Inspiring Great British Manufacturing

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Executive Summary

This executive summary covers all activities conducted in the second evaluation campaign, WP4000, of the "ESA Additive Manufacturing Powder Material Supply Chain: Verification and Validation" project (ITT reference: G61A-018QT).

WP4100 & WP4200

In WP4100 two AlSi10Mg plasma atomised powder batches were procured from two different powder suppliers, AP&C (P6 powder) and TEKNA (P5 powder). In WP4200, the powder batches were sampled in accordance with the methodology described in TN4.2 and the powder batches were dispatched to consortium partners (ESA and Swerim), external laboratories (Inspire AG, Microtrac, Sirris and Wolfson Centre) and two AM service bureaus (AnyShape (AS) and 3D MetalPrint (3DMP)).

The inspection of powder containers on receipt did not raise concerns regarding the condition of any powder containers. Both AP&C and TEKNA conformed to the powder procurement specification issue 2 (PS2) for chemical composition, apparent density and tapped density. The mass percentage of both undersized (< 20 µm) and oversized (> 63 µm) particles of the AlSi10Mg powder supplied by AP&C conformed to the PS2 specification. The mass percentage of oversized particles of the AlSI10Mg powder supplied by TEKNA conformed to the PS2 specification. The mass percentage of the undersized particles (< 20 µm) was not provided by TEKNA. However, both AP&C and TEKNA followed a different technique for determination of the percentage of oversized particles (sieve analysis) than the technique specified on the PS2 specification (laser diffraction). None of the suppliers provided the morphology data as evaluated using Dynamic Image Analysis (DIA) as specified within the powder procurement specification PS2 document.

The sampling and splitting of the AP&C and TEKNA powders were conducted in accordance with the activities in WP3100 and accounted for recommendations provided in WP3100. The adapted ASTM sampling process accounted for consideration of the health & safety implications when handling the powder, and reduced risk of contaminating the AlSi10Mg powder batches. Learning from this activity is summarised in TN4.2.

WP4300

In WP4300, powder characterisation tests were performed at consortium laboratories (ESA, MTC and Swerim) and external laboratories (Inspire AG, Microtrac, Sirris and Wolfson Centre). The selection of tests conducted in the WP4300 originated from the recommendations provided in the TN3.4. The test results were reported and were evaluated for repeatability, reproducibility and consistency (comparison of data outputs from different tests which measure the same variable, conducted by the same lab). The full details can be found in TN4.3 Chapters 1, 2, 3, 4 and 5. The summary of conducted tests in Task 3 alongside test repeatability, reproducibility and consistency is outlined in Table 1. Techniques and individual parameters exhibiting good repeatability, reproducibility, and consistency are highlighted in green. While techniques and individual parameters exhibiting poor repeatability, reproducibility and consistency are highlighted in red. A dataset with an RSD value lower than 5% was deemed to have an acceptable level of repeatability, whilst one with an RSD greater than 5% was believed to have poor repeatability. The same approach was used to evaluate technique's reproducibility and consistency.

Table 1: Summary of tests conducted in Task 4 alongside the summary of test repeatability, reproducibility and consistency. Please not that ICP-OES was subcontracted to UKAS accredited laboratory. N/A indicates not applicable. Green represents good repeatability, reproducibility and consistency. While, red represents poor repeatability, reproducibility and consistency.

Test	Laboratory conducting the test	Repeatability	Reproducibility	Consistency
Automated Scanning Electron Microscopy (ASEM)	ESA	No data	No data	N/A
Inductively coupled plasma optical emission spectroscopy (ICP-OES)	MTC		No data	N/A
O, N, H content evaluated using Inert Sas Fusion (IGF)	MTC		No data	N/A
BET Surface area	Wolfson Centre		No data	N/A
Dynamic Image Analysis (DIA) (Camsizer XT)	MTC, Swerim		Size and Sphericity evaluations Aspect ratio	d10, d50 and shape evaluations d90 evaluations
Laser absorptivity	Inspire	No data	No data	N/A
Laser diffraction	MTC, ESA			d10 and d50 evaluations d90 evaluations
Laser diffraction & DIA using SYNC	Microtrac		No data	d10, d50 and shape evaluations d90 evaluations
Scanning Electron Microscopy (SEM)	MTC	No data from Task 4	No data	N/A
Apparent, poured, tapped density; Hausner ratio	MTC, ESA			N/A
Dynamic tapped density (GranuPack)	Sirris	Initial bulk density, Bulk density after n number of taps Slope α, Dynamic compaction factor n1/2	No data	N/A
Gas pycnometry (helium)	Sirris		No data from Task 4	N/A
Layer Density (Inspire spreading test rig)	Inspire		No data	N/A
Moisture content via Karl Fischer	Sirris		No data	N/A
Dynamic angle of repose via GranuDrum	ESA	Avalanche angle Avalanche energy, Surface fractal, Cohesion-T	No data	N/A
Dynamic angle of repose via Revolution Powder Analyser	MTC, Swerim	Dynamic angle Dynamic cohesive index		N/A

The two powder batches (P5 and P6) were characterised in terms of their chemical, geometric, physical and rheological properties. Clear differences were observed between P5 and P6 powder batches as measured by the ensemble of techniques used in this analysis. For geometrical and physical properties, there was general agreement in how the powders differ in reference to each other. However, whilst individual rheological property tests measured differences between the two powders, collectively the tests did not agree on the rank order of flow behaviours. The comparison of the standard operating procedures is discussed in TN4.3 Chapter 3.

Conformity to the PS2 Specification

Both, P5 (TEKNA) and P6 (AP&C) AlSi10Mg powder batches passed powder procurement specification PS2 (procurement specification developed in the deliverable entitled: "PS2 ESA Additive Manufacturing Powder Material Supply chain: Verification and Validation") criteria for chemical composition, particle morphology, tapped density, apparent density and particle density. The P5 powder failed against percentage of oversized particles (> 63 µm) as evaluated by the MTC and the ESA. The P6 powder failed the PS2 criteria for percentage of oversized particles (> 63 µm) (as evaluated by ESA) and the BET surface area (evaluated by Wolfson Centre).

Repeatability and Reproducibility Analyses

Considering the consortium tests, size, density and Sphericity (a parameter describing particle shape) evaluations were found to be repeatable and reproducible. Aspect ratio (another parameter describing particle shape) evaluations were observed to be highly repeatable but were found to exhibit low reproducibility. Rheological evaluations of powders were considered to have low repeatability and reproducibility. Bulk alloy and trace element chemical composition evaluations were considered as repeatable. Evaluations of interstitial elements should be considered repeatable, although, the interstitial element analysis has failed repeatability analysis conducted as a part of this project. The full explanation is provided in TN4.3 Chapter 2. Reproducibility data for bulk alloy, trace element chemical composition and interstitial element analysis were not available as these were only tested by the MTC laboratory.

Consistency Analysis

d10 and d50 size evaluations prove to be consistent across test techniques. This was both when comparing actual values and trends between the P5 and P6 powders. d90 size evaluations prove to be inconsistent across test techniques only when comparing actual values. The same trends were observed between the analysed powders indicating that the P5 powder was coarser than the P6 powder. Whilst the differences may be explained by virtue of the calculation and conditions used in the tests, comparative analyses still did not always provide comparable results.

Shape evaluations prove to be highly consistent across different definitions (x_area and xc_min) used for shape parameters calculations and across different equipment (Camsizer and SYNC) based on the same methodology (DIA). The observed trends for the analysed powders for both Aspect Ratio and Sphericity were the same as evaluated using Camsizer and SYNC. The full details can be found in TN4.3 Chapter 2 and Chapter 3.

Cross Comparison between Characterisation Labs and Techniques

Novel characterisation tests were conducted at external contract laboratories and by consortium partners. The test included cleanliness assessment using automated scanning electron microscopy

(ESA), laser density evaluated using spreading test bed (Inspire), laser absorption (Inspire), tapped density evaluated using GranuPack (Sirris), particle density via helium pycnometry (Sirris), moisture content via Karl Fischer Titration (Sirris), BET Surface area (Wolfson Centre), size and shape characteristic using SYNC (Microtrac).

The cleanliness assessment using the automated scanning electron microscopy (ASEM) revealed that the technique is capable of detecting different types of contaminants present within a powder batch. However, the technique was found to be immature, highly dependent on the skill of the operator and influenced by multiple factors. The technique requires further considerations and improvements to enable standardisation of contamination detection process using ASEM.

Measurements of the powder layer density (Inspire) were observed to correlate well with other test methods used to measure packing density. The laser absorptivity measurements test revealed some differences between the analysed powders. However, it was suggested by Inspire that the laser absorption of powders is not expected to affect Laser Beam Powder Bed Fusion (PBF-LB) process and a melt pool would exhibit different laser absorption than the powder.

Tapped density evaluated by Sirris was observed to correlate well with the density evaluations conducted by consortium partners and Inspire. However, Hauser Ratio as evaluated by GranuPack was not observed to correlate with the Hausner Ratio as evaluated by the consortium. It should be noted that the results for the dynamic compaction factor n1/2 and the slope α exhibited very poor repeatability (RSD > 11%), thus, these results were not used in the further analyses conducted in WP4500.

The results for helium pycnometry indicated that lower surface area did not seem to correspond to higher particle density. This evaluation intended to assess whether BET surface area might indicate open porosity of particles. The particle density measurements via helium pycnometry were observed to exhibit high repeatability (RSD ≤ 0.008%). Both P5 and P6 powders were observed to conform to the PS2 specification for the particle density.

With the available data, it was not possible to draw an explicit conclusion that there is relation between the water content as evaluated via Karl Fischer titration and the BET surface area. Sphericity data was inconclusive to indicate whether there is a link between BET surface area and the morphology of powders. BET surface area test was considered to not add any extra value beyond that of morphology assessment.

The results for particle size descriptors d10 and d50 as evaluated using SYNC (Microtrac) were found to be consistent with particle size as evaluated using both laser diffraction (The MTC and ESA) and DIA (MTC) when comparing actual values and trends between P5 and P6 powders. Additionally, the results for morphology (Aspect ratio and Sphericity) as evaluated using SYNC were found to be consistent with morphology as evaluated using Dynamic Image Analysis (the MTC and Swerim). The observed trends for the analysed powders for both Aspect Ratio and Sphericity were the same as evaluated using Camsizer and SYNC. The full details can be found in TN4.3 Chapter 4.

Cross-comparison Between Six AlSi10Mg Powders Evaluated in the Study

In the WP4300, the measured properties of AlSi10Mg powders analysed as a part of the first evaluation campaign (TE, TS, PH and RE) and the second evaluation campaign (P5 and P6) of the “ESA Additive Manufacturing Powder Supply Chain: Verification and Validation” were compared to the PS2

procurement specification developed in the deliverable titled: “PS2 ESA Additive Manufacturing Powder Material Supply chain: Verification and Validation”. Additionally, the trends between results for P5 and P6 powders analysed (analysed in WP4300) against the testing results for TE, TS, PH and RE powders (analysed in WP3200) were identified. The results suggested that that the plasma atomisation process (P5 and P6) does not necessary produce powders with the lower oxygen content than the vacuum induction gas atomisation process (VIGA) (RE, PH, and TE powders) and the electron induction gas atomisation process (EIGA) (TS powder). The full details can be found in TN4.3 Chapter 5.

WP4400

In the WP4400, the analysis of AM artefacts manufactured using two AlSi10Mg powder batches was conducted. Each powder batch was processed at AnyShape and 3DMP. The selection of the AM service bureaus, processing parameters, AM test pieces and techniques for evaluating part properties was based on the lessons learnt from Task 3.3: 1st Test and Analysis Campaign on AM Artefacts and Generic Space Parts and Task 3.4. TN4.4 Chapter 2 provides comprehensive assessment of methodologies applied by the bureaus for the manufacture of AM artefacts.

The characterisation campaign evaluating the quality and properties of the AM parts included both non-destructive investigations (density and surface roughness) and destructive investigations (tensile testing evaluating mechanical properties, fractography and microstructure). The aim of WP4400 was to analyse the findings of the characterisations conducted as a part of WP4400; and to evaluate the trends of properties across all evaluations in order to identify possible correlations between the properties of AM parts, the applied AM process and used metal powder feedstock.

Overview of AM Process Information

The powders were pre-treated prior the start of the additive manufacturing processing to reduce the moisture content present within AlSi10Mg powder batches, however different methods were used between bureaus. The provided data indicated that AnyShape effectively reduced the moisture content present within the powder batches. The effectiveness of the process applied by 3DMP remains unknown. 3DMP reported that particles the P5 powder displayed colour heterogeneity in the as-received containers. It has to be noted that the colour heterogeneity was not observed in powder containers received by 3DMP. Additionally, the results of the chemical analysis did not reveal any abnormalities of the P5 powder batch. Possibly, the observed colour heterogeneity at 3DMP was due to particle segregation. Effectiveness of powder conditioning process and its impact on AM part properties is not well understood. Additionally, the conditioning process is not standardised and can vary between AM service providers. It is recommended that effect of powder conditioning process prior AM process should be evaluated in the future research.

There were some differences in the initial temperature of the build plate observed between AnyShape and 3DMP. Also, the bureaus used a soft re-coater either a silicon blade (3DMP) or a carbon brush (AS). The material of the re-coater could contribute to the eventual charging effect between the powder particles and the re-coater. The velocity of the re-coater was higher at 3DMP (185 mm/s) than at AS (150 mm/s). Additionally, 3DMP applied a bi-directional re-coating process, meanwhile AnyShape applied unidirectional re-coating process. Both bureaus reported that P5 and P6 powders exhibited good powder spreading behaviour without displaying tendency for charging. It was suggested that silicon blade recoater and higher spreading velocity potentially contributed to the

higher spread layer density. Increasing S_a values on the up-skin surfaces observed with decreasing walls' angle were related to the increasing exposure to condensate and increasing contact with the powder of the parts' up-skin surfaces.

Both bureaus used argon as a process gas. However, the maximum allowed partial pressure of the oxygen applied by AS and 3DMP was of 1000 mbar and 0.025 bar respectively. Due to the higher pressure of the gas applied by AS, the partial pressure of oxygen was expected to be higher at AS. Surface roughness of AM parts was observed to correlate with the pressure used in the build chamber. Low pressure applied by 3DMP potentially could lower the thermal conductivity of the powder bed, thus enhanced the formation of a rough surface. Additionally, the observed high surface roughness of parts made of P5 powder, manufactured by 3DMP might be related to reaction of the melt with the gas flow (oxygen residues in argon). The down-skin surface of P5 parts that was in contact with the laminar gas flow in the build chamber had higher surface roughness than the side that was not in the contact with the gas flow. Additionally, presence of AlMg-rich oxide particles and films was observed within the defects on the fracture surface for the parts manufactured of P5 powder at 3DMP. The AlMg-rich oxide particles and films were barely notable or not observed for other analysed Alsi10Mg samples. Therefore, it was suggested that the reaction of the melt with the laminar gas flow in the build chamber contributed to the formation of AlMg-rich oxides on the melt pools.

The removal of parts from build plates was conducted by Swerim. All parts made of P5 and P6 powder batches manufactured by AS and 3DMP were heat treated simultaneously in a single cycle (300 ˚C 2hr) by a subcontractor. It is expected that part removal and heat treatment applied in Task 4 minimised the potential impact on AM part properties. The full details of the AM processed applied by AS and 3DMP can be found in TN4.4 Chapter 2.

Density Evaluations

Generally, powders processed by 3DMP were measured to have higher density of the deposited layer as evaluated using powder capsules (via Archimedes technique) than the powders processed by AS. However, the P5 powder was measured to have the higher powder capsule density than the P6 powder as processed by both AS and 3DMP. It was concluded that the density of the deposited layer was influenced by the characteristics of the power. It was indicated that the applied AM process by 3DMP, especially, low pressure of the process gas, bi-directional re-coating process, and characteristic of the re-coater blade could contribute positively to the density of the deposited layers.

It was concluded in TN4.4 Chapter 1 that the higher powder capsule density of the powders processed by 3DMP correlated with a high density in the final material. It was observed that the density of the powder capsules correlated with a high surface roughness S_a (when calculating a mean for the S_a (the arithmetic mean difference in height from the mean plane) value from all angled wall surfaces in the batch including up-skins, down-skins, all angles). A high layer density improves the thermal conductivity of the powder bed and could contribute to the measured higher surface roughness values for builds conducted by 3DMP. However, there was no correlation observed between the powder capsule density and the mechanical properties.

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Surface Roughness Evaluations

Surface roughness of the angles walls was investigated using Infinite Focus Variation Microscopy (IFM). The P5 powder processed by 3DMP was found to have the highest surface roughness (as evaluated using S_A) across all builds with presence of several and large protrusions on a relatively flat bulk material. In general, surface roughness as evaluated using S_a of builds conducted by 3DMP was higher than builds conducted by AS. S_a values on the down-skin surface were higher than the S_a values on the up-skin side which might be caused by the more dominant effect of the powder bed including effects such as low thermal conductivity of the powder bed, gravitation and capillary forces.

The results of IFM evaluations correlated with the finding from the fractography analysis, Light Optical Microscopy (LOM) and Electron Backscattered Diffraction (EBSD) evaluations of the surface contours. Additionally, a correlation between high surface roughness, low ultimate tensile strength, low elongation (especially for un-treated condition) and presence of large defect was observed for the parts made of P5 powder by 3DMP (as evaluated by mechanical testing, fractography and LOM).

EBSD analysis indicated that large particles present on the surface of the heat pipe of P5 powder processed by 3DMP exhibited similar grain structure as the bulk material. This finding suggests that the fused particles solidified at the same time as the material within the heat pipe. The conducted evaluations indicated that the formation of large particles was related to the high surface roughness of parts made of P5 powder at 3DMP.

3DMP reported that P5 powder did not exhibit tendency to moisture pick up. However, they indicated that open spots present on the spread layer were observed by the naked eye during spreading process. This observation alongside the presence of large defect as evaluated using LOM and fractography suggest that the large defects were formed due to lack of powder and the rough protrusions caused mechanical hinders for the deposition process.

Mechanical Properties Evaluations

The mechanical properties were evaluated for machined and as-built tensile bars, for both untreated and heat-treated conditions. It was concluded that mechanical properties were influenced by the applied PBF-LB process. The parts manufactured by AS were observed to have a lower yield strength in both un-treated and heat-treated conditions and higher elongation in heat-treated conditions than

the parts manufactured by 3DMP. The P5-3DMP parts exhibited abnormal mechanical properties in all conditions. The machined tensiles were observed to have higher ultimate tensile strength and elongation than as-built tensiles which appeared to correlate to characteristic of the contour areas (presence of defects, stress concentration sites (surface roughness)). The higher spherical porosity at the contour areas was observed for parts made by AS than by 3DMP. Additionally, the size of the pores within the contour areas was higher for AS parts than for 3DMP parts as evaluated by LOM, fractography and evaluations of heat pipes. It is recommended that more attention should be paid to investigation of an effect of contours on mechanical properties and crystallography of the surface contours in the future research.

In general, better repeatability for mechanical properties in un-treated conditions was observed for parts manufactured by AS than 3DMP which might be related to lower size of the defects present within parts manufactured by AS. Size of the defect appeared to correlate to the ultimate tensile strength and elongation. The grain size and stored deformation in the microstructure as well as the yield strength of the material was clearly higher for the 3DMP machined bars than for AS machined bars.

The relatively high variation for mechanical testing for parts made of P5 powder at 3DMP might be related to presence of local large defects and defect clusters. It was concluded that mechanical properties (low ultimate tensile strength and elongation, high standard deviation) of P5-3DMP parts might be related to microstructure of the material which was characterised by the lowest grain size and the highest amount of stored deformation in both un-heated and heat-treated conditions. It was concluded that the defects also acted as stress concentration sites for crack initiation and thus, contributed to rupture before full deforming capability of the material with a fine grain utilised.

The applied heat treatment improved elongation in as-built samples which might be correlated to the improved crack growth resistance caused by larger grain size and lower amount of stored deformation presumably in both bulk and contours areas.

Fracture Surface Evaluations

Fractography evaluations indicated that size of the defect present on the fracture surface correlate to mechanical properties. It was observed that ultimate tensile strength and elongation at rupture decreases as the size of the defect increases. It was concluded that the largest defects were caused by presence of lack of powder during the PBF-LB process and possible were correlated to random disturbances of the powder layer deposition.

It was concluded that lower ultimate tensile strength and elongation of the as-built tensiles than the machined tensiles correlated to the sensitivity of the contours for crack initiation and propagation. The stress concentrations induced by defects contributed to the fracture mechanism during tensile testing. Spherical gas porosity, surface roughness and microstructure characteristic promoted formation of stress concentrations. It was suggested that the effect of various contouring parameters to reduce sensitivity for formation of stress concentrations at the surface areas should be further studied. It has to be noted that the applied contouring parameters used by AS and 3DMP have not been revealed by the AM service bureaus due to IP protection. Additionally, it was recommended that grain and crystallography characteristics of the contours in un-treated and heat-treated conditions should be studied in detail in the future investigations. The results indicated that crack propagation was lower for heat-treated material that exhibited higher ductility and a larger grain size than

untreated parts. The results indicated that crack propagation was lower for heat treated material that exhibited higher ductility. The final fracture in the materials that contained a low number of defects followed the borders of the melt pool boundaries characterised by limited deformation through a fine grain size and a dense Si network.

Microstructure Evaluations

The EBSD and SEM evaluations of un-treated and heat-treated test pieces and thin features in heat pipes indicated that the microstructure was complex, and variations could be seen in different size scales from texture and grain size variations to segregation and solidification patterns of Silicon. Microstructure evaluations using LOM could connect the gray scale variations in the sample to the presence of solidification pattern of Silicon, therefore, LOM effectively revealed melt pool boundaries, defect, and surface contours without sample etching.

The porosity of fully densified parts (as evaluated via image analysis) indicated that P5 powder produced parts of lower porosity than P6 powder as manufactured by both AS and 3DMP. The porosity of fully densified parts as evaluated via Archimedes suggested that P5 powder processed by AS and P6 powder processed by both AS and 3DMP exhibited similar porosity level. While the P5 powder as processed by 3DMP was measured to have slightly higher porosity level than other powder batches. The formation of small spherical pores observed within the AM parts might be related to formation of gas porosity. The small pores present within P5-3DMP could originate from the formation of gas bubbles (hydrogen gas through decomposition of hydro-oxides of the surface films).

It was suggested by Swerim that achieving various attractive properties of heat pipes with a wall thickness of 0.3 mm might be challenging using AM technologies. Homogeneous and defect-free microstructure and shape accuracy might be influenced by the applied contouring and scanning strategy. Overlapping scan beams enable a very fine grain size. A However, silicon rich areas, typical for overlapping scan beams, induce inhomogeneous thermal conductivity for the material as silicon displays low thermal conductivity. These findings pose a question whether alternative materials would enable better thermal conductivity and phase stability at elevated temperatures than AlSi10Mg.

WP4500

The WP4500 combines the analyses conducted in Task 4.3 and Task 4.4. The aim of this project is to develop our understanding of links between powder and AM part properties. Ultimately, the WP4500 provides further revision of the correlations between powder and part properties identified in Task 3 (WP3000). The evaluation enables recommendations for changes to the powder procurement specification PS2; and to develop a third iteration of the powder procurement specification issue 3 (PS3) based on links between powder and part properties.

The evaluations of correlations between powder and part properties included powder shape, size, density, flow characteristics, moisture content, hydrogen content, part density and its defects. Generally, the conducted evaluations indicated that the observed correlations in TN4.5 were in agreement with the correlations observed in TN3.4.

A correlation between the lab-based powder layer density as evaluated using the spreading testbed and in-process powder spreading behaviour as evaluated using Archimedes powder capsule was observed. Additionally, tapped density as evaluated using GranuPack was found to correlate well with the powder capsule density. No correlation was observed between the powder capsule density and

apparent density, poured density as evaluated using Quantachrome and Hausner ratio as evaluated using both Quantachrome and GranuPack.

The particle density was observed to correlate with the density of the fully densified AM parts as indicated by porosity of the fully densified parts based on the image analysis. The particle shape appeared to correlate more to the powder capsule density than the particle size for PBF-LB AlSi10Mg feedstock with the nominal particle size within 20-63 µm. It was not possible to define a link between size and part porosity. Additionally, it was not possible to assess whether there is a link between hydrogen content and porosity of fully densified parts due to low repeatability of hydrogen content measurements.

The powder batches were conditioned prior processing in AM machines. Therefore, the given data do not enable to assess whether there is a correlation between the moisture content as measured using Karl Fischer titration and the powder capsule density. Additionally, the effectiveness of applied conditioning process by AS and 3DMP is unknown. Therefore, it remains unclear whether in-process spreading behaviour of AlSi10Mg was influenced by environmental conditions of the AM processing room during pre-build operations. It is suggested that understanding the effectiveness of conditioning process of a powder prior its processing in the AM machine should be further investigated. Additionally, impact of environmental conditions of the AM processing room on powder spreading behaviour should be investigated.

The full details of correlations between powder and AM part properties can be found in TN4.5. The proposed changes and the rationale behind the recommendations for changes to the powder procurement specification PS2 are discussed within the TN4.5. The summary of lessons learnt from the entire project and the recommendations are discussed within the final report.

References

TN 3.4 – Powder and part properties, and powder test and supplier selection

TN 4.2 – Powder Distribution Methodology and Outcome

TN 4.3 Ch1 – Introduction and Conclusions

TN 4.3 Ch2 – MTC Analysis

TN 4.3 Ch3 – Consortium Analysis

TN 4.3 Ch4 – External Laboratory Assessment

TN 4.3 Ch5 – Comparison of Powder Properties Against PS2 for Six AlSi10Mg Powders

TN 4.4 Ch1 – Introduction and Conclusions

TN 4.4 Ch2 – AM Process Information

TN 4.4 Ch3 – Non-destructive Analysis

TN 4.4 Ch4 – Destructive Physical Analysis

Version Control

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0.1	16/05/2023	Aneta Chrostek-Mroz	Draft	Document created
0.9	30/05/2023	Aneta Chrostek-Mroz	Draft	Document revised
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