AM Design and Analysis WG Meeting

CMH-17 Spring Coordination Meeting

WG Session Agenda

- Introductions
- FFF and PBF Outline Review
- Ch 13 Outline
- YP Comments Review

11.3.1 Design for AM Outline

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COMPOSITE MATERIALS HANDBOOK

- 11.3.1 Design for AM
  - 11.3.1.1 Characteristic of FFF
    - General Description
    - Material Characteristic
    - Advantage /Disadvantage
    - Economics and Time Efficiency
    - Feature Characteristic
  - 11.3.1.2 Design Guideline
    - Minimum Wall Thickness
    - Surface Profile Tolerance
    - Surface Finish
    - Part Built Orientation
    - Minimum Features
    - Modeling Best Practice
    - Inspection and Part Acceptance
    - Emboss/ Engrave
    - Integration and Assembly
    - Fill Density
    - Support wall/Overhang
  - 11.3.2.1 Characteristic of SLS
    - General Description
    - Material Characteristic
    - Advantage /Disadvantage
    - Economics and Time Efficiency
    - Feature Characteristic
  - 11.3.2.2 Design Guideline
    - Minimum Wall Thickness
    - Surface Profile Tolerance
    - Surface Finish
    - Part Built Orientation
    - Minimum Features
    - Modeling Best Practice
    - Inspection and Part Acceptance
    - Emboss/Engrave
    - Integration and Assembly
    - Line of Sight
    - Packing Density

Design Guideline Example: Stratasys

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FDM design considerations

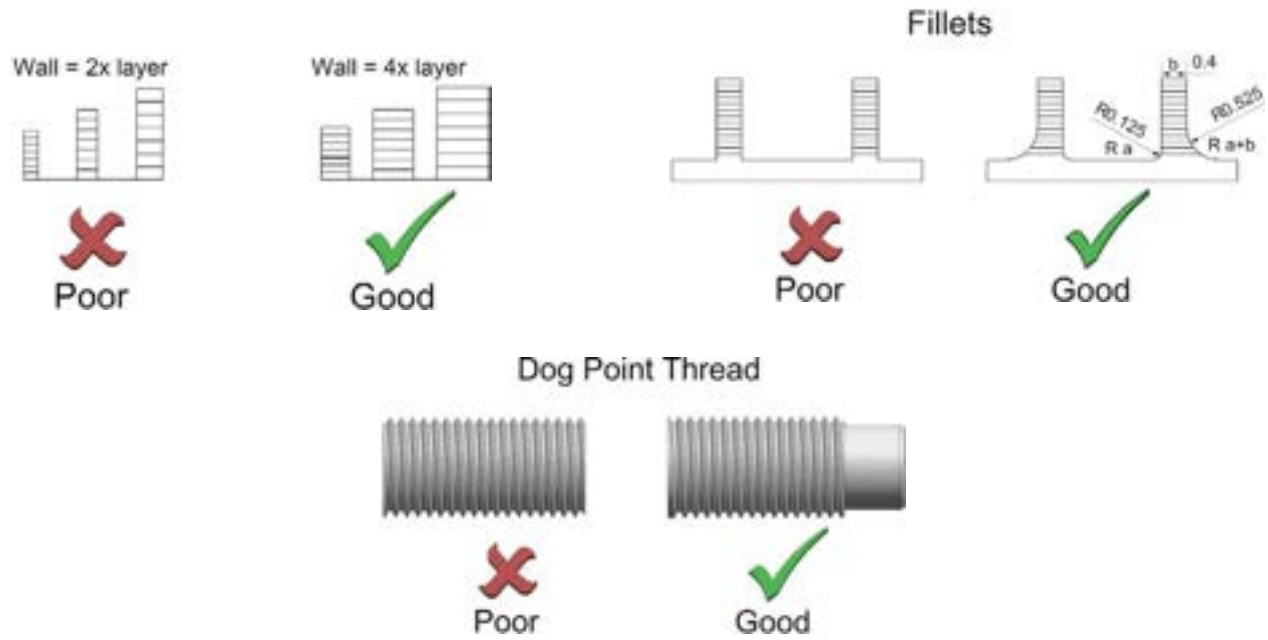
1. Shrinkage
2. Warp

Key feature considerations

1. Holes
2. Columns and pins
3. Wall thickness
4. Threads
5. Living hinge
6. Undercuts
7. Bosses and ribs
8. Draft angle and fillets
9. Text

Secondary operations & assemblies

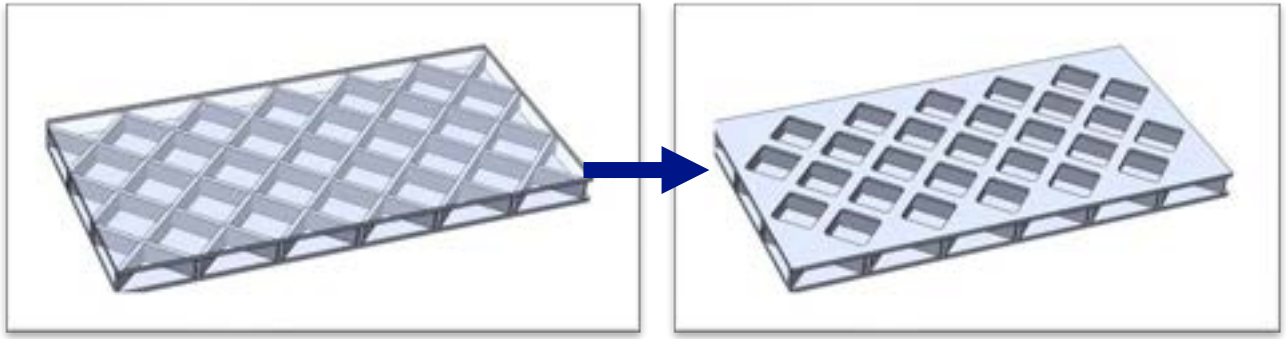
1. Size and orientation
2. Assemblies
3. Sectioning parts
4. Fastening hardware
5. Finishing and secondary operations



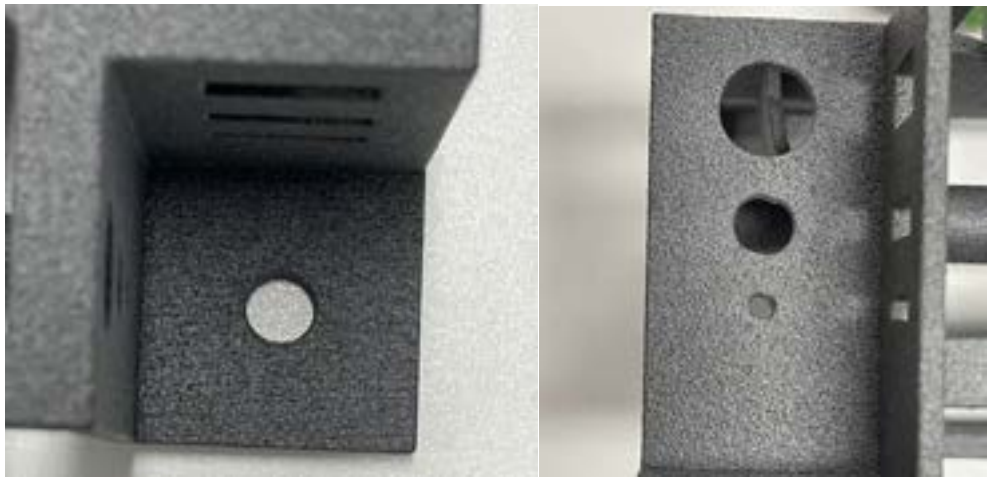
SLS Design Guideline Examples: Hexcel

Part Requirements		
Maximum Part Size	L x W x H [mm]	616 x 318 x 527
	L x W x H [in]	24.25 x 12.5 x 20.75
Minimum Thickness (As-Sintered)	mm	2.032
	in	0.080
Minimum Hole Diameter (As-Sintered)	mm	2.032
	in	0.080
Thickness Tolerance [I]	mm	+0.508/-0.254
	in	+0.020/-0.010
Surface Profile Tolerance [II]	mm	2 * (0.0075 * [Part Max Dimension] + 1)
	in	2 * (0.0075 * [Part Max Dimension] + 0.04)
Surface Roughness, Typical (Touch Comparator)	Ra, µm	<12.5
	Ra, µin	<500

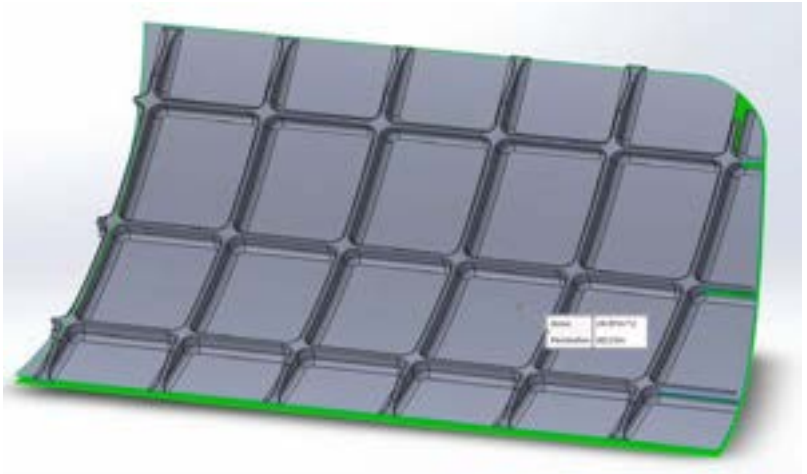
- Line of Sight



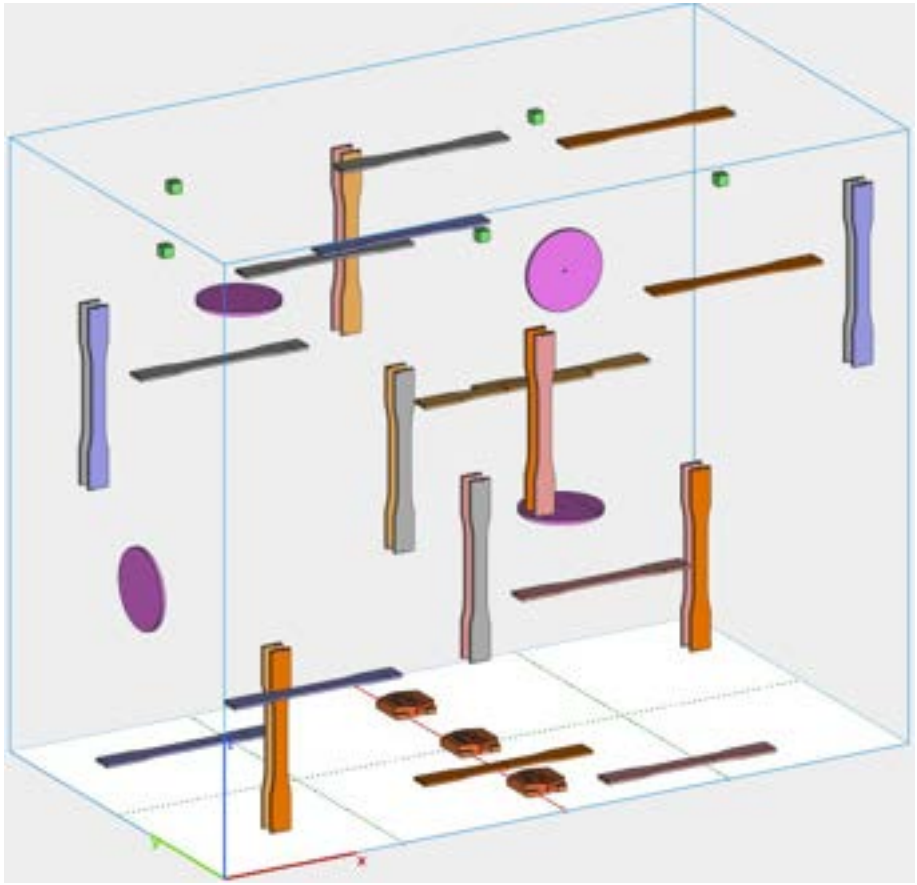
- Hole: As-is vs Machined



- Stiffener Ribs



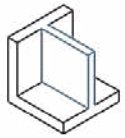
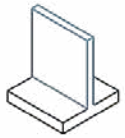
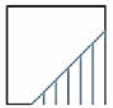
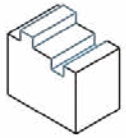
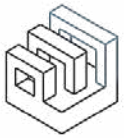
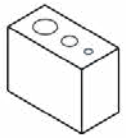
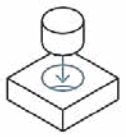
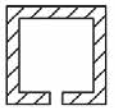
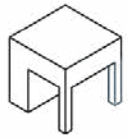
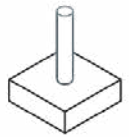
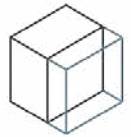
Design Guideline Examples: Hexcel



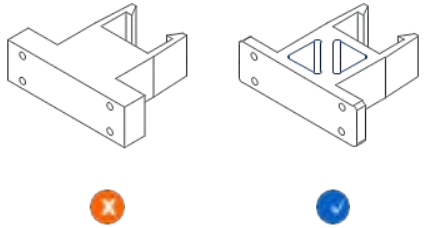
Every production build includes the following quality control specimens, which are evenly distributed around the parts.

- X-Direction Tensile Bars (10)
- Z-Direction Tensile Bars (16)
- Knit Line Bars (3)
- X-Direction Resistivity Disks (2)
- Z-Direction Resistivity Disks (2)
- Specific Gravity/Density Cubes (5)
- Laser Alignment Check Pieces (3)

Design Guideline Examples: Protolabs

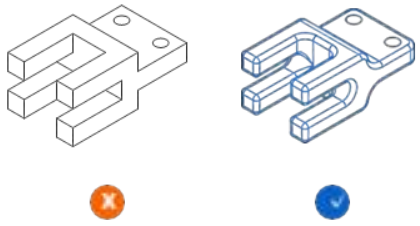
	Supported walls	Unsupported walls	Support & overhangs	Embossed & engraved details	Horizontal bridges	Holes	Connecting /moving parts	Escape holes	Minimum features	Pin diameter	Tolerance
	Walls that are connected to the rest of the print on at least two sides.	Unsupported walls are connected to the rest of the print on less than two sides.	The maximum angle a wall can be printed at without requiring support.	Features on the model that are raised or recessed below the model surface.	The span a technology can print without the need for support.	The minimum diameter a technology can successfully print a hole.	The recommended clearance between two moving or connecting parts.	The minimum diameter of escape holes to allow for the removal of build material.	The recommended minimum size of a feature to ensure it will not fail to print.	The minimum diameter a pin can be printed at.	The expected tolerance (dimensional accuracy) of a specific technology.
											
Fused deposition modeling	0.8 mm	0.8 mm	45°	0.6 mm wide & 2 mm high	10 mm	Ø2 mm	0.5 mm		2 mm	3 mm	±0.3% (lower limit ±0.3 mm)
Stereo-lithography	0.5 mm	1 mm	support always required	0.4 mm wide & high		Ø0.5 mm	0.5 mm	4 mm	0.2 mm	0.5 mm	±0.2% (lower limit ±0.13 mm)
Selective laser sintering & Multi jet fusion	0.7 mm			1 mm wide & high		Ø1.5 mm	0.3 mm for moving parts & 0.1 mm for connections	5 mm	0.8 mm	0.8 mm	±0.3% (lower limit ±0.3 mm)
Material jetting	1 mm	1 mm	support always required	0.5 mm wide & high		Ø0.5 mm	0.2 mm		0.5 mm	0.5 mm	±0.1 mm
Binder jetting	2 mm	3 mm		0.5 mm wide & high		Ø1.5 mm		5 mm	2 mm	2 mm	±0.2 mm for metal & ±0.3 mm for sand
Direct metal Laser sintering	0.4 mm	0.5 mm	support always required	0.1 mm wide & high	2 mm	Ø1.5 mm		5 mm	0.6 mm	1 mm	±0.1 mm

Design Guideline Example: Formlabs



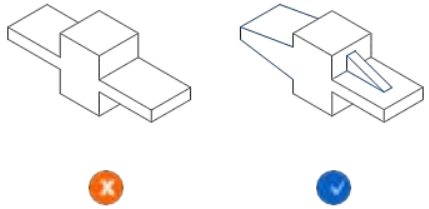
MAINTAINING UNIFORM THICKNESS

Where possible, keep the thickness of your parts relatively consistent. This will alleviate warping issues as parts cool. Consider shelling thicker parts to maintain a uniform thickness and save material.



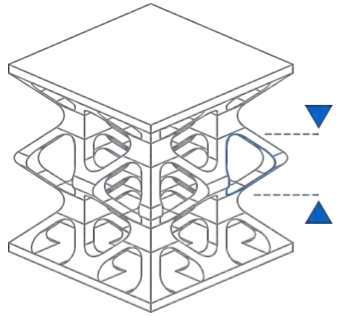
REDUCING STRESS CONCENTRATIONS

Parts can experience stress buildup at sharp changes in cross-section, such as thin extrusions from thick bases. Design gradual edge transitions instead of abrupt ones to reduce these stress concentrations.



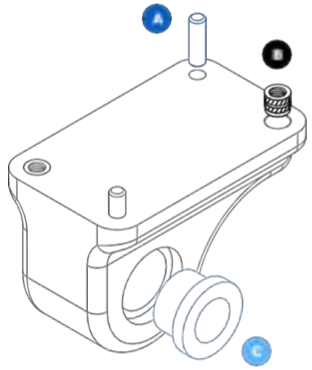
MANAGING ASPECT RATIO

Parts with a high aspect ratio are susceptible to warping. Features such as ribs or drafts can mitigate risk of warping on thin, extruded sections like cantilevers and wires.



DESIGNING LATTICES

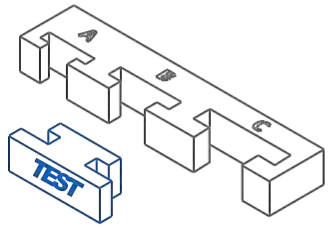
When designing a lattice structure, keep in mind that loose powders will need to be cleared from the lattice. To ensure easy powder removal in the Fuse Sift, design lattices with no smaller than **8 mm** gaps, and leave open faces in your lattice so that you don't trap powder inside.



INTEGRATING HARDWARE IN YOUR DESIGNS

Identify where it makes sense to integrate hardware into your printed designs. Here are some examples:

- Dowel pins as precise locating features
- Heat set inserts for durable threaded connections
- Bushings for concentric interfaces to shafts or rails



WHEN IN DOUBT, TEST!

If you are concerned about the success of a specific feature, create a small test print of the specific geometry in question. Isolate the feature and print the test part in the same intended orientation as the full part to get the best indication of design success.

Note: You might want to try printing multiple test pieces with different dimensions at once to test various fits before committing to a larger print.

Chapter 13. Application, Historical Cases, Lesson Learned

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13	Applications, Case Histories, and Lesson Learned.		Case 1
	13.1	Application	Interior Ducts
	13.2	Background	Legacy program needed to replace limited number of parts. However, the part supplier is no longer in business and a new start on production is cost inhibitive and wont meet the schedule
	13.3	Challenges in AM Implementation	Lack of Allowables, specifications, only vendor data available
	13.4	Design Methodology	
		13.4.1 Design Driver	FS&T, light pressure load, non critical component, No ESD compliance needed
		13.4.2 Process Used	FFF selected due to part size (height) , no assembly required
		13.4.2 Material Selection	Ultem 9085
		13.4.3 Sizing of Part	Over designed to compensate the limited set of data available
	13.5	Qualification Methodology	
		13.5.1 Verification Method	Point Design Qualification
		13.5.2 Inspection Methods	No inspection done, proof load test
	13.6	Benefits	
		13.6.1 Economics	ROI >10
		13.6.2 Schedule	Met short delivery schedule
		13.6.3 Other	
	13.4	Lesson Learned	Lack of full set of data was not a show stopper.
			Customer willingness to take risk based certification based on part criticality, cost and delivery schedule
			No repair or other maintenance protocol needed. Simply replace part if fails prematurely. More cost effective.

YP Summary

Chapter and Section	Title	Notes	YP Summary
11.1	Introduction	Submitted to YP2 March 2023	
11.1.1	When to Utilize AM	Submitted to YP2 March 2023	Total Votes 12 Affirmative 3 Affirmative with Comment 4 Negative with Comment 3 Abstain 2
11.1.2	Which AM Material/Process to Choose?	Submitted to YP2 March 2023	
11.1.3	Decision Tree and Qual Matrix	Submitted to YP2 March 2023	
11.1.4	AM Risk Assessment	Submitted to YP2 March 2023	
11.2	Definition of Requirements	Submitted to YP2 March 2023	
11.2.1	Establishment of Design Requirements	Submitted to YP2 March 2023	
11.2.2	Guidance for Material and Process Specifications	Submitted to YP2 March 2023	
11.2.3	Considerations Related to Part Criticality	Submitted to YP2 March 2023	
11.2.4	Planning for Substantiation/Verification	Submitted to YP2 March 2023	
11.2.5	Data Collection and Categorization by Application.	Submitted to YP3 Sept 2023	Total Votes 12 Affirmative 9 Affirmative with Comment 0 Negative with Comment 2 Abstain 1
11.2.5.1	Table Format of Excel sheet	In work	
11.3	AM Component Design and Analysis Considerations	In work	
11.3.1	Design for AM	In work	
11.3.2	Analysis for AM	Submitted to YP2 Fall 2023	Total Votes 12 Affirmative 9 Affirmative with Comment 2 Negative with Comment 0 Abstain 1
11.4	Design Verification for Material and Component	In work	
11.4.1	Point Design Verification framework	Submitted to YP2 Fall 2023	Total Votes 12 Affirmative 9 Affirmative with Comment 2 Negative with Comment 0 Abstain 1
11.4.2	Building Block Part Verification framework	In work	Submit to YP

Point Design Section Comments

- Request an up front sentence - what is the point of this section? Is it a part or the building block approach or a stand alone approach to qual/cert? To support analysis? How does this fit? Is this Design? Is this Analysis? Is this cert? How does this fit within the rest of the document? Maybe this needs to point to the discussion in the guidelines 2.1 and reference why this is offered as an option to building block.
- Seems “point design” is being used here to describe more configured tests, higher up in the building block (element, subcomponet) which can capture complex failure modes. Makes sense, but not sure how this helps?
- Suggest better explanation that this is a method of "cert by test" that is currently useful for non-metallic AM when the building block approach is out of reach or impractical. Minimize comparison between this cert by test and subcomponent tests used by the building block approach.
- Sidebar (for here and other locations in the volume) - are "process control coupons" defined anywhere? Guidelines? M&P?
- If this is "point design verification framework" it is confusing to start talking steps in the building block approach.

CMH-17 Spring Design and Analysis WG Meeting

- D&A meets once a month on Fridays from 10-11 AM PST.
- We are always looking for volunteers so please reach out!

CMH-17 AM
Data Review Working Group
Wednesday April 24, 3:30 – 5:30 pm MST

Working Group Chairs

Seeking WG chair

(Facilitated by Michelle Man)

Agenda

- Introduction:
  - What it means to be a DRWG member
  - Overview of Volume 7 content
- Content development & Progress
  - Draft to date and work needed
- Available Data
- Call for Volunteers; members and chairs
- Work through Yellow Page comments

Data Review Working Group (DRWG)

- Goal:
  - Establishes data documentation requirements, develops formats for data presentation, and provides the final technical and editorial review of all data prior to inclusion in the Handbook.

- Objectives:
  - Develop data table formats including recommended reduced data for presentation.
  - Data reduction and draft data tables for the Handbook.
  - Work with potential data sources for the Handbook and review documentation/pedigree of potential data sets.
  - Maintain data section of the CMH17 AM volume.
  - Work with Statistics Working Group to ensure the methods used for data analysis are captured in the Statistics chapter.

PMC's Voting Process

- Sub-group of Data Review formed to focus on data set approval known as Active Voting Members (AVM)
- Review format:
  - Phase reviews (usually 1 or 2)
  - Yellow Pages are voted on by ALL members
- Majority of AVM must vote for the review to be valid
- Voting Members (PMC <30 members)
  - # of votes needed: half of total voting member count or 10 votes minimum
  - After not voting in 3 consecutive voting cycles, members are removed from the voting list

- AM has general voting members only.
  - Do we want to follow this approach?
  - Active voters need to vote

What it means to be a member

- Content development and review (until initial release)
- Content maintenance
  - Edit and review
  - Update as needed to accommodate new test method or capturing information important with new process/print methods
- Data review
  - voting as an active voting member (if applicable)
- Data voting
  - Yellow Page Balloting

Caution

- Content for review is to DRWG use only
- Do not distribute content shared within this group
  - Or when content is balloted
- Any supplementary (to CMH17 data tables) materials should not be shared without written consent of content supplier/submitter

Current Activities in AM DRWG

- Content development for chapters we are responsible for in Vol 2 (shown next slide)
- Review to ensure appropriate content coverage
  - Collaborate with WGs to ensure correct content placement
- Resolve Yellow Page comments
- Review of incoming data set

Overview of Volume 7 content

WG	Chapter	Title	% drafted	% approved
Guidelines	1	CMH-17 AM INTRODUCTION AND GUIDELINES	90	65
Guidelines	2	CHARACTERIZATION CONSIDERATIONS	50	40
Testing	3	EVALUATION OF FEEDSTOCK	50	0
Materials and Processes	4	PROCESSING AND MANUFACTURING	0	0
Materials and Processes	5	QUALITY CONTROL OF PRODUCTION MATERIALS AND PROCESSES	0	0
Testing	6	MATERIAL TESTING & CHARACTERIZATION FOR **SUBMISSION OF DATA TO CMH-17**	12	4
Testing	7	PROPERTY TESTING OF ADDITIVELY MANUFACTURED MATERIALS	70	0
Statistics	8	STATISTICAL METHODS	90	55
Testing	9	EVALUATION OF AM PARTS	0	0
Testing	10	ELEMENT LEVEL TESTING	0	0
Design and Analysis	11	DESIGN AND ANALYSIS	90	60
Design and Analysis	12	MAINTAINABILITY AND SUPPORTABILITY	0	0
Design and Analysis	13	APPLICATIONS, CASE HISTORIES, and LESSONS LEARNED	0	0
Data Review	**14**	**AM PROPERTY DATA**	**25**	**5**

- Targeting Vol 7 release in 2025
- Good amount of work before we're there

Content Development and Progress

% drafted	% approved (through YP)	Sections	YP Activity	Authors/Reviewer
60	20	6.5 Data Submission, Format and Requirements (Data Review)	Submitted to Fall 2023 YP1	
		6.5.1 Introduction (Data Review)		
		6.5.2 Material and Process Specification Requirements (Data Review)		
		6.5.3 Sampling Requirements (Data Review)		
		6.5.4 Test Method Requirements (Data Review)		
		6.5.5 Formats and Units (Data Review)		
		6.5.6 Design Properties (Data Review)		
20	0	14.1 INTRODUCTION (Data Review)		
		14.1.1 Organization of Data		
		14.1.2 Database Generation Methodology		
		14.1.3 Presentation of data		
		14.1.4 Material Systems		
		14.1.5 Material Build Orientation Codes		
		14.1.6 Symbols, Abbreviations, and Systems of Units		
		14.1.7 Definitions		
0	0	14.2 DATA REDUCTION AND DOCUMENTATION (Data Review)		
		14.2.1 Introduction		
		14.2.2 Material Mechanical Properties		
		14.2.3 Data Normalization		
		14.2.4 Dispositioning of Outlier Data		
		14.2.5 Data Documentation		
50	10	14.3 AM Methods – Property Data Tables (Data Review)	Submitted to Fall 2023 YP1	

Incoming Data

- Ultem dataset
  - Fortus 900mc with Certified Ultem 9085
  - Fused filament fabrication (FFF)
  - NCAMP qualification – has supporting reports. Approved and published
- Intended for inclusion in Vol 7 initial release
- Tables are partially complete
- Pooled allowables are presented as reference only
- Do we want to include reference dataset – Compression and Izod data

- HexPEKK 100
  - EOS P800 with HexPEKK 100
  - Laser powder bed fusion
  - NCAMP qualification – has supporting reports. Reports approved, pending Hexcel for publication
- MarkforgedX7
  - Markforged X7 with Onyx FR-A w/ Carbon Fiber FR-A
  - FFF with continuous fiber reinforcement
  - No guidance planned for reinforced printing yet
    - Do we want to include this data?
    - Not at this time. Too many uncertainties

Call for Volunteers

- Writers
- Chairs
- Reviewers

Summary

- Need a WG co-chair
- Need help with content development
- Participation always welcome
  - Contact: info@cmh17.org or Michelle Man

AM Guidelines Working Group Meeting - Scottsdale, Arizona

Wednesday, 24-April-2024,
10:15am – 12:15pm

		Finish by
CALL TO ORDER		10:15am
Content Preparation:		
Cole	Fall 2023 Yellow Page Results Review	10:30am
Cole	Chapter 1 – Section Status Review • Review status sections 1.1 through 1.8 • Review bulk of 1.9 Definitions • Discuss definition for "Build"	11:00am
Deris	Chapter 2 – Section Status Review • Review status sections 2.1, 2.2, 2.3 • Determine plan for 2.4 Data Classes • Determine plan for 2.5 Qualification vs Equivalency vs Interchangeability • Determine plan for 2.6 Recommended Test Matrices >> Stefan & Rick to draft • Determine plan for 2.7 Data Substantiation for Use of CMH-17 Basis Values >> Move to Design & Analysis or Testing chapter ??	11:30am
New Business:		
Cole	Title for CMH-17 Volume 7	
Cole	SOTA for structural application of non-metallic AM	
Cole	Reset monthly GWG meeting date/time	11:45am
Cross-WG Coordination Activities:		
Deris	Statistics support in drafting content for 2.5.1 Qualification and 2.5.2 Equivalency	
Cole	Statistics support in drafting 2.6 Recommended Test Matrices	
Deris	Guidelines support to M&P in drafting content on sources of variability	
Cole	REMINDER: All WG Chairs to provide inputs on Definitions + Symbols and Abbreviations for inclusion in Chapter 1	
	ADJOURN	12:15pm

AM Guidelines Working Group Meeting - Scottsdale, Arizona

CMH-17
COMPOSITE MATERIALS HANDBOOK

Fall 2023 Yellow Pages Results Review

YP1 Results :

SECTION 1.9	
TOTAL VOTES	11
Affirmative	6
Affirmative with Comment	3
Negative with Comment	2
Abstain	0

SECTION 2.1	
TOTAL VOTES	11
Affirmative	9
Affirmative with Comment	1
Negative with Comment	1
Abstain	0

SECTION 2.2	
TOTAL VOTES	11
Affirmative	7
Affirmative with Comment	2
Negative with Comment	2
Abstain	0

SECTION 2.3	
TOTAL VOTES	11
Affirmative	10
Affirmative with Comment	1
Negative with Comment	0
Abstain	0

YP2 Results :

SECTION 2.1	
TOTAL VOTES	12
Affirmative	9
Affirmative with Comment	0
Negative with Comment	1
Abstain	2

SECTION 2.2	
TOTAL VOTES	12
Affirmative	8
Affirmative with Comment	1
Negative with Comment	1
Abstain	2

Chapter 1 – Section Status Review

- Sections 1.1 through 1.5 (intro), 1.6 (intro), and 1.7 accepted in March 2023 YP1 or YP3 (except for editorial correction needed to figure in 1.3)
- Sections 1.5 (body) through 1.6 (body) drafted and in review between GWG Chairs. Sections to be submitted in next YP cycle.
- Section 1.8.1 Symbols and Abbreviations – Needs input from all WG's.
  >> Please capture symbols and abbreviations as you write your chapters, and forward them to Guidelines.
- Section 1.8.2 System of Units - Drafted and in review between GWG Chairs. Section to be submitted in next YP cycle.
- Section 1.9 Definitions –
  - Fall 2023 YP1 – Negatives from Stefan Kloppenborg addressed through discussion and e-mails. Revised section to be submitted in next YP cycle.
  - Fall 2023 YP1 – Most negatives from Boeing Team addressed through discussion and e-mails. One remaining item relates to definition of "Build". Intend to resolve this week so revised section can be submitted in next YP cycle.
  - >> As you write your chapters, please bring any new definitions to Guidelines WG so we can coordinate with other WGs and decide if they should be included in Section 1.9.

Chapter 1 – Section 1.9 Definitions

See file "JCC comments to RC reply CMH-17 Vol 7 Section 1.9 DEFINITIONS -Boeing 20240308 - RC (003).docx"

NOTE - The "Definitions" section must necessarily be a "living" part of the document, always open to additions, corrections, and improvements.

Chapter 1 – Section 1.9 Definitions

"Build" - First version (Fall 2023 YP1) attempted to define "groups of parts" that come out of a single printing process run on a specific machine, but caused some confusion since many thought of the word more in a "process description" light instead of "group of parts"

Following input from many, we now propose to define "Build Cycle" using a definition very close to ISO/ASTM 52900 except that we have agreed to limit the definition to a single additive manufacturing machine (ISO/ASTM allows for an "additive manufacturing system" which can include multiple machines).

Then we will need to add a definition for "Manufacturing Lot" to delineate the "group of parts" that come out of a single (?) printing process run on a specific machine.

>> *Multiple "identical" runs of the same part – single Manufacturing Lot ??*

We propose to not include the need for "a single manufacturing work order" as per the ISO/ASTM definition since we don't discuss production control systems elsewhere within CMH-17.

Question : Given that a single printing process run on a single machine can produce multiple copies of different parts, should "Manufacturing Lot" explicitly include only a single Part Number ?

- If yes, then a single printing process run will be able to produce multiple Manufacturing Lots.

AM Guidelines Working Group Meeting - Scottsdale, Arizona

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Chapter 2 Status:

- Section 2.1 Introduction to Non-Metallic AM Design and Development –
  - Fall 2023 YP1 – 1 negative.
  - Section revised and submitted into Fall 2023 YP2. - 1 negative.
- Section 2.2 Sources of Variability –
  - Fall 2023 YP1 – 2 negatives.
  - Section revised and submitted into Fall 2023 YP2. - 1 negative (Boeing has asked for extension with negative)
- Section 2.3 Building Block - Fall 2023 YP1 – Accepted with no negatives.
- Section 2.4 Data Classes – Not drafted >> Need volunteers
- Section 2.5 Qualification vs Equivalency vs Interchangeability – Not drafted >> Need volunteers
- Section 2.6 Recommended Test Matrices – Not drafted >> Rick and Stefan to draft
- Section 2.7 Data Substantiation for Use of CMH-17 Basis Values – Move to Design & Analysis or Testing chapter ??

Sources of Variability:

1) Capturing effects when generating allowables,

2) Controlling effects when producing parts

Common Sources of Variability				
Material	**Process**	**Geometry**	**Machine**	**Testing**
- Composition - Feedstock shape - Storage & shipping	- Slicer software - Process settings - Build envelope - Feedstock pre-processing - Build post-processing - Machining	- Part orientation - Tool path -Surface condition	- Configuration - Environment - Maintenance - Performance repeatability - Firmware	- Test article - Test fixtures - Test procedures - Data analysis

NEW BUSINESS

Title for CMH-17 Volume 7 : We have not yet set a formal title for the Volume.

Proposal 1 :

VOLUME 7 NON-METALLIC ADDITIVE MANUFACTURING

Proposal 2 :
(based on Volume 3)

VOLUME 7. NON-METALLIC ADDITIVE MANUFACTURING

MATERIALS USAGE, DESIGN, AND ANALYSIS

Proposal 3 :
(based on Volumes 1 and 3)

NON-METALLIC ADDITIVE MANUFACTURING

GUIDELINES FOR MATERIALS USAGE, DESIGN, AND ANALYSIS

VOLUME 7.

NEW BUSINESS

State Of The Art (SOTA) for structural application of non-metallic AM :

We need to agree on the Scope of Volume 7, specifically the “boundary” beyond which we will not include content in the Volume.

Guidelines WG perspective (reflected in current draft of Section 1.5 Scope) :

The volume captures the best available technical knowledge and best engineering practice . . .

In-line with other CMH-17 volumes, we should not include information that is clearly research and is unproven.

We need to agree on SOTA for non-metallic AM so we all write content that reflects the same “boundary”.

Question : Is anyone aware of any certified airworthy polymer AM parts that are required to carry at least moderate loads ??

NEW BUSINESS

Reset monthly Guidelines WG meeting date / time (1 hour duration) :

Options for meeting start :

Monday (need to select 1 per month) 7:00 or 8:00 PT = 10:00 or 11:00 ET (problem for Stat holidays)

3rd Tuesday 7:00 or 11:00 PT = 10:00 or 2:00 ET (later time would be right after AM Exec)

1st Thursday 8:00 or 9:00 PT = 11:00 or 12:00 ET

Friday (need to select 1 per month) 9:00 PT = 12:00 ET

Non-Metallic AM Material & Process WG

CMH-17 Non-Metallic AM Material & Process WG – Spring 2024 Joint Coordination Meeting

Wednesday, April 24th @ 1:15pm – Room 2

Material & Process WG group meets the 2nd Thursday of the Month @ 10am EST / 7am PST

Next Meeting (Virtual) May 9th @ 10am EST / 7am PST

Co-Chairs:

Chloe McGuffin – Markforged

Eric K Moyer – Boeing

Fei Liang - Gulfstream

Non-Metallic AM Material & Process WG

CMH-17 Non-Metallic AM Material & Process WG – Spring 2024 Joint Coordination Meeting

Wednesday, April 24th @ 1:15pm – Room 2

Material & Process Working Group Objectives:

- Provide the framework of the overall process flow for polymer AM material qualification, machine qualification, facility qualification and part qualification.
- Provide guidance on key performance variable (KPV) identification and necessary KPV controls for polymer AM material qualification, machine qualification, facility qualification and part qualification.
- Provide guidance on employee training and quality assurance procedures for polymer AM material qualification, machine qualification, facility qualification and part qualification.
- Provide guidance on the use and incorporation of CMH-17 AM volume published data and processes into a company's production system.
- Update sections accordingly when developments in new feedstock materials and/or new polymer AM fabrication processes become available and mature for use in regulated applications

Non-Metallic AM Material & Process WG

CMH-17 Non-Metallic AM Material & Process WG – Spring 2024 Joint Coordination Meeting

Wednesday, April 24th @ 1:15pm – Room 2

Material & Process Working Group Key Future Work:

- Writing content for Selective Laser Sintering section(s) – need volunteers
- Complete terminology, abbreviations & nomenclature section(s) for M&P

Non-Metallic AM Material & Process WG

CMH-17 Non-Metallic AM Material & Process WG – Spring 2024 Joint Coordination Meeting

Wednesday, April 24th @ 1:15pm – Room 2

Material & Process Working Group Planned Meeting Agenda:

- Introductions
- Moving M&P meeting to start 1 hr later (i.e. 8am PST instead of 7am PST)
- Guidelines Carry-over: Sources of Variability (this may move)
- Fall YP2 Yellow Page Summarization w/ Proposed Disposition
- M&P Definitions – How To Deal with Industry Definitions (~20min)
- Review M&P Chapter/Section progress tracker (if time allows)

Potential Categories of Definitions

CMH-17
COMPOSITE MATERIALS HANDBOOK

1. New/scratch definition. CHM-17 creates brand new definition.
2. Existing CMH-17 definition
   - Should if be fully copied in Volume 7 OR just referenced back to Volume
   - Should we “identify” CMH-17 carry over definitions as such?
3. Same name as existing CMH-17 definition BUT the definition is different.
4. Existing industry definition (i.e. ASTM 52900), used “as-is”
   - Should the definition be copied over and referenced OR just referenced.
5. Same name as existing industry definition BUT different definition.
   - Recommend denoting deviations from “industry” definitions as such.

Non-Metallic AM Material & Process WG

M&P Definitions – How To Deal with Industry Definitions? (~20min)

Problem: The industry has already documented/defined common additive manufacturing terms (i.e. ISO/ASTM 52900). How should M&P capture these terms in our definition section?

Proposals:

- Do NOT include definition text, instead reference industry specification/source

Nozzle *– See ASTM Standard F3529 (References X.X.X.X)*

- Include definition text AND reference industry specification/source

Nozzle *– tip of the material extrusions head….. See ASTM Standard F3529 (References X.X.X.X)*

Open Questions:

- Are there any definitions that are NOT aligned with an industry specification OR with the definition from CMH-17 Volume 3.

Meeting Minutes

- Meeting started with group introductions and ice breaker exercise.
- Based on member feedback, presented proposal to move the start time of our monthly M&P back 1 hour (i.e. 8am PST start instead of the current 7am PST start)
  - No objections, Eric took action to send additional email with the goal to implement the new, later start time for June 13th Meeting.
- Group had long discussion on Sources of Variability, which was a carryover discussion from the earlier Guidelines meeting.
  - M&P to have more discussion on this topic in future working group meetings including working on a definition for variability and variation.

CMH-17 AM Guidelines Working Group Meeting, 24 April 2024

During Joint Coordination Committee Meetings

Phoenix, AZ

Agenda:

		Finish by
	CALL TO ORDER	10:15am
Content Preparation:		
Cole	Fall 2023 Yellow Page Results Review	10:30am
Cole	Chapter 1 – Section Status Review • Review status sections 1.1 through 1.8 • Review bulk of 1.9 Definitions • Discuss definition for "Build"	11:00am
Deris	Chapter 2 – Section Status Review • Review status sections 2.1, 2.2, 2.3 • Determine plan for 2.4 Data Classes • Determine plan for 2.5 Qualification vs Equivalency vs Interchangeability • Determine plan for 2.6 Recommended Test Matrices >> Stefan & Rick to draft • Determine plan for 2.7 Data Substantiation for Use of CMH-17 Basis Values >> Move to Design & Analysis or Testing chapter ??	11:30am
New Business:		
Cole	Title for CMH-17 Volume 7	
Cole	SOTA for structural application of non-metallic AM	
Cole	Reset monthly GWG meeting date/time	11:45am
Cross-WG Coordination Activities:		
Deris	Statistics support in drafting content for 2.5.1 Qualification and 2.5.2 Equivalency	
Cole	Statistics support in drafting 2.6 Recommended Test Matrices	
Deris	Guidelines support to M&P in drafting content on sources of variability	
Cole	REMINDER: All WG Chairs to provide inputs on Definitions + Symbols and Abbreviations for inclusion in Chapter 1	
	ADJOURN	12:15pm

Fall 2023 Yellow Page Results:

YP1 – 11 Total votes (1 was compilation of 9 reviewers from Boeing) ; Negatives on Sections 1.9, 2.1, 2.2. Accepted Section 2.3

YP2 – 12 Total votes (1 was compilation of 9 reviewers from Boeing) ; Negatives on Sections 2.1, 2.2

Chapter 1 Status Review:

- Sections 1.1 through 1.5 (intro), 1.6 (intro), and 1.7 accepted in March 2023 YP1 or YP3 (except for editorial correction needed to figure in 1.3).
- Sections 1.5 (body) through 1.6 (body) drafted and in review between GWG Chairs. Sections to be submitted in next YP cycle.
- Section 1.8.1 Symbols and Abbreviations – Needs input from all WG's. >> All AM WGs requested to capture symbols and abbreviations as they write their chapters, and forward them to AM Guidelines.
- Section 1.8.2 System of Units - Drafted and in review between GWG Chairs. Section to be submitted in next YP cycle.

- Section 1.9 Definitions –

    - Fall 2023 YP1 – Negatives from Stefan K. addressed through discussion and e-mails. Revised section to be submitted in next YP cycle.

    - Fall 2023 YP1 – Most negatives from Boeing Team addressed through discussion and e-mails. One remaining item relates to definition of "Build". Working meeting Monday morning (22 Apr) with Boeing representative decided to replace with 2 definitions – "Build Cycle" to define AM process for creating parts ; "Manufacturing Lot" to define groupings of parts that come out of "Build Cycle(s)". Revised definitions to be submitted in next YP cycle.
      It was noted that for CMH-17 these definitions of Build Cycle and Manufacturing Lot will need to depart from the definitions in ISO/ASTM 52900 in that the CMH-17 AM leadership had previously determined that for quality control and traceability purposes, part Lots for aerospace applications need to be limited to a single AM machine (single S/N).

      >> All AM WGs requested to capture any new definitions as they write their chapters, and forward them to AM Guidelines.

Chapter 2 Status Review:

- Section 2.1 Introduction to Non-Metallic AM Design and Development – Fall 2023 YP1 – 1 negative. Section revised and submitted into Fall 2023 YP2 – 1 negative. Negatives discussed during working meeting Monday morning (22 Apr) with Boeing representative. Section to be revised and submitted in next YP cycle.

- Section 2.2 Sources of Variability – Fall 2023 YP1 – 2 negatives. Section revised and submitted into Fall 2023 YP2 – 1 negative. Meeting discussed figure included in Section 2.2 listing common sources of variability. Section to be revised and submitted in next YP cycle.

- Section 2.3 Building Block - Fall 2023 YP1 – Accepted with no negatives.

- Section 2.4 Data Classes – Not drafted >> Need volunteers.

- Section 2.5 Qualification vs Equivalency vs Interchangeability – Not drafted >> Need volunteers. Beth Clarkson to draft short paragraphs for Qualification and Equivalency.

- Section 2.6 Recommended Test Matrices – Not drafted >> Rick C. and Stefan K. to draft.

- Section 2.7 Data Substantiation for Use of CMH-17 Basis Values – Meeting agreed to delete this Section.

New Business:

Meeting discussed and agreed that title for the new volume will be "Non-Metallic Additive Manufacturing".

Meeting discussed State Of The Art (SOTA) for non-metallic AM to help determine "boundary" for content in the volume. All agreed that information that is clearly research and unproven should not be included. To the question of criticality of non-metallic AM parts being used in aerospace applications, it was generally agreed that while there are no parts of high load and significant criticality flying in aircraft, space applications are already flying "significant structural parts" including some that are "mission critical" (though it was noted that all significant space application parts are proof tested).

Meeting discussed including non-aerospace materials and processes in the Volume. There was general agreement to include Large Format AM (LFAM) and tooling. It was suggested the M&P chapter might be the best place for this, but recognition that there might need to be short discussions in several other places as well.

Meeting recognized need to reset day/time for monthly AM GWG meetings, but didn't have time to come to conclusion.

Action Items:

- Rick C. and Bijan D. to revise and submit to next YP cycle Sections: 1.5, 1.6, 1.8.2, 1.9, 2.1, 2.2.
- Rick C. and Stefan K. to prepare first draft of 2.6 Recommended Test Matrices based on NIAR test matrices.
- Eric M. and M&P to look into incorporating Sources of Variability details provided by Bijan D.
- All WG Chairs to consider adding information on LFAM and tooling in their chapters.
- Rick C. to contact all WG Chairs to ask availability so can reset AM GWG monthly meeting day/time.

Standing Actions:

- All AM WGs requested to capture symbols and abbreviations as they write their chapters, and forward them to AM Guidelines.
- All AM WGs requested to capture any new definitions as they write their chapters, and forward them to AM Guidelines.

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CHM-17 Coordination Meeting: AM Testing Working Group

4/23/2024

Testing Working Group

- **Objective:** Give guidance on appropriate test methods and test conditions for use with AM materials while taking into account, material type, machine capabilities, process information, industry desired data, statistical analysis requirements, and available standards. Test standard creation and/or appropriate changes may be necessary by working with applicable industry leaders and standards organizations to ensure the test method is understood, usable, appropriate, and repeatable for use with AM materials. Working with other groups of the CMH17 AM community to ensure proposed test methods are applicable for their purposes and can help in harmonizing all aspects that control a data set prior to submission and inclusion into the CMH17 AM volume.

- **Working Group Chairs:** Royal Lovingfoss-NIAR, Brian Kitt-Spirit, Joe Costanzo-Boeing
- **Recap:**
  - **Sections 9.8 and 9.11 (Tensile testing and Shear testing) are in draft and will be headed to "internal" review by the group during the WG working group meeting. Email sent out on 4/26/2024, responses due May 31, 2024.**
  - **Joe Costanzo sent email on 4/26/2024 (Royal Lovingfoss forwarded) on "yield point" of neat polymer materials. For Testing Group discussion - Is there any interest in writing this up as a test method to include in Volume 7?**
  - **If you would like the presentation on Modulus Calculations given by Rick Cole please request from Royal Lovingfoss.**

Testing Working Group

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- **Recap Continued:**
  - **Discussion of Rick Cole's modulus reporting proposal:**
    - **Most in room seem to "require" curve and equation, in addition to modulus (at RT and ETW?)**
    - **the scope of this proposal is for material with no fiber reinforcement**
    - **Stefan Kloppenborg, Statistics WG co-chair, suggested review of 8.6.1 for best practice curve fit procedure. This could possibly replace steps 2-5 of Cole method. Stefan offered to help write up how to do this curve fit in a way that simplifies the method**
    - **As far as curve fit, Frank Dixon asked if we could do a small study to review/compare the difference between linear or quadratic versus quartic curve fit. Maybe we can get something useful without higher order eqn curves**
    - **John Moylan, Element, has concerns with requiring curve fit using higher order polynomials. Called these two proposed methods the "linear method" and the "complicated method". He really doesn't like the "complicated method"**
    - **Comment regarding this method… it may be OK but you need to match the method to the usage. "quasi-static data, if the application is outside those bounds, is no good"**
  - **Section 7.3 "data reduction and documentation" moved to DRWG**
  - **Question "Does design need 'normalization' like pre-pregs do"? Agreement was that we do not, since at this point we don't have allowables for a fiber reinforced product**
  - **Question also raised relative to trying measure void content to account for it when calculating part stress. Consensus seemed to be that with adequate inspection, argument could be made that coupons also have voids, and that the coupon test data will reflect the final part void content with no additional knockdowns required.**
  - **Frank Dixon volunteered to write sections for density testing and FVF testing (fdixon@ups.com)**

Testing Working Group

- Stephanie Svetlik-Haley offered to author a section on component testing (stephanie.svetlik-haley@fireflyspace.com)
- Question – what is in scope, only materials with published specs or best practice guidance? Answer - at this point in material/process maturity, we will cover both
- Group consensus that its OK to use "T.B.D." for sections not currently used (for example, unreinforced Polymer AM doesn't need OHC, so we won't write up the test method at this point)
- Member list updated. From Webex chat: new email for Tim Chavez – TCMK.timc@gmail.com and request to add Aziz Ahmed – AZIZ.AHMED@FAA.gov
- Outline updated with member responsibilities.
- Group discussion point for future Testing (and maybe Guidelines?) meeting - do we, as a CMH-17 AM team, need to reevaluate the current content and philosophy regarding the usage of Building Block Method with AM (best practice guidance)? Guidelines section has a truncated building block, peaking with a part/component test. But the Testing section has a copy/paste of the whole Building Block approach from PMC Vol 1. Several people (smaller independent companies, not the big airframe OEMs) commented that the approach needs to only cover coupon tests and component tests. They don't want/need a building block approach when they want to print full-scale complex parts and test them, then implement. Maybe we should delete the section on the full building block approach, lean on the Guidlelines version, and then offer a pointer to PMC Vol 1 for anyone that things they are ready to tackle the whole building block approach?

- **Agenda:**
  - Go through YP comments on submitted content.
  - Deep dive discussion of sub-component and component testing (best practices). We will need to decide where we want to place this in the outline and what "types" of testing we want to discuss, and what types of things need to be thought about when thinking of testing these types of articles.