Considerations for Certification of Additive Manufacturing

MITRE Advanced Manufacturing Trust Showcase

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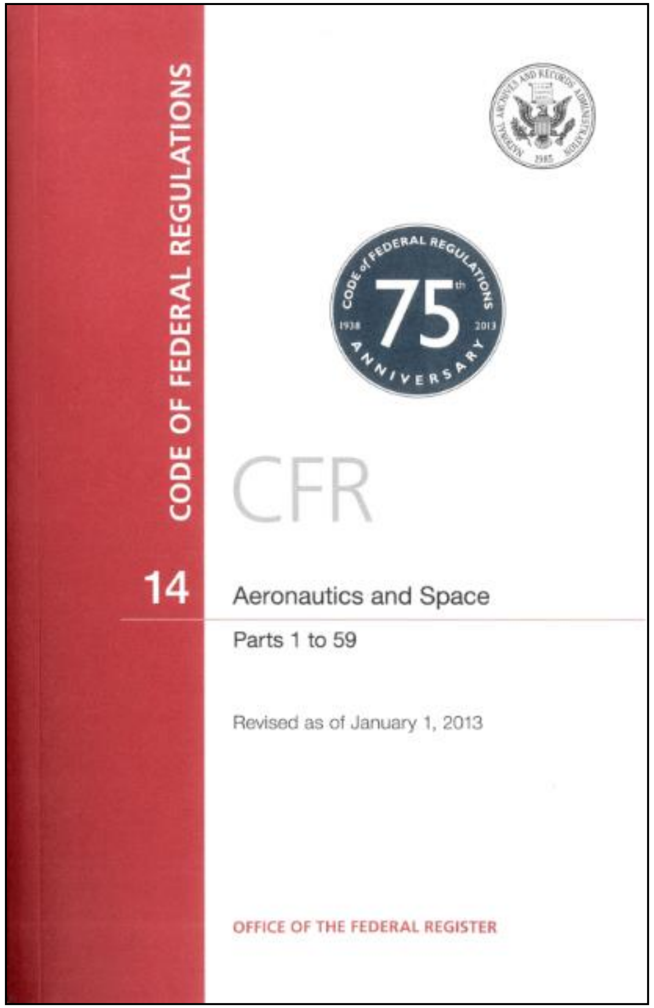
Federal Aviation Administration
STEP SENIOR TECHNICAL EXPERTS PROGRAM
ADVANCING SAFETY THROUGH SCIENCE

Fundamental Requirements

Regardless of material or process, some fundamental regulations always apply to civil aviation products and articles

1. Design must define the configuration and the design features with sufficient detail to ensure the final product will comply with the applicable airworthiness requirements
   - Could be called a specification and/or process control document (PCD), instructions on a drawing, or other documentation, as long as all necessary information is documented
2. Changes to the design data, including materials or processes and their associated specifications, are a design change that must be approved
3. Implementing advanced manufacturing may change the quality system, which must be coordinated with the FAA
   - For example, if inspection methods change



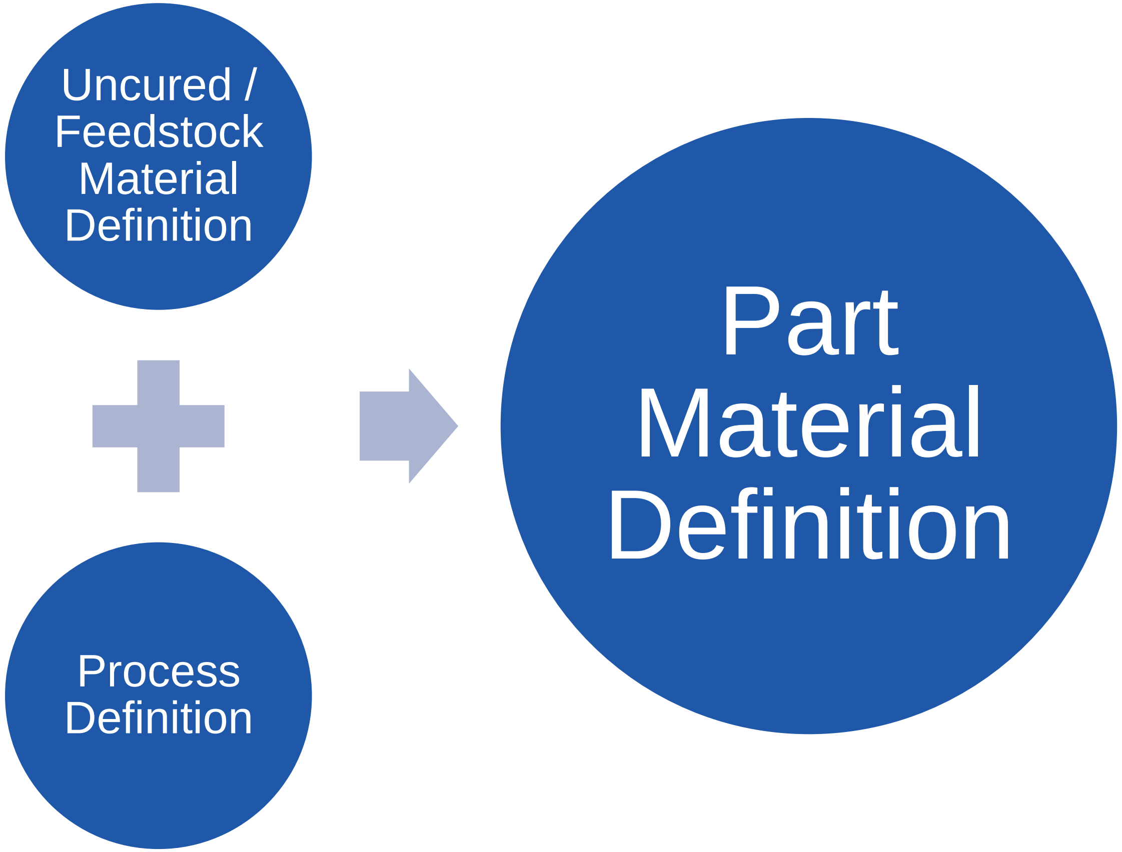
Material & Process Definition and Control

The first step for certification of any advanced material and process, in any application, is the most critical – the materials and processes must be defined and stable

- The **degree of rigor** can be commensurate with the criticality of the application

Three Items to Define and Control

1. **Raw or Feedstock Material**
    - This includes reuse methods, but may also include build plate and support materials
2. **Process to Convert to a Part**
3. **Final Part Material**
    - Ensure required chemical, physical and mechanical properties are achieved
    - Tied to the process specification used to create the part
        - Can be done at the part level



Part Level Control is much more relevant to new materials and processes

1. Raw or Feedstock Material Control

Generally covered by a specification

- Company or industry specifications can be used, when shown to be appropriate
- May have separate standards to define reused AM feedstock
- Should include standards for chemical and physical properties at a minimum; may also include mechanical properties and/or flammability
  - Some of these properties may not be able to be evaluated without transforming the material into a printed coupon
  - These coupons for quality control purposes do not have to match the process for producing parts, but best practice is to stay as similar as possible

The number of properties measured and controlled for feedstock materials can vary based on the criticality of the application

2. Process Control

Potentially many process parameters to control and understand the effects of variations, including the effects on long term behavior and aging

Process Control Considerations

- The designer may closely control process parameters
  - Simplified method to ensure repeatability
  - May be difficult to meet tight process tolerances

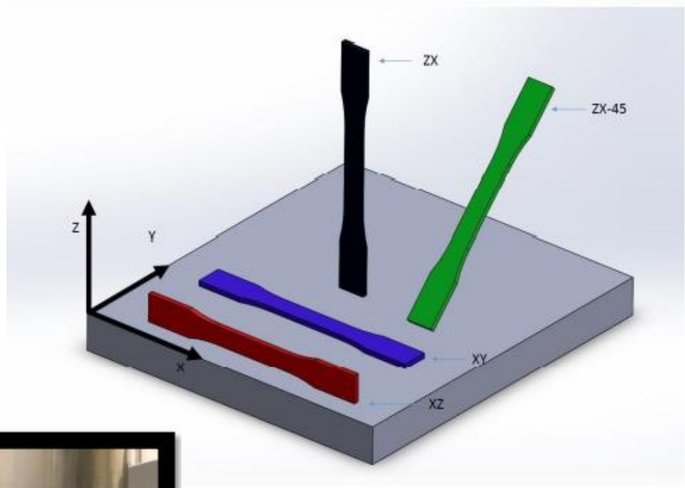
OR

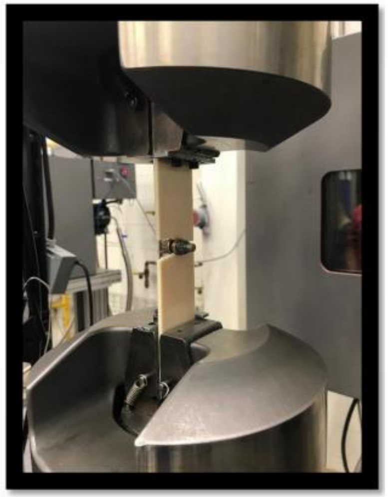
- The designer may allow more variations in parameters
  - Must understand and account the effects of those variations

3. Final Material Properties

Flexibility in defining final properties – Option 1, coupon / material level control

- With traditional material controls, coupon-level properties such as XY and ZX tension and compression strength and modulus are defined for material that is produced using the approved uncured/feedstock material and following the approved process specification. The manufacturer's quality assurance system will ensure the final **material** properties have been achieved (at least as measured at the coupon scale)





3. Final Material Properties

Flexibility in defining final properties – Option 2, part level control

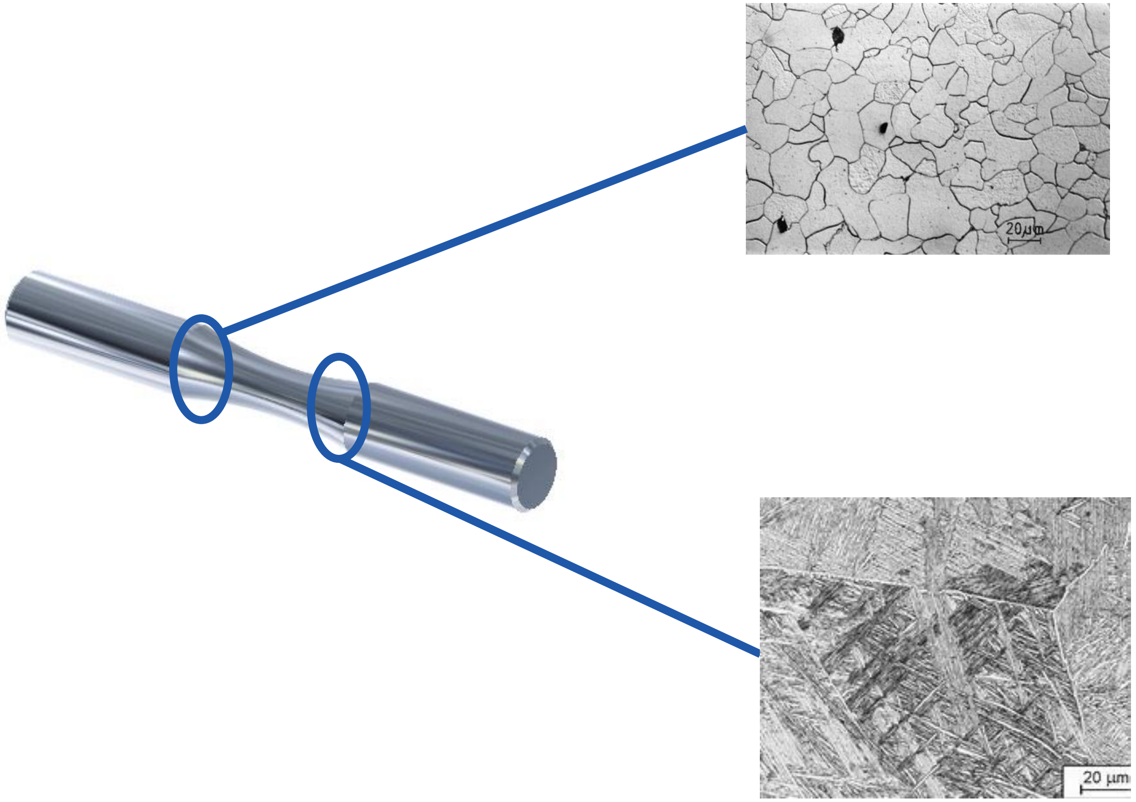
- With part-level material control, specific properties like 0° and 90° tension and compression strength and modulus may not be defined or measured; instead the part as a whole is characterized for its strength, stiffness, or other mechanical behavior and the manufacturer’s quality assurance system will ensure final **part** properties have been achieved.

In either case, final material properties are being controlled; what changes is the *scale* at which they are controlled

Material Control – AM

Variations within a part may be acceptable

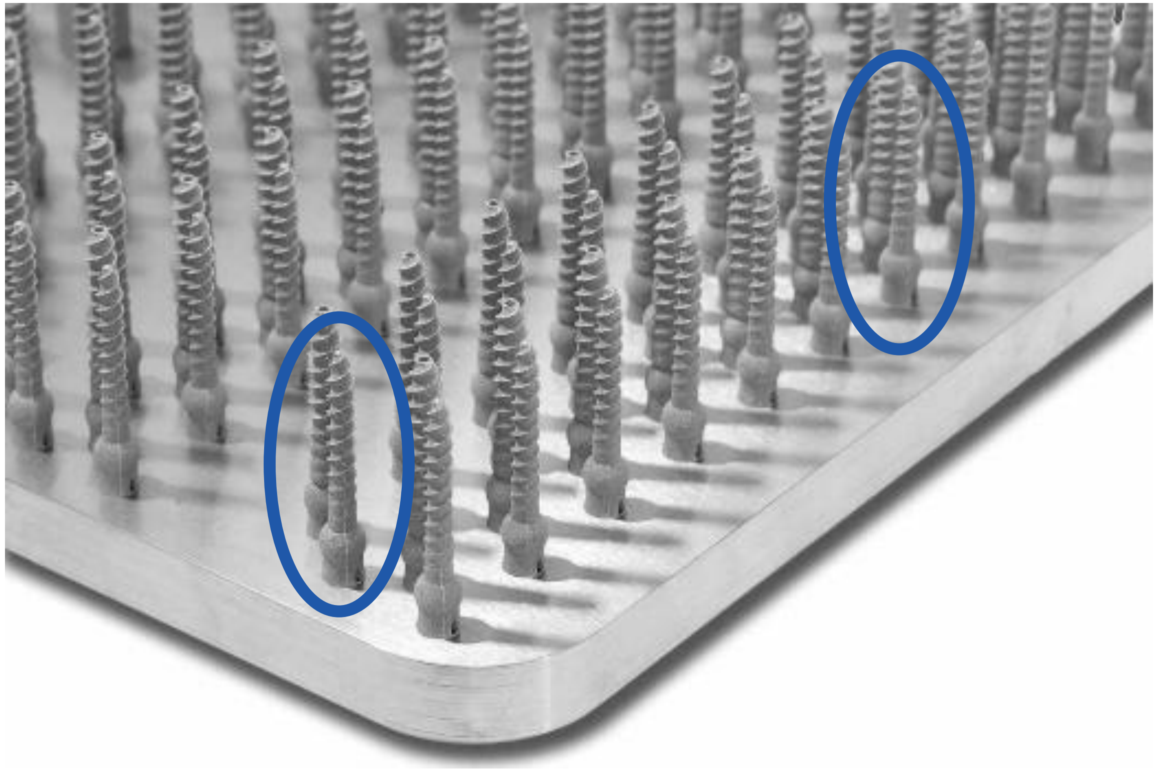
- Parts may have different microstructure along the part build direction
- Should be consistently built the same way



Material Control – AM

Variations within the build space

- Currently finding that parts at one end of the build space are not always the same as those at the other end
- This may be acceptable if they are a repeatable pattern (e.g., Part 1 is always the strongest and Part 10 is always the weakest)

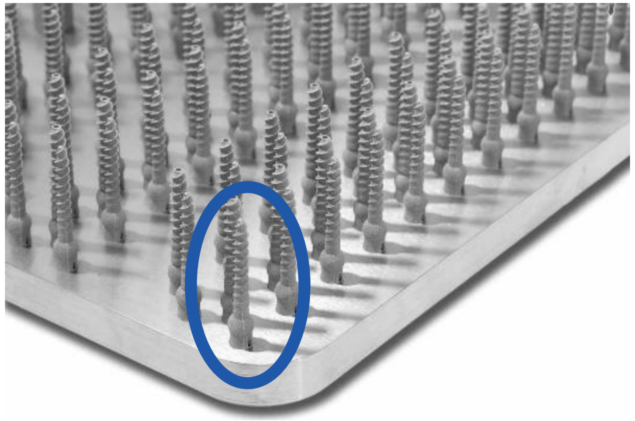


Are these parts the "same"?

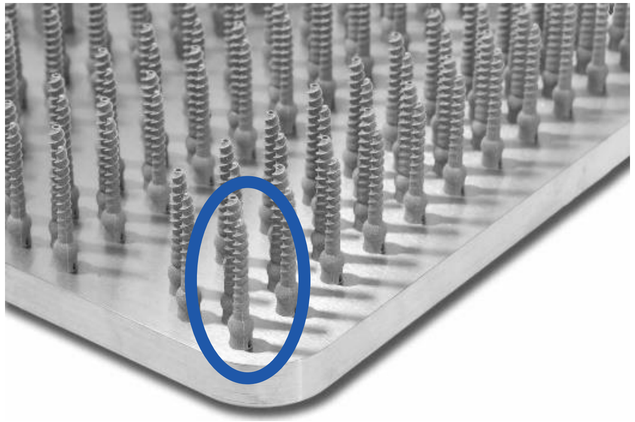
Material Control – AM

Variations between builds

- Are parts produced in different build runs the same?
- Always some variation around the mean, however…
- If the process has significant differences in final properties that appear inconsistently (e.g., sometimes Part 1 is strongest and Part 10 is weakest, and sometimes vice-versa), that indicates “randomness” that may not be acceptable



Are these parts the “same”?



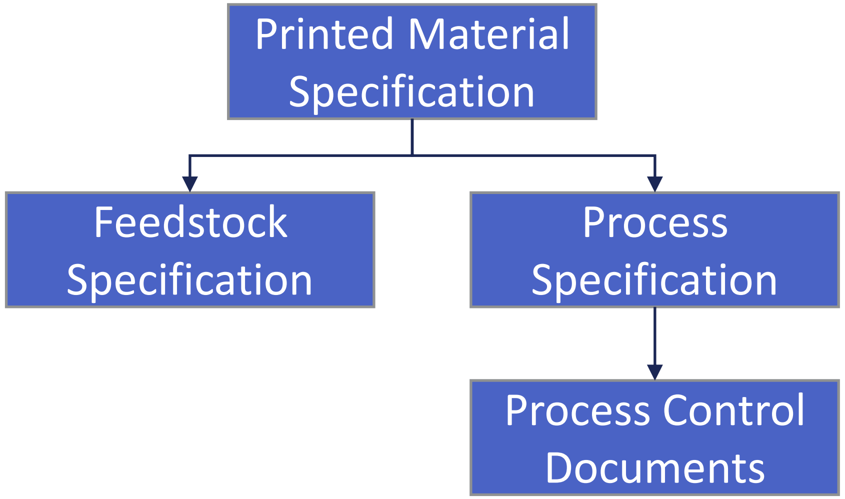
Material and Process Control

For each of the three control areas – feedstock, process, and final material properties – the degree of rigor in demonstrating compliance may be scaled for the criticality of the application

- "<u>Appropriate</u> Definition and Control" is tricky

The importance of adequate M&P control cannot be overstated

- You cannot certify a product if the final product isn't stable
- Properties may vary throughout the part, but at the part level, the properties must be consistent unit-to-unit
- Supported by a stable uncured / feedstock material



Potentially Affected Regulations

Only after the design is repeatable, should you begin showing compliance to other airworthiness requirements

- **Products and articles must meet all applicable regulatory requirements**
  - The specific requirements will vary depending on the type of design approval and application
- **Applicants should be aware that means of compliance to airworthiness regulations may change when incorporating advanced manufacturing techniques due to unique considerations associated with the technology**
  - Affected regulations may include, but are not limited to, strength, fatigue and damage tolerance, and flammability

Structural Substantiation

- **Strength and design values must reflect not only the variability of the feedstock material(s) as purchased by the part manufacturer, but also account for the variability introduced by the manufacturing process**
- **Consider that structural behavior of parts produced with advanced manufacturing techniques may not be the same as those produced with traditional manufacturing methods**
  - Parts may exhibit anisotropic and/or inhomogeneous properties as a function of part geometry and other factors, or develop and propagate damage in different manners during cyclic loading
  - The number and type of flaws and anomalies in parts produced with advanced manufacturing techniques are often quite different from those found in traditional manufacturing, which may necessitate an investigation into the effects of defects* and use of additional safety factors or inclusion of intentional defects* in static and dynamic test articles
- **Existing guidance may or may not still be applicable**

**Technically not a defect until it is shown to be unacceptable. Sometimes called an "anomaly" or "discontinuity"*

Recommend the use of conservative, simplified engineering approaches with point design substantiation, followed with a more rigorous, fully developed building block approach for expanded applications once structural performance characteristics are better understood and can be generalized

- Fundamental behaviors include static strengths and fatigue behaviors in all axes with and without damage, effects of process parameters, effects of notches, curves, or other geometric features/details, aging behaviors, repair techniques, inspection methods, etc.

Bottom Line:

Early applications won’t have all the fundamentals covered or even understood but conservative engineering practices can work as long as the primary thesis holds – that materials and processes are controlled for repetitive and safe products/parts

Questions?

Request More Information

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