

AIPS
Airbus Process Specification
Filament Layer Manufacturing

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Contents

AIPS

- 1 Scope
- 2 Normative References
- 3 Definition, Applicability and Limitations
- 4 Engineering Requirements
- 5 Technical Qualification
- 6 First Part Qualification
- 7 Measurement of tensile properties
- 8 Rework
- 9 Environment, Health and Safety

1 Scope

This Airbus Process Specification defines the Engineering requirements for the Filament Layer Manufacturing (FLM) process.

This specification does not give detailed instructions; these are given in the Process Instructions (PI) / Airbus Process Instruction (API) and the Work Instructions.

This specification shall not be used as an inspection document.

It shall be applied when mentioned in the relevant standard, material specification or Definition Dossier.

2 Normative References

Only normative references cited in the text are listed hereafter.

The latest issue of the publication referenced shall be used.

ISO291	Plastics – Standard atmospheres for conditioning and testing
ISO527-2	Plastics – Determination of tensile properties – Part 2: Test conditions for moulding and extrusion plastics
ISO1183	Plastics – Method for determining the density of non-cellular plastics
ISO/ASTM52900	Additive manufacturing — General principles — Terminology
ISO/ASTM52921	Standard terminology for additive manufacturing—Coordinate systems and test methodologies
EN9103	Aerospace Series - Quality management systems - Variation management of key characteristics ¹
A1091	Airbus Directive – Airbus Requirements for the Management of Hazardous Substances
AITM2-0002	Flammability of non-metallic materials – Small burner test

3 Definition, Applicability and Limitations

3.1 Definition

3.1.1 Batch

A quantity of non-reinforced thermoplastic material manufactured at one time with unique features, e.g. single color or melt viscosity.

3.1.2 FLM

Filament Layer Manufacturing (FLM) is a manufacturing process building three dimensional parts layer per layer. A plastic filament is fused and deposited on a build sheet creating each two dimensional layer in X and Y axis. Building up a three dimensional part, support material might be necessary to avoid part collapsing in e.g. overhang or cavity areas.

Figure A1 (Annex A) shows a schematic model of the FLM process.

3.1.3 Manufacturer

The company or organization responsible for producing the part in conformity with an Airbus drawing.

¹ Published as ASD Standard at the date of publication of this standard Process Instruction

3.1.4 Manufacturing shop

The specific workshop intended for manufacture to this Process Specification.

A document specifying the essentials of a process and the quality requirements for a specific manufacturing technology. It is a detailed in house Process Instruction and shall be used in conjunction with the drawing and relevant Airbus Process Specification.

3.1.5 Reference manufacturing shop

A manufacturing shop selected in order to develop a manufacturing process and improve current processes.

3.1.6 Rework

Rework means the removal of production and assembly related non-conformances with the aim of fulfilling the component requirements defined in engineering documents.

3.1.7 STL

STL is a file format used for model data describing the surface geometry of an object as a tessellation of triangles used to communicate 3D geometries to machines in order to build physical parts

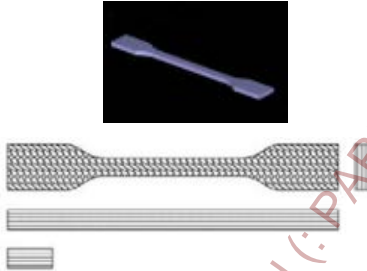
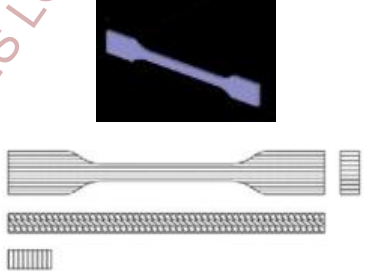
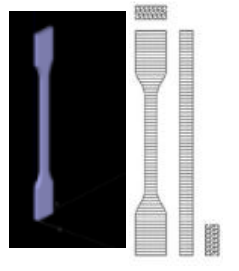
3.1.8 Support material

The support material is used to provide a build substrate if the component has undercuts or cavities. This additional material avoids the collapse of the part during the building process.

3.1.9 Build direction

Location of the part related to a coordination system according to ISO/ASTM52921 is described in the Table 1.

Table 1: Description of build direction according to ASTM52921

In-Plane		Out-of-Plane
 <p>Figure 1: YXZ=XYZ (XY) direction (0°;0°;0°=0°;0°;90°)</p>	 <p>Figure 2: XZY=YZX (XZ) direction (90°;0°;0° = 90°;0°;90°)</p>	 <p>Figure 3: ZXY=ZYX (ZX) direction (0°;90°;90° = 0°;90°;0°)</p>

Other definitions see ISO/ASTM52900

3.2 Applicability and Limitations

This Airbus Specification shall be applied to manufacture non-reinforced thermoplastic materials using the Filament Layer Manufacturing (FLM) process. It is applicable when it is invoked directly by the drawing or through another document for the purpose given in the scope.

The materials to be processed by the reference manufacturing shop under this specification shall be qualified by Airbus according to a pertinent Airbus Material Specification.

4 Engineering Requirements

Engineering requirements are minimum requirements specified by Responsible Engineering to ensure optimal performance of the manufacturing process.

All Engineering requirements have to be met and controlled in production.

4.1 Performance Requirements

Unless otherwise specified, the requirements of this specification shall be mandatory.

4.1.1 New Shop/Machine/Material

Each new shop shall be qualified for the process and each qualified shop which uses filament material shall make all tests for the new filament material as requested in chapter 5 "Technical Qualification". All required tests and results shall be summarized in a report and sent for validation to the responsible Airbus M&P department

4.1.2 Design / Part

The product form and dimensions shall conform to the relevant requirements specified on the drawing or another document.

The product weight shall conform to the requirements specified on the drawing or another document.

The product shall meet the mechanical and functional requirements specified on the drawing or another document.

The admissible tolerances of the process shall comply with the dimensional tolerances of the finished product.

The products shall fulfill the defect requirements according to Table 3, if not otherwise defined in the drawing or another document. Manufacturing process induced defects caused by displacement or temperature changes are visually observable. Therefore they can be sufficiently detected by visual inspection.

4.1.3 Defects

The definition of acceptable defects is dependant on part related requirements and printing direction.

Following defects serve as the baseline for the unacceptable defects.


Parts with defects described below shall be rejected.

For other defects please refer to relevant drawing set.

4.1.3.1 Examples of Extreme Defects.




Examples of extreme defects are described in the table 2

Table 2: Examples of Extreme Defects

Type of defect	Description of Failure	Example
Abnormal Printing	Failure in the printer	



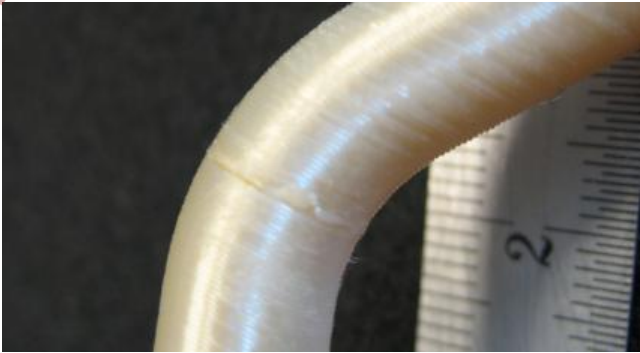
(continued)

Table 2: Examples of Extreme Defects (continued)

Type of defect	Description of Failure	Example
Abnormal printing	Clear defects in layer adhesion / filament stacking	
Abnormal printing	Surface abnormalities	
Abnormal printing	Delamination	


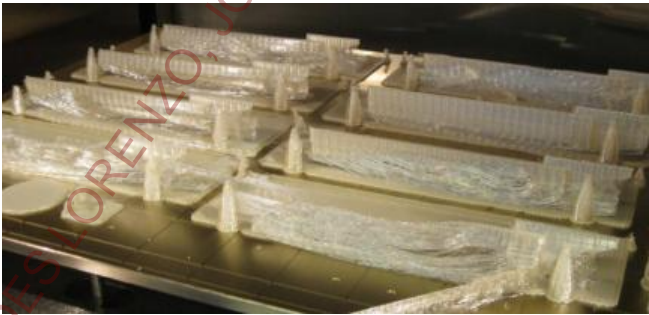
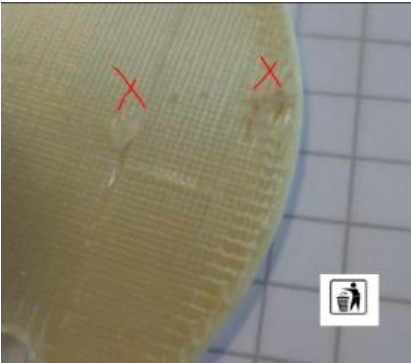
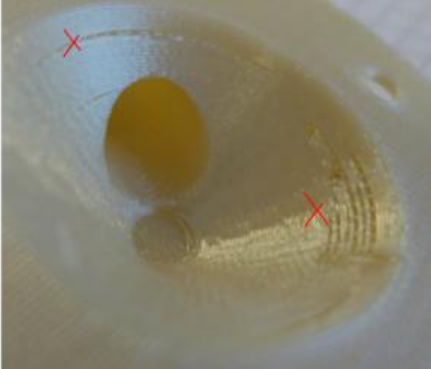
(continued)

Table 2: Examples of Extreme Defects (continued)

Type of defect	Description of Failure	Example
Abnormal Printing	Part not connected to build plate	
Abnormal Printing	Material missing / not finished print job	
Abnormal printing	Material missing / not finished print job	


(continued)

Table 2: Examples of Extreme Defects (continued)

Type of defect	Description of Failure	Example
Abnormal printing	Material missing / not finished print job	
Abnormal printing	Material missing / not finished print job	
Abnormal printing	Airbubbles within the part	
Abnormal printing	Material missing / not finished print	

(continued)

Table 2: Examples of Extreme Defects (concluded)

Type of defect	Description of Failure	Example
Abnormal printing	Material missing / Lack of material	

4.2 Other Requirements

4.2.1 FLM Material

The material performance according to the relevant Material Specification or other documents shall not be negatively influenced by the process.

The FLM materials and the finished product shall be free from external contaminants and irregularities not complying with the requirements of the Qualification Process.

Only specified and qualified materials shall be used.

The materials shall be stored damp proof and dust-free in sealed containers. The storage conditions for each specific material shall be indicated in the corresponding Material Specification, Individual Product Specification or Process Instruction.

After the required quantity of material has been processed, the unused material shall be stored with the necessary precautions to avoid any damage or contamination and to ensure its traceability in accordance with the relevant Material Specifications.

4.2.2 Support materials

Only approved support materials shall be used.

Only support materials that do not adversely affect the material / part properties shall be used.

The support material shall be removable and the removal process shall not influence the part negatively.

4.2.3 Additive Manufacturing procedure specification (APS)

For each machine an APS is required. The amount of testing required to validate a new APS or an updated APS depends upon the change categories "Major", "Midi" or "Minor". Any Major change leads to a new APS. The Categorisation of a change is captured in Table 3.

Table 3: Categorisation of Change for Test Requirements for APS validation

No.	Change	Categories	To be tested
1	Machine brand/Type	Full Qualification	Specimen
2	Configuration	Major	Specimen
3	Serial number	Midi	Specimen
4	Location	Midi	Specimen
5	Material supplier	Major	Specimen

Continued

Table 3: Catagorisation of Change for Test Requirements for APS validation (Concluded)

No.	Change	Categories	To be tested
6	Material, support	Major	Specimen
7	Build plate	Major	Specimen
8	Material specifications	Major	Specimen
9	Build temperatures	Major	Specimen
10	Build envelope temperature	Major	Specimen
11	Nozzle temperature during production	Major	Specimen
12	Nozzle temperature during standby	Major	Specimen
13	Machine software versions	Major	Specimen
14	Preparations software versions and tools to generate the machine-file	Midi	Specimen
15	Manufacturer maintenance specification reference	Minor	none
16	Manufacturer calibration specification reference	Minor	none

The APS shall be inline with the AIPI. The APS shall be held as Airbus retention policy and shall be available upon request from Airbus or Audit.

4.2.4 Facility

An adequate facility for processing shall be available.
Adequate storage facilities for FLM material, support material and finished products shall be available.
They shall be inside buildings and shall provide adequate protection from moisture, damage and contamination.

4.2.5 Equipment and tooling

The tooling and equipment used in the manufacturing process shall be approved.

Maintenance shall be scheduled and performed periodically to keep the machine in a safe and serviceable condition. The tip of the FLM machine shall be changed regularly in order to avoid optical defects of the finished products and a variation of the mechanical properties. Additionally, the tips shall be calibrated after every change in accordance with the manufacturer instructions.

A maintenance and inspection schedule for the equipment and tooling shall be established in the Quality Assurance documents or in the Process Instruction.

The process parameters shall be monitored and documented. In particular, all the STL files processed by the machine shall be stored to ensure the traceability of the process.

The feed of the machine with the modeling and support material shall be continuously.

Machine and preparation software shall be updated if needed. The update of the software can be effective only after release and approval.

4.2.6 CAD/CAM Interface

The needed machine input shall be complete.
The 3D data files shall be in a machine compatible format.

4.2.7 Personnel

All work steps of the manufacturing procedure shall be carried out by authorized and competent personnel who attended a specific training program.

4.3 Key Characteristic

Key Characteristics acc. to EN9103 are defined by responsible engineering based on a risk analysis for parts manufactured by this process. Key characteristics shall be defined on product level and if necessary also on process level.

They shall be subject to variation control by production organization according to EN9103.

Key Characteristics of Table 4 do not relieve the production organization from meeting all engineering requirements defined in this document.

Table 4: Key Characteristics

Product Key Characteristic			Process Key Characteristic		
No.	Designation	Requirement/ Limit	Sub.- No.	Designation	Requirement/ Limit
1	Dimension / weight / function / appearance	See chapter 4.1.1	1.0	Slice height	According to relevant AIPI
			1.1	Part fill style	
			1.2	Contour width	
			1.3	Part raster width	
			1.4	Part interior style	
			1.5	Link contours	
			1.6	Use parallel offset part raster	
			1.7	Bypass seam placement method	
			1.8	Minimize transition moves	
			1.9	Raster angle	
			1.10	Visible surface style	
			1.11	Part XY shrink factor	
			1.12	Part Z-shrink factor	
			1.13	Contour to raster air gap	
			1.14	Raster to raster air gap	
			1.15	Contour to contour air gap	
			1.16	Material	
2	Printing orientation of part	According to drawing or another document	2.1	Build direction	According to design requirements; shall be defined by design responsible.
			2.2	Part build orientation	

5 Technical Qualification

The Technical Qualification shall be performed, according to the relevant Airbus Procedure.

Additional testing is required in following cases:

5.1 New production shop and/or new machines

If a new production shop and/or new machines will be released, the production shop shall carry out tests according to Table 5 of this AIPS. The test coupons shall be printed on each available machine. The test results shall be documented and validated by the responsible M&P engineer.

Table 5 :Qualification test program for new production site and/or new machine type

Line	Properties		Test Methods	Units	Build direction	Requirements	Dimension of test specimens	Total number of test samples per area		Test conditions and supplementary instructions
								small machine platform ^a	larger machine platform ^b	
1	Mechanical properties									
2	Tensile strength		ISO527-2/1A/5	MPa	XZ	according to relevant AIMS	According to figure 2	60	75	To be Separated in 3 Different build jobs
3	Tensile strain			%						
4	Tensile Modulus		ISO527-2/1A/1	MPa						
5	Tensile strength		ISO527-2/1A/5	MPa	ZX	according to relevant AIMS	According to figure 2	75	75	
6	Tensile strain			%						
7	Tensile Modulus		ISO527-2/1A/1	MPa						
8	Fire tests									
9	Flammability, vertical 60 s	Burn length	AITM2-0002A	mm	XY	max. 152	(305 x 75 x 1,5) mm	4	4	If possible to be added in one of three build jobs
10		After flame time		s		max. 15				
11		After flame time of drips		s		max. 3				
12	Others									
13	Density		ISO1183	g/cm³	XY	according to relevant AIMS	-	3	3	If possible to be added in one of three build jobs

Note 1: Number of test specimen according to relevant test method.

Note 2: All tests shall be conducted at atmosphere 23/50 according to ISO291 unless otherwise stated in the table.

^a Small machine platform e.g. 400 x 400 mm refer to figure 4

^b Larger machine platform e.g. 600 x 900 mm refer to figure 6

For small machine platform, test coupons shall be printed according to configurations shown in Figure 4 and Figure 5.

The test coupons shall be printed in four separate print jobs. First three print jobs shall be conducted without fire test coupons according to Figure 4. The fourth print job shall only consist of fire test coupons according to Figure 5.

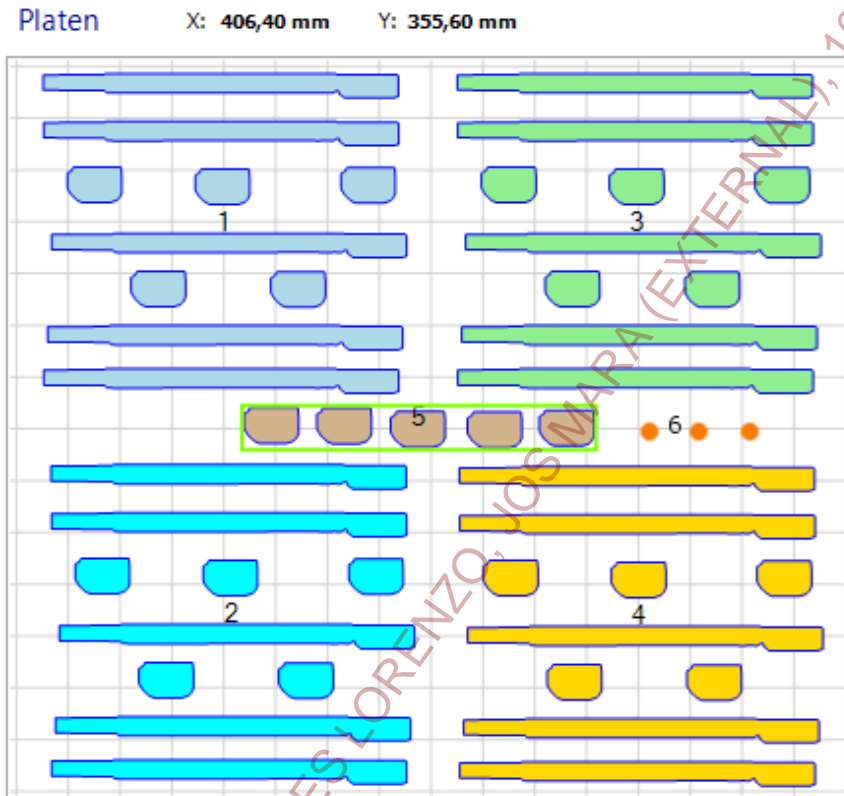


Figure 4: Print Job Configuration for Smaller Machine Platform – Dog bones and Density Cubes

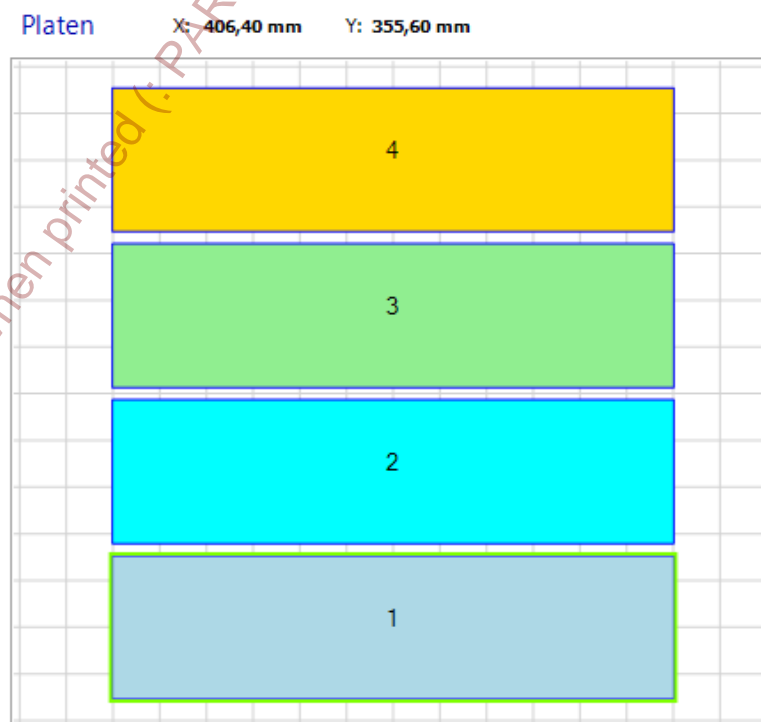


Figure 5: Print Job Configuration for for Smaller machine Platform – Fire Test Coupons

For larger machine platform, test coupons shall be printed according to configuration shown in Figure 6.

Test coupons shall be printed in three separate print jobs. First print job consists of dog bones, density cubes and fire test coupons. Second and third print jobs shall only consist of dog bones and density cubes only. Fire test coupons shall not be printed in the second and third print job.

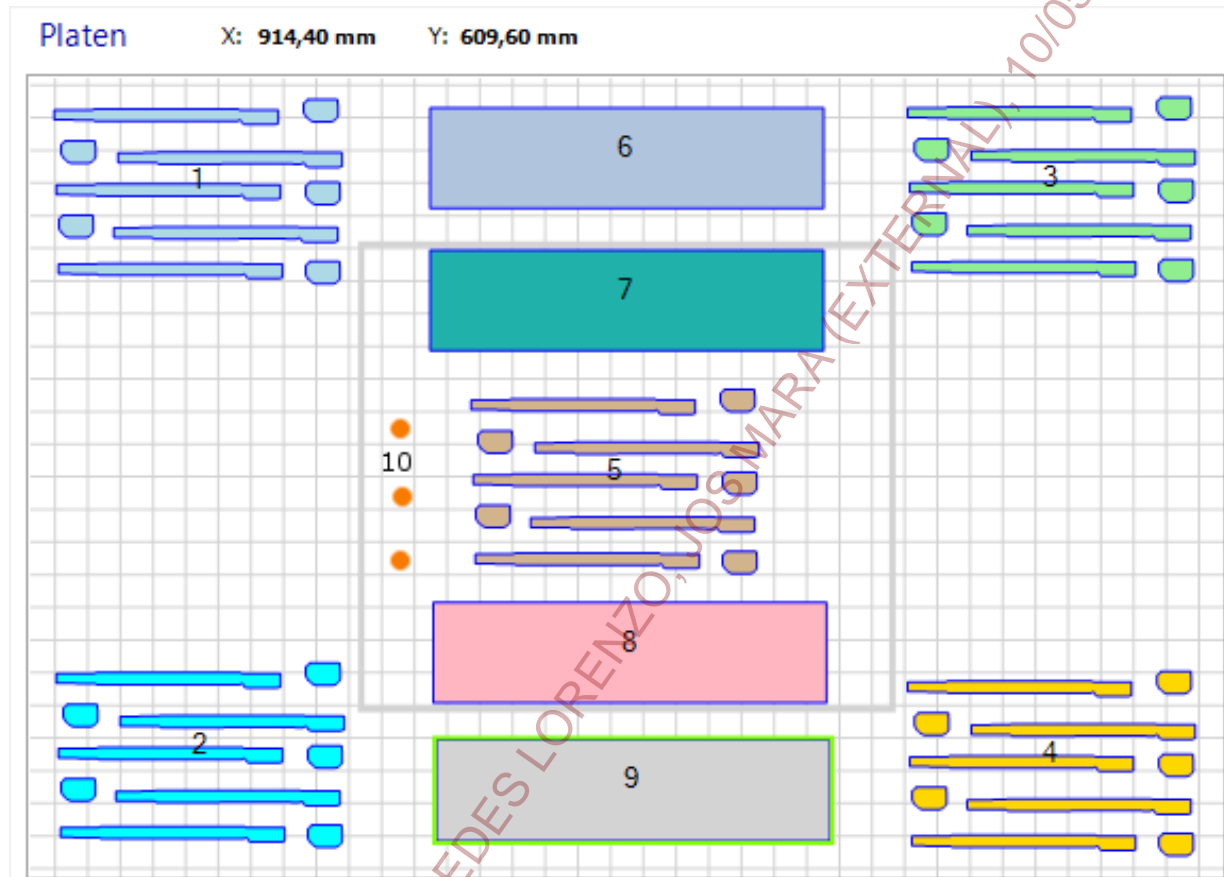


Figure 6 : Print Job Configuration for Larger Machine Platform

5.2 New qualified FLM material using qualified machines.

If a manufacturer will use a new FLM material, additional tests are requested for verification. Tests given in Table 6 shall be performed and related results shall be documented.

Table 6 : Qualification test program for new FLM material

Line	Properties	Test Methods	Units	Build direction	Requirements	Dimension of test specimens	Total Number of test samples per area		Test conditions and supplementary instructions
							small machine platform ^a	Larger machine platform ^b	
1	Mechanical properties								
2	Tensile strength	ISO527-2/1A/5	MPa	XZ	according to relevant AIMS	According to Figure 11	20	25	-
3	Tensile strain		%						
4	Tensile Modulus	ISO527-2/1A/1	MPa						
5	Tensile strength	ISO527-2/1A/5	MPa	ZX	according to relevant AIMS	According to Figure 11	25	25	-
6	Tensile strain		%						
7	Tensile Modulus	ISO527-2/1A/1	MPa						
Note 1: Number of test specimen according to relevant test method unless otherwise stated in the table.									
Note 2: All tests shall be conducted at atmosphere 23/50 according to ISO291 unless otherwise stated in the table.									
^a Small machine platform e.g. 400 x 400 mm refer to figure 7									
^b Larger machine platform e.g. 600 x 900 mm refer to figure 8									

For smaller machine tests shall be conducted without density and fire test coupons according to configuration shown in Figure 7

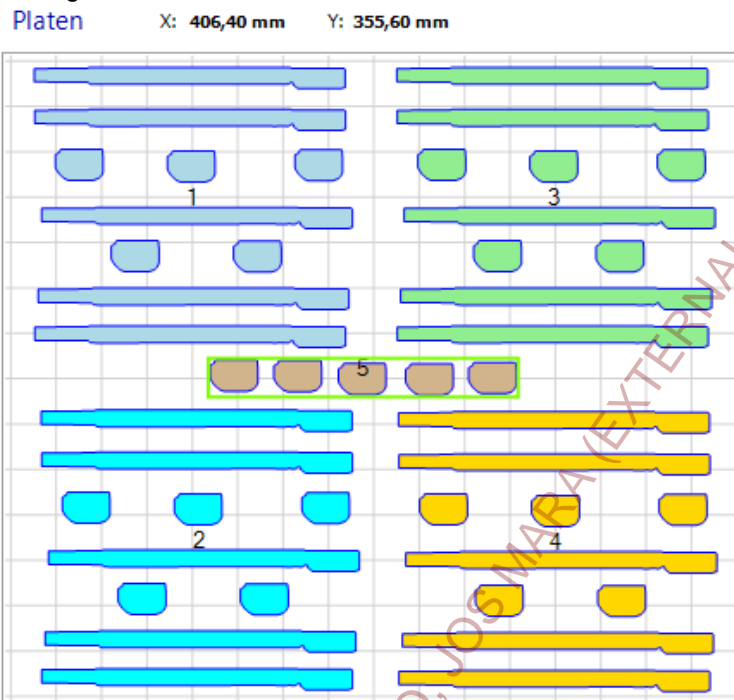


Figure 7 : Print Job configuration FLM material using smaller qualified machines

For larger machine tests shall be conducted without density and fire test coupons according to configuration shown in Figure 8.

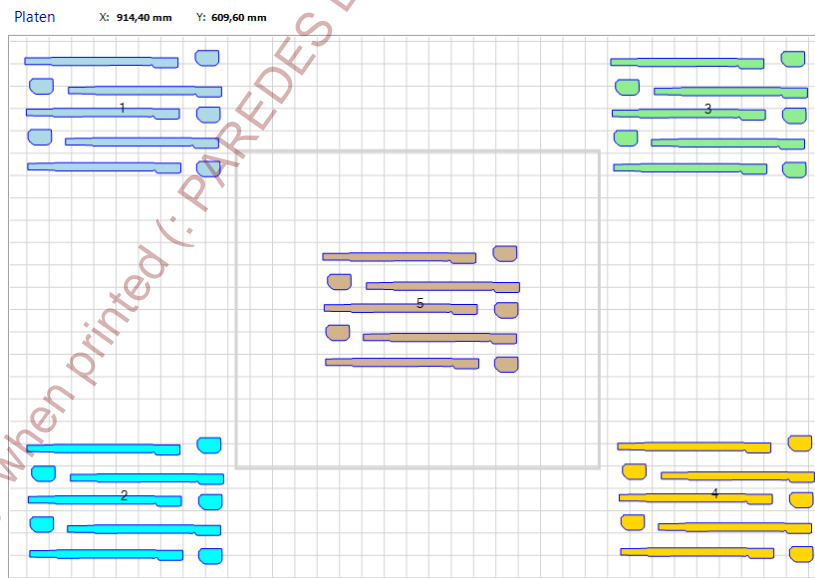


Figure 8 : Print Job configuration FLM material using larger qualified machines

5.3 Tests in case of an APS Change

If a change in APS is required the manufacturer shall perform tests according to Table 7.

For major changes, tests and test coupons shall be according to chapter 5.1.

The test coupons for midi changes shall be printed according to configuration shown in Figure 9 and Figure 10.

Table 7: Qualification Test Program for APS changes

Line	Properties	Test Methods	Units	Build direction	Requirements	Dimension of test specimens	Number of tests samples per change			Test conditions and supplementary instructions
							Major	Midi	Minor	
1	Tensile strength	ISO527-2/1A/5	MPa	XZ	according to relevant AIMS	According to figure 11	25 (According to Figure 7 & 8)	0	0	-
2	Tensile strain		%							
3	Tensile Modulus	ISO527-2/1A/1	MPa							
4	Tensile strength	ISO527-2/1A/5	MPa	ZX	according to relevant AIMS	According to figure 11	25 (According to Figure 7 & 8)	25 (According to Figure 9 & 10)	0	-
5	Tensile strain		%							
6	Tensile Modulus	ISO527-2/1A/1	MPa							
7	Visual and Dimensional Inspection for first build after change			-			ALL			
Note 1: Number of test specimen according to relevant test method unless otherwise stated in the table.										
Note 2: All tests shall be conducted at atmosphere 23/50 according to ISO291 unless otherwise stated in the table.										

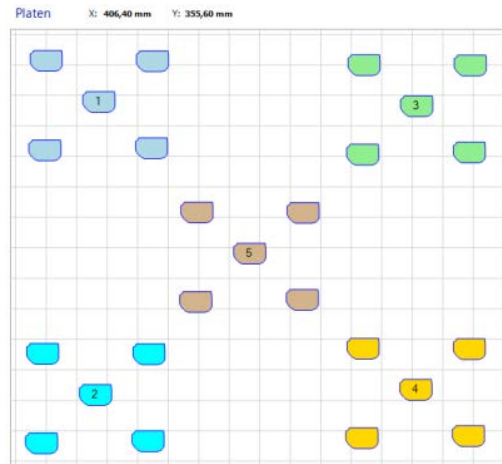


Figure 9: Print Job configuration for Smaller Machine Platform in case of APS change



Figure 10: Print Job configuration for Larger Machine Platform in case of APS change

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6 First Part Qualification

Not Applicable

7 Measurement of tensile properties

Test specimens (see Figure 11) shall be printed for each incoming delivery of cartridges.
The cartridges shall be selected at random from the batch delivered from raw material supplier.
The selected cartridges shall be marked and spreaded plain over the full batch.
The numbers of cartridges are defined in Table 8.

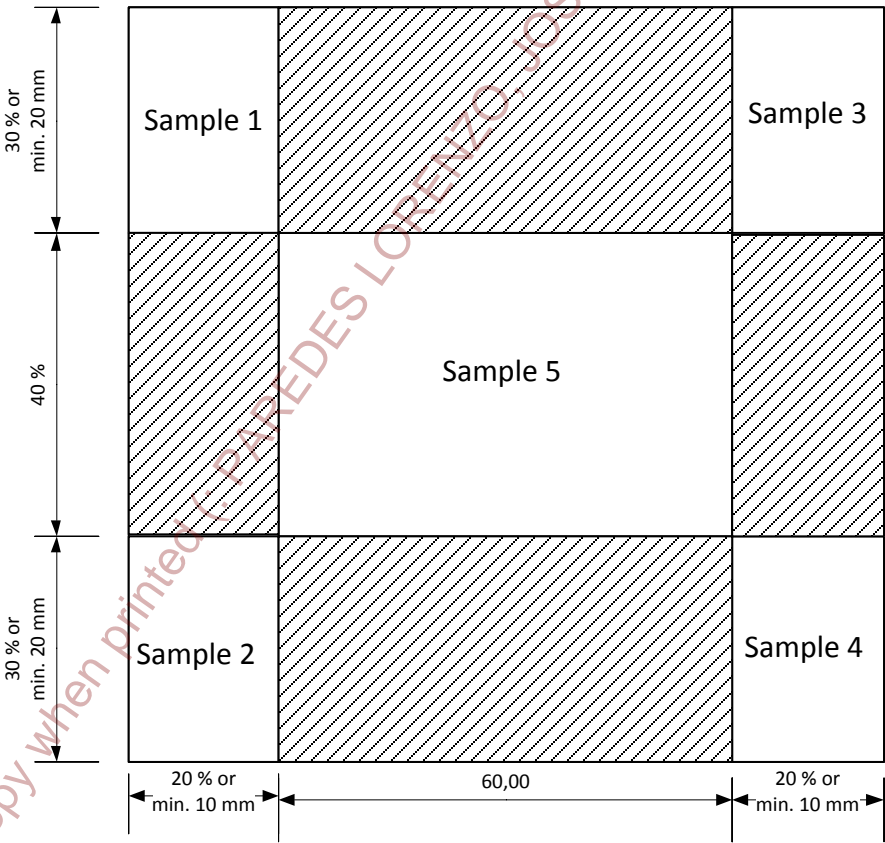
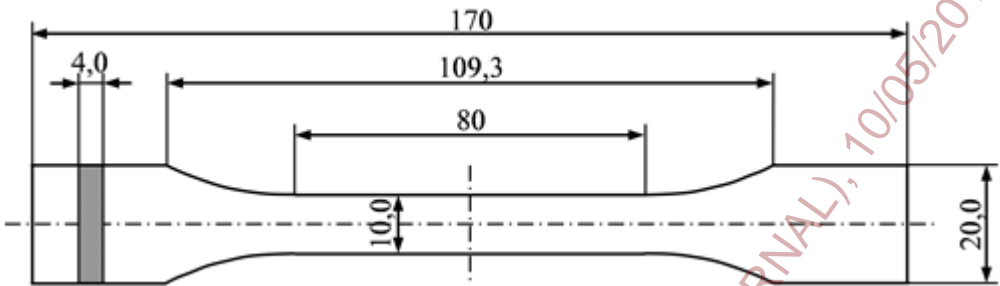
The manufacturing of test specimens shall be within the daily production run.
The location of test specimens on build platform and the tests shall be in accordance with Table 9 and Figure 12.
The related results shall be documented.

The location of samples 5 in Figure 12 can vary depending on part dimension, but it shall be located always next to the part. In case the sample 5 cannot be located in the foreseen area shown in Figure 12 due to part dimensions, a placement outside this area is possible. The deviation shall be documented.

The quantity and configuration of tensile test specimens may be reduced with prior agreement from the Airbus Materials & Processes specialist.

Table 8 : Sampling from cartridges

Number of cartridges per delivery	Number of cartridges from which samples shall be taken
1 to 5	All
6 to 11	5
12 to 20	6
21 to 35	7
36 to 60	8
61 to 99	9
100 to 149	10
150 to 199	11
200 to 299	12
300 to 399	13



*) see text above

Table 9 : Serial inspection tests – tensile properties

Line	Properties	Test Methods	Units	Build direction	Requirements	Test conditions and supplementary instructions
1	Mechanical properties					
2	Tensile strength	ISO527-2/1A/5	MPa	ZX	according to relevant AIMS	-
3	Tensile strain		%			
4	Tensile Modulus	ISO527-2/1A/1	MPa			
Note 1: Number of test specimen according to relevant test method.						
Note 2: All tests shall be conducted at atmosphere 23/50 according to ISO291 unless otherwise stated in the table.						

7.1 Rejection

If the product does not meet the requirements of defects given in chapter 4.1.2, it shall be rejected. Any defect not detected during acceptance testing, but which becomes apparent during the subsequent use of the product shall be cause for rejection of the unused portion of the batch, whether such a defect does not fulfill the requirements of the relevant specification.

8 Rework

Defects in parts may be reworked provided that the technical properties are not affected thereafter. Rework procedures shall be defined in the relevant process instructions and/or in the relevant drawings.

9 Environment, Health and Safety

The manufacturing process shall be in line with Airbus Health and Safety and ecoefficiency policies.

Compliance with A1091 shall be ensured for all materials, substances and/or articles implemented during process.

In particular, targeted substances according to A1091 shall not be used, if a safer alternative is available.

Uses made of all substances involved in the process shall be documented in Safety Data Sheet as required by REACH regulation (Registration Evaluation and Authorization of Chemicals).

Annex A
(informative)

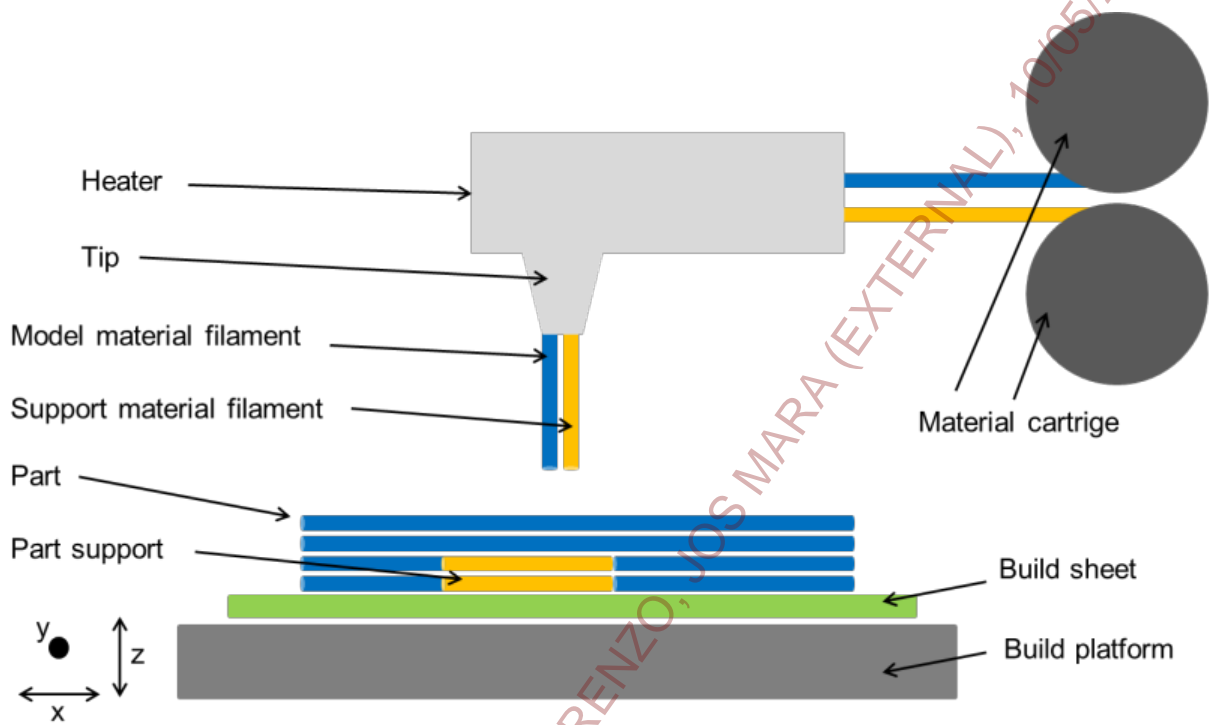


Figure A1: Schematic model of FLM process

RECORD OF REVISIONS

Issue	Clause modified	Description of modification
1 03/14	-	New Standard.
2 06/16	Title	Change of process designation from "Fused Deposition Modeling (FDM)" to "Filament Layer Manufacturing (FLM)"
	General	FDM replaced by FLM in standard.
	§2	ISO/ASTM52900 added. ISO/ASTM52921 added.
	§3	Build direction added.
	§4	Chapter 4.2.1 for defects added. Chapter 4.2.2 updated.
	§4.2.4	Requirements for software added.
	§5	Chapter 5.1 and 5.2 added. Qualification test programs for new manufacturing shop, new machine type and new materials on qualified machines.
	§7	Chapter 7.1 Measurement of tensile properties added. Figure 1 and figure 2 added. Table 5, Table 6 and Table 7 added.
	§8	Chapter updated.
(Continued)		

RECORD OF REVISIONS (Concluded)

Issue	Clause modified	Description of modification
3 10/17	Title	Change of Title to " Filament Layer Manufacturing"
	Table 1	Table 1 added.
	§4.1.1	Chapter 4.1.1 for New Shop/Printer/Material added.
	§4.1.2	Chapter 4.1.2 formally Chapter 4.1.1
	§4.1.2.2	Chapter 4.1.2.2 Description of size and quantity removed.
	§4.1.3.1	Chapter 4.1.3.1 Examples of only Extreme Defects added in table 2.
	Table 2	Table 2 formally table 1
	§4.2.3	Chapter 4.2.3 Additive Manufacturing Procedure Specifications added.
	§4.2.4	Chapter 4.2.4 formally Chapter 4.2.3
	§4.2.5	Chapter 4.2.5 formally Chapter 4.2.4
	§4.2.6	Chapter 4.2.6 formally Chapter 4.2.5
	§4.2.7	Chapter 4.2.7 formally Chapter 4.2.6
	Table 3	New Table 3 Categorisation of Change for Test Requirements for APS validation added.
	Table 4	Table 4 Formally Table 2 modified
	Figure 4,5 & 6	Figure 4 ,5 and 6 added
	Table 5	Table 5 formally table 3 modified- Number of test specimen for small and larger machine added. Build direction from YXY, XZY & ZXY to XZ and ZX.
	Table 6	Table 6 formally table 4 modified- Number of test specimen for small and larger machine added. Build direction from YXY, XZY & ZXY to XZ and ZX
	Figure 7&8	Figure 7 and 8 added without density cubes.
	§5.3	Chapter 5.3 Tests in case of an APS Change added.
	Figure 9 &10	Figure 9 and 10 Tests for midi APS change added.
	§7	Chapter 7 Modified to Measurement of Tensile properties Figure 11 and 12, formally Figure 1 and 2.
	Table 8	Build direction from XZ to ZX changed.
	Figure 12	Figured changed - Extension of area for sample 5 deleted.