ADDITIVE MANUFACTURING COMPONENT CERTIFICATION STRATEGY

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Abstract

The certification strategy for the selected component highlighted multiple challenges: firstly, the lack of international and agreed material allowables for AM Inconel 718, secondly, the usage of a known but yet to be standard technology such as AM-LPBF. Lastly, in accordance with FAA guidance, also the safety assessment of the selected component.

This activity has covered a robust qualification program for both the L-PBF system involved in component production and the related Inconel 718 material. It has provided the minimum material properties required for the use of this alloy processed using the L-PBF process. This strategy included characterization of the mechanical properties of the material at high temperatures and following a thermal cycle as well as process related discontinuity. In this scenario a unique and innovative solution to powder reuse was proposed: instead of binding powder reuse to manufacturing lots, a multi-parameters powder control was developed.

1. INTRODUCTION

Additive Manufacturing (AM) is increasingly used in aerospace for producing complex, lightweight, and high-performance components. Among AM technologies, Laser Powder Bed Fusion (L-PBF) enables the fabrication of optimized metal parts, improving structural efficiency and reducing material waste. By selectively fusing metal powders with a high-power laser, L-PBF offers excellent mechanical properties and design flexibility. As one of the first case studies a primary exhaust for one of the Leonardo Helicopters (LH) platforms has been developed and it is currently under authority approval. The hereafter certification strategy has been approved by the FAA.

2. PROJECT DESCRIPTION

2.1. General

The certification strategy for the selected component posed multiple challenges.

Firstly, the lack of international and agreed material allowables for AM Inconel 718; secondly, the usage of a known but yet to be standard technology such as L-LPBF; lastly, in accordance with FAA guidance, also the safety assessment of the selected component.

This activity has covered a robust qualification program for both the L-PBF system involved in component production and the related Inconel 718 material. It has provided the minimum material properties required for the use of this alloy processed using the L-PBF process. This strategy has also included characterization of the mechanical properties of the material at high temperatures and following a thermal cycle.

As part of the material & process characterization and qualification activity, Non-Destructive Evaluation (NDE) by means of micro Computed Tomography (μ-CT) has been performed on representative witness specimens (i.e. randomly chosen from the entire population of tensile specimens, powder and density specimens) as well as several prototype components in order to evaluate (any related) process discontinuities (type, size, distribution), assessing variability in build direction and manufacturing process.

In parallel with μ-CT NDE the applicability of conventional NDI (Non-Destructive Inspection) like Radiographic Testing (RT) Non Film technique and Penetrant Testing (PT), was investigated for post-process control.

Leonardo Helicopters strategy has resulted into three different phases: Powder Reuse validation, Extensive Material Characterization and Test on Components / Subcomponents.

2.2. Powder Reuse Validation

An innovative approach to powder reuse was introduced: rather than linking reuse to specific manufacturing lots, a multi-parameter powder control strategy was developed.

The four selected parameters able to characterize the key factors associated with to powder degradation are the following

- number of manufacturing jobs;
- weight of components and specimens manufactured;
- total surface of the manufacturing job;
- height of the building chamber filled by the manufacturing job;

as shown in Figure 1.

To prove the effectiveness of this strategy and to monitor powder quality over multiple reuse cycles, LH performed multiple tests and analysis focusing on powder properties, mechanical testing, metallurgical analysis and NDE of the printed material.

Experimental activity has involved eight different manufacturing jobs widespread among two years.

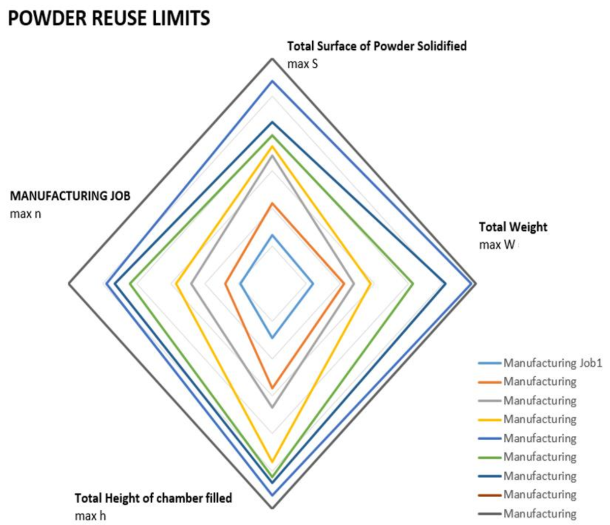

Figure 1: Representation of defined powder reuse limits.

2.3. Extensive Material Characterization

To validate mechanical and physical material properties, multiple tests involving five dedicated manufacturing jobs with more than one thousand specimens: three unique virgin powder lots, as well as two manufacturing jobs using reused powder has been investigated covering test type reported in Table 1; the manufacturing job layout is represented in Figure 2.

Table 1: Test for Extensive Material Characterization.

Test Type
Tensile Tests
Compression Yield strength Tests
Shear Ultimate Strength Tests
Stitching line investigation (Tensile tests)
Density Tests
Metallurgical Analysis
Bearing Yield and UTS Tests
Powder sample

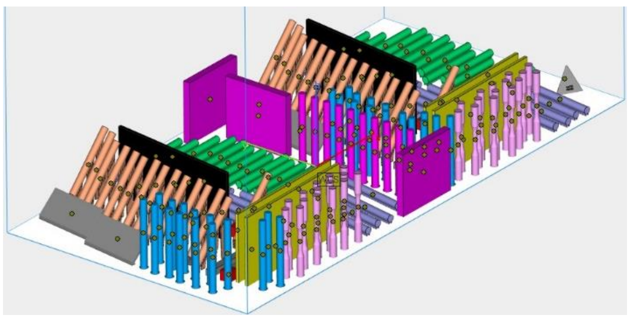

Figure 2: Extensive Mechanical Characterization Manufacturing job layout

2.4. Test on components / Subcomponents

The final step of the certification strategy was developed including components and subcomponents manufacturing. Preliminary evaluations were performed to identify the high stress areas by design analysis (i.e. FEM). Five different components were cut up to carry out metallographic analysis on different areas of the part; tensile specimens were also extracted from the component itself for correlation. The evaluation was completed by means of NDT i.a.w. ASTM E3166 on the subcomponents represented in Figure *3* i.e.

a) volumetric inspection (detectability threshold, sensitivity) by RT Non-Film techniques, comparing the outcomes with those from μ-CT NDE;

b) surface inspection through Type 1 Penetrant Testing (PT), on As Built fractured controlled plates representative of Down skin, Up skin and sidewall roughness.

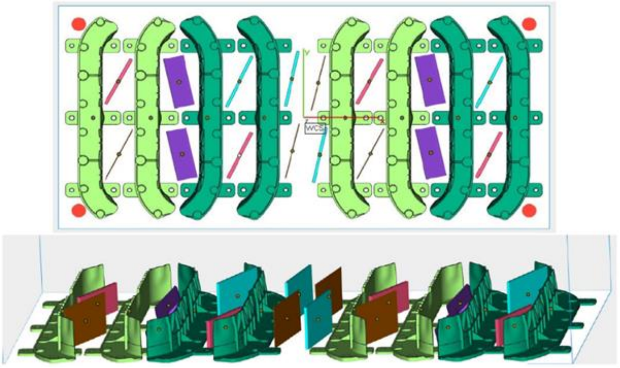

Figure 3: Layout of the Build Plate for subcomponent manufacturing.

The final test campaign, under relevant design office responsibility, has been focused on different additional S/Ns to complete the component certification.

3. CONCLUDING REMARKS

It has been proved that the proposed powder reuse strategy, for Inconel 718 alloy, achieves high repeatability and stability with the possibility of being effectively applied to other metallic alloys used for L-LPBF. The economical and industrial impact is expected to lead to cost saving of 28% to 65% per individual component, compared to existing validated industrial powder reuse strategies. This improvement involves extending the reuse of AM powder beyond the current 3–10 cycles, based on the four parameters described above.

The extensive testing activity allowed to develop a robust material database, encompassing mechanical properties and process discontinuities, while leveraging the application of both established and emerging NDT methods for post-process inspection.

The validation method developed by LH and approved by the Authority (FAA), has proven to be reliable and industrially applicable methodology for additive manufacturing material and component certification.

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