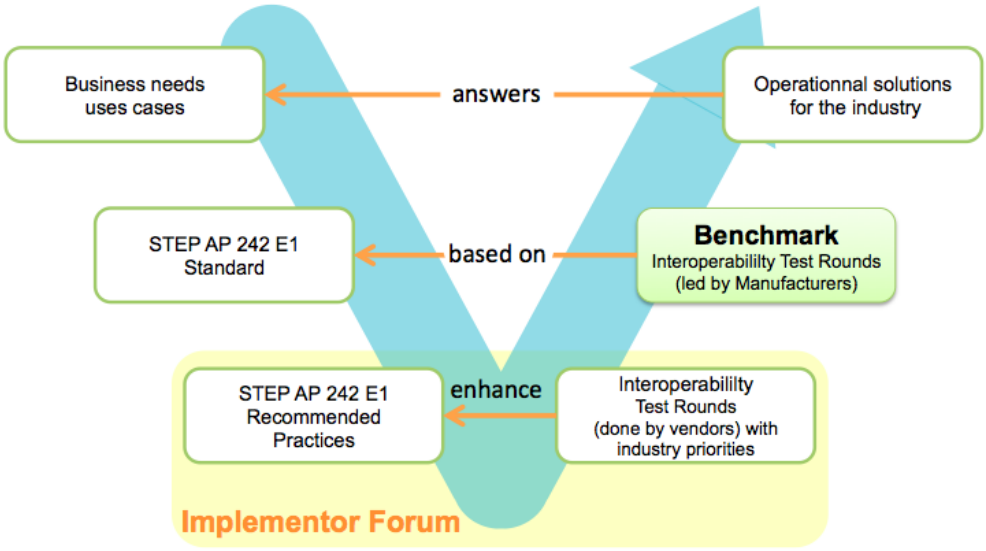


Figure 1 – V cycle for STEP AP242 solutions

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

Name	Status / version	Link
CAx-IF Recommended Practices for the Representation and Presentation of Product Manufacturing Information (PMI) (AP242)	Release 4.0 or earlier (4.04 or 4.06, available for CAx-IF member)	https://www.cax-if.org/documents/rec_pracs_pmi_v40.pdf
STEP AP242 edition 1 **AIM long-form EXPRESS schema**	IS	https://www.cax-if.org/documents/ap242_is_mim_lf_v1.36.zip
NIST STEP File Analyzer	3.81	https://www.nist.gov/services-resources/software/step-file-analyzer-and-viewer

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.

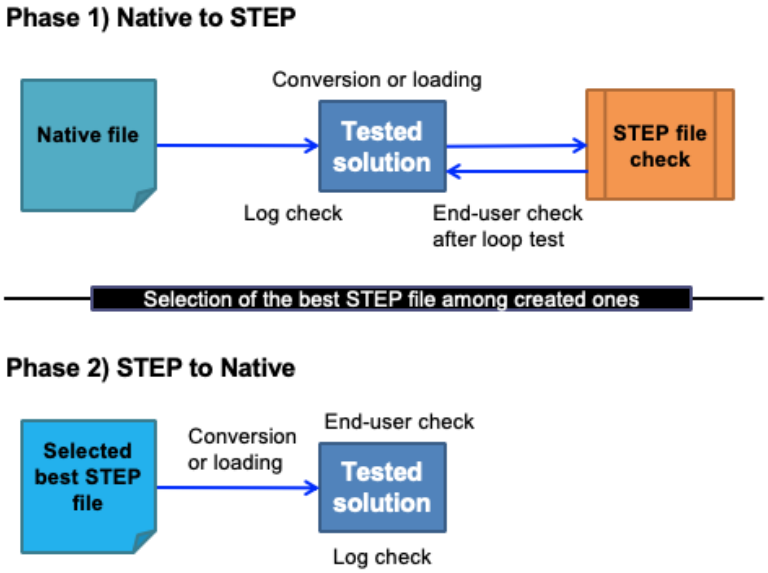


Figure 2 – Illustration of the CAD test procedure

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.

The test model comes from NIST “MBE PMI Validation and Conformance Testing” (http://www.nist.gov/el/msid/infotest/mbe-pmi-validation.cfm).

4.3 Test model overview

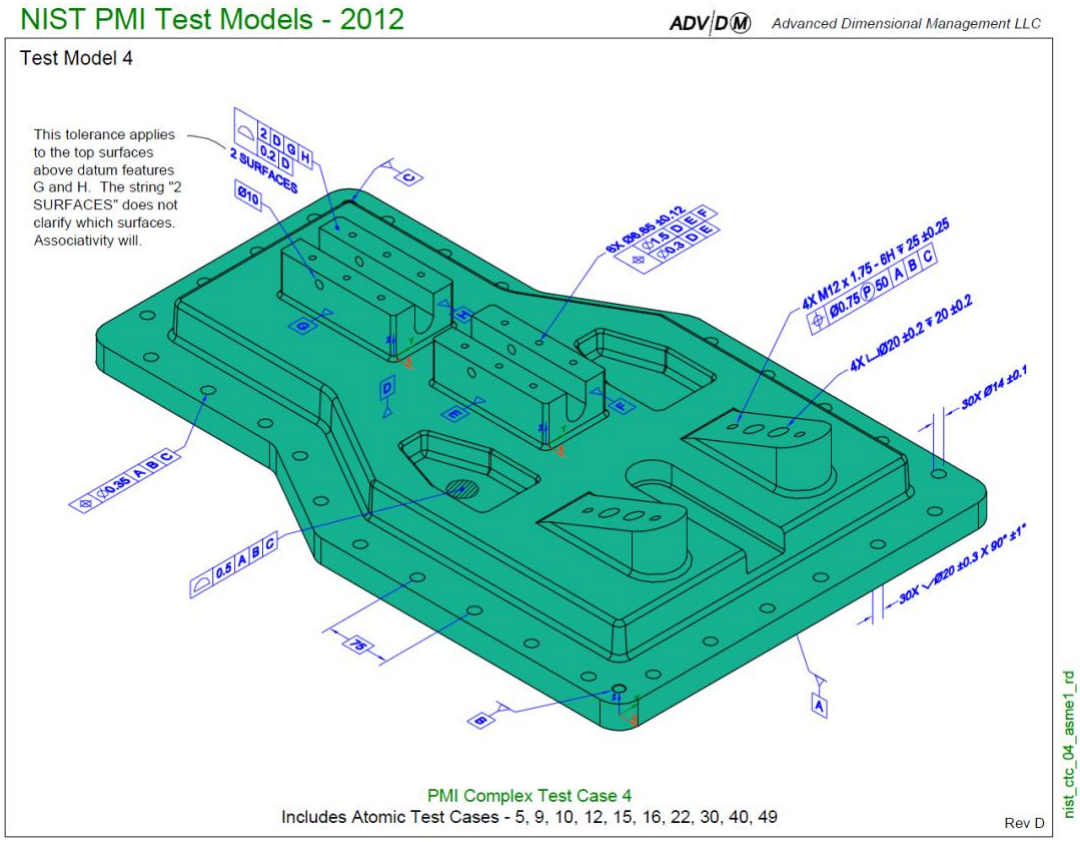


Figure 3 – nist_ctc_04_asme1_ct5210_rc illustration

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.

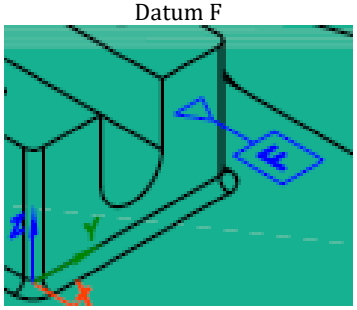
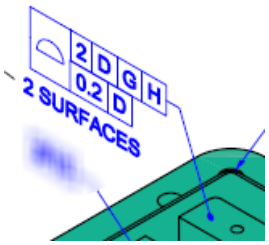
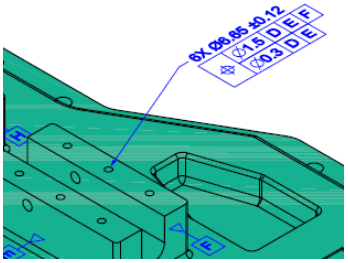
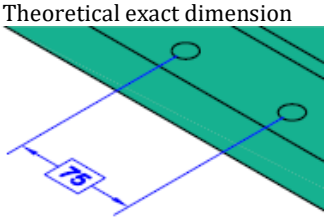
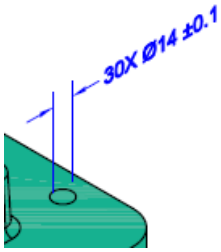
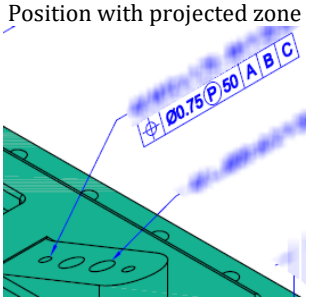
Datum F 	Composite Feature Control Frame 	Composite Feature Control Frame on multiple feature 
Theoretical exact dimension 	Multiple feature size 	Position with projected zone 

Table 2 – List of GD&T for the end-user check for nist_ctc_04_asme1_ct5210_rc

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.

Criteria name	Test criteria description
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 semantic dimensions	The end user tests that the Number of Semantic Dimensional Location and size in the target CAD system is the same as it is in the native CAD System
End-user validation of the number of semantic tolerances	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
End-user validation of the number of semantic data	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 is in the native CAD System
Number of semantic PMI: Summary	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.
End-user validation of the semantic dimensions	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.
End-user validation of the semantic tolerances	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)
End-user validation of the semantic data	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.
Quality of the Semantic PMI: Summary	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.

Criteria name	Test criteria description
Validation of the number of PMI VP during the export written in the STEP file	Total Number of Semantic PMI of the part as it is written in the STEP file and computed during the export (NIST SFA can be used to extract this value)
Validation of the number of PMI VP during the import computed by the interface	Total Number of Semantic PMI of the part as it is computed by the STEP interface during the import (Phase 1: loop test)
Validation of the functionality of the comparison of the number of PMI VP read and computed	pass/fail: end-user validation of the functionality of the comparison of the number of Semantic PMI VP read and computed.
Validation of the functionality of the comparison of affected geometry VP read and computed	pass/fail: end-user validation of the functionality of the comparison of affected geometry area VP read and computed.
PMI VP: Summary	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.

Table 3 – Test criteria

The following table contains the ratios between the test criteria used to compute the "% of success" of summarized results.

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

Table 4 – Criteria ratios for each criterion for the summary of the long report

Criteria name	Weight of each criteria to conclude on the summary rows
Number of semantic PMI: Summary	33%
Quality of the Semantic PMI: Summary	33%
PMI VP: Summary	33%
Public Result Summary	Average

Table 5 – Criteria ratios for each criterion for the summary of the short report

5 Tested solutions & test results

This chapter present 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

Company	Application name	Solution type *	Tested conversion
CT CoreTechnologie	3D_Evolution 4.3 SP1	Converter	CATIA V5 ⇨ STEP AP242 NX ⇨ STEP AP242 Creo ⇨ STEP AP242
Dassault Systèmes	CATIA V5-6R2020 SP1	CAD System	CATIA V5 ⇦⇨ STEP AP242
Dassault Systèmes	**3D**EXPERIENCE R2020x FD01	CAD System	**3D**EXPERIENCE ⇦⇨ STEP AP242
Datakit	CrossManager V2020.1	Converter	CATIA V5 ⇨ STEP AP242 NX ⇨ STEP AP242 Creo ⇨ STEP AP242
Elysium	ASFALIS EX8.2	Converter	CATIA V5 ⇦⇨ STEP AP242 NX ⇦⇨ STEP AP242 Creo ⇨ STEP AP242

Table 6 – CAD systems and converters

* 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.

	CoreTechnologie	Dassault Systèmes		Datakit	Elysium
	3D_Evolution v4.3 SP1	***CATIA V5R2020 SP1***	***3DEXPERIENCE R2020x FD01***	***CrossManager V2020.1***	***ASFALIS EX8.2***
NATIVE to STEP					
CATIAv5	●	●	●	●	●
Creo	◕	n/a	n/a	●	●
NX	◕	n/a	n/a	●	●
STEP to NATIVE					
CATIAv5		●	●		◕
Creo		n/a	n/a		
NX		n/a	n/a		◕

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

Test result	Symbol	% of success
Success	●	100%
Partial success fail	◕	>=66%
	◑	>=33%
	◔	<33%
Total Fail	○	=0%
Not supported		
Not applicable	n/a	

Table 8 – Legend

NOTE Dassault Systèmes's CATIA v5-6 & **3D**EXPERIENCE 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.

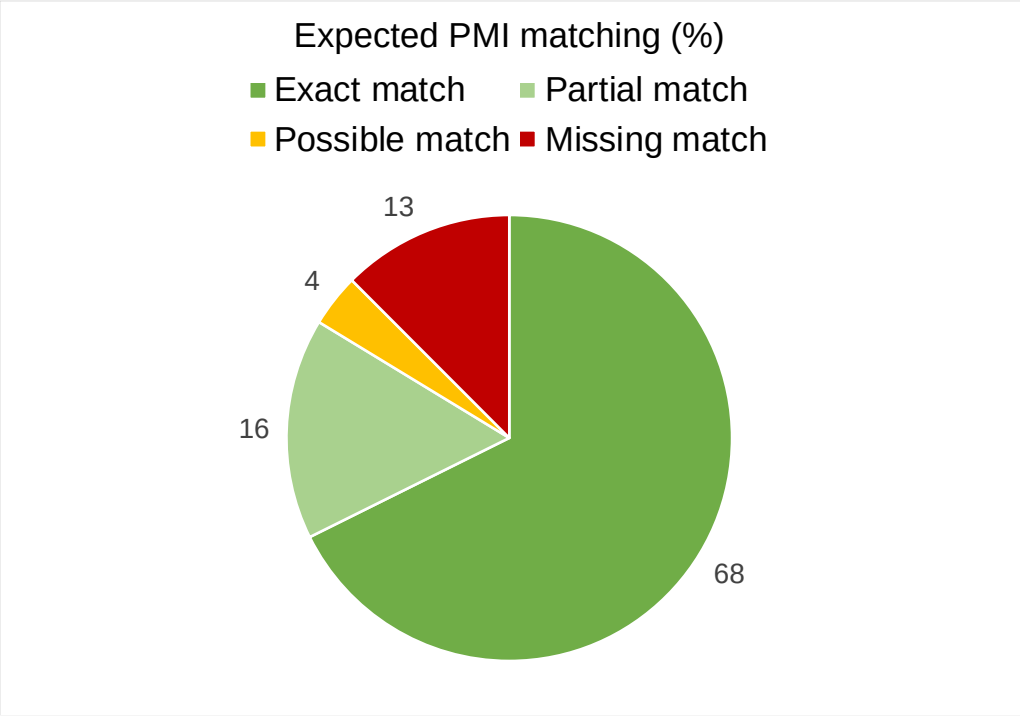


Figure 4 – Expected Semantic PMI matching pie chart in percentage

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:

- http://www.afnet.fr/dotank/sps/ap242benchmark/

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.