Whitepaper: MetalFab x AMiRIS: The perfect pairing for a quality outcome

Additive Industries

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Additive Industries and Additive Assurance have partnered to deliver a process monitoring solution for all MetalFab Systems

Process monitoring is fast becoming an integral tool for best practice in additive manufacturing. With the process becoming faster and build envelopes becoming larger, the risk of higher cost resulting from poor quality is increasing. It is therefore important to ensure that integrating quality assurance into the front end of the process is key to achieving the best part price and delivery. The high resolution 8-camera solution, called AMiRIS, from Additive Assurance offers just that.

AMiRIS – The smart lens for achieving low cost of poor quality

Large frame LPBF systems typically tend to build large parts which have a lot of value locked into them. These parts then can undergo extensive post-processing which may contribute heavily to the cost of poor quality (COPQ) if issues are undetected early in the value chain. Furthermore, understanding the poor quality parts that may need rework or rebuild as early as possible makes it possible to re-run the build or quickly reschedule the project to ensure that the client is aware of the changes. AMiRIS integrated into MetalFab enables this.

AMiRIS and MetalFab - the perfect pairing

One of our design requirements when developing MetalFAB was to allow for large areas for external instrumentation to be integrated over time. To this point, a very large viewing area with the picture frame window at the front of each core was included in the design. This major design feature in MetalFAB gives an uninterrupted view of the build area for AMiRIS to do its magic, without compromising the operation of your MetalFAB series L-PBF machine.

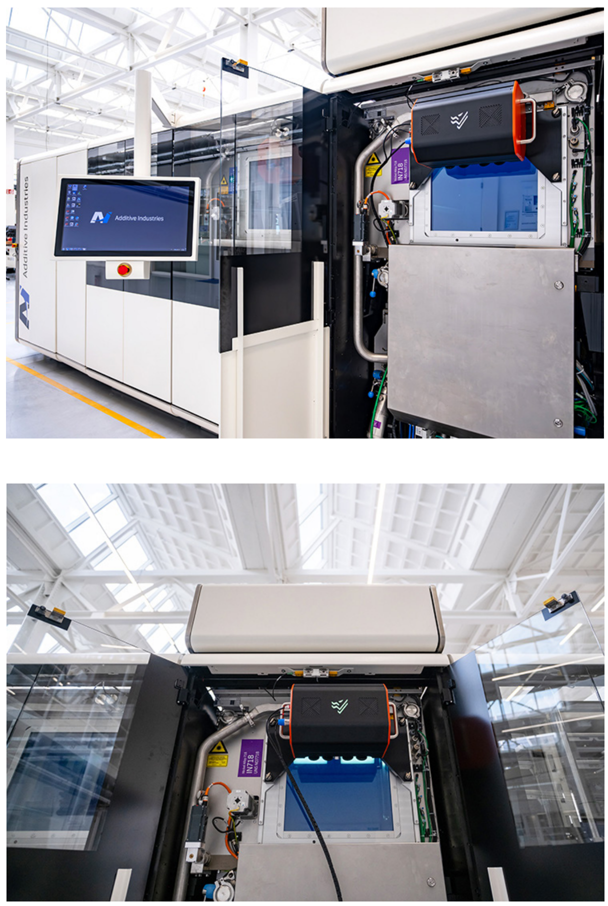

Fig 1: Setup of AMiRIS hardware in MetalFab system

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8x 47-megapixel CMOS sensors with deep neural network models

A highly engineered sensor unit consisting of 8 separate cameras makes full field coverage possible as seen in Fig 2 which provides a pixel resolution of approximately 35µm across the entire powder bed. A live Webcam is also connected to the machine which allows the operator to observe the process remotely.

Fig 2: AMiRIS-LF 8 cameras

All data is fed into Additive Assurance's machine learning model which builds onto an already large library of defects from most AM machines. A specific version has been built for MetalFAB to ensure that all the factors from the process such as gas flow and the recoater are accounted for.

Additive Assurance software in conjunction with AMiRIS-LF is able to provide:

- Powder Bed and Scan Vector monitoring and generation of 2D and 3D defect maps
- Micron level detail and defect identification
- Real time non-conformity detection
- Consistency across a fleet of machines in distributed manufacturing situations
- In-process QA reporting for rapid delivery of parts

The AMiRIS system generates superior quality data than other commercially available process monitoring systems owing to the high resolution imaging at approximately 35µm. Spatter, hot and cold spots are very easily detected which assists in improving support positioning, part orientation and detects any porosity (see Fig 3). Email alerts can be set up to notify users of any defects rising while building – improves decision on rebuilding. Thanks to advanced analytic methods it is possible to extract scan path data and assess individual vectors for melt and process stability.

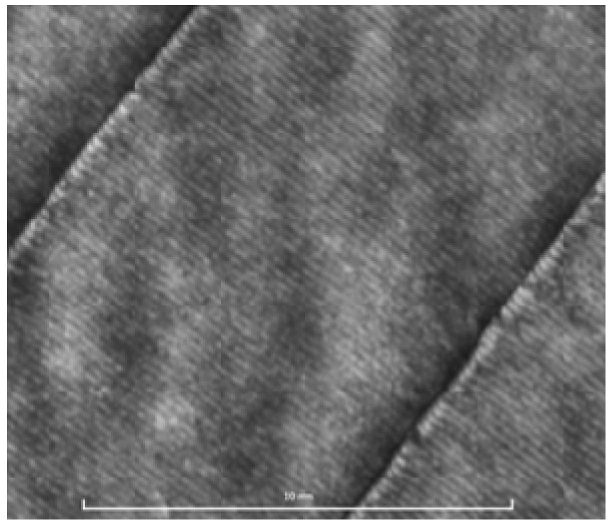

Fig 3: Example of high resolution raw meltpool imagery captured on the MetalFab machine

The AMiRIS system can also be used to supplement or replace non-destructive evaluation (NDE). Using the system alongside standard NDE methods, AMiRIS can show regions of interest that require additional investigation, or allow manufacturers to reduce the frequency of costly NDE.

Due to extensive deep learning models and library it is possible to predict XCT results, defect size and location as shown in Fig 4. Advancing CT analysis tools and diversified defect type portfolio provides causal defect analysis when using AMiRIS. This has a potential of reducing XCT testing which can reduce overall production lead time and cost.

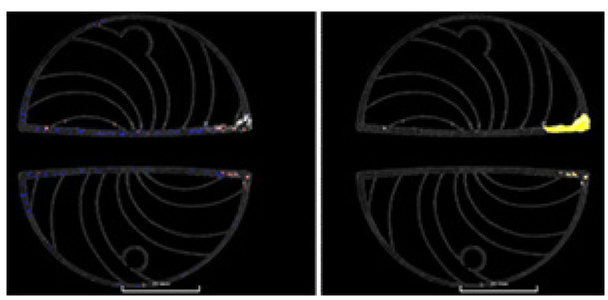

Fig 4: AMiRIS data resolving hot and cold spots (left) and spatter (right)

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At the end of the build, a QA report and 3D visualization is generated to further insight and reduce the analysis time for the user. This becomes important when seeking to determine the severity of defects that are identified in the individual layers (see Fig 5.). A similarity module has been developed to take this data and compare each individual part built with a reference gold standard. If the part is too dissimilar, it is flagged for further testing or rejection depending on the severity of the defects that have been mapped. This, alongside custom quality reports post build, allow for quality control to be performed in a timeframe that is far more aligned with best practice manufacturing.

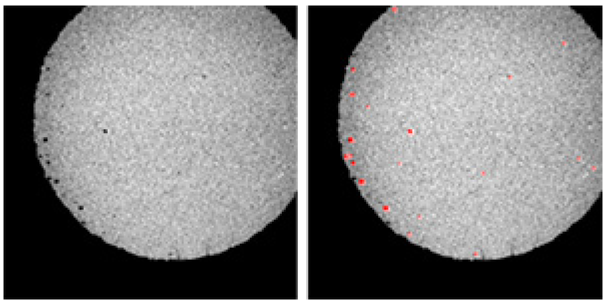

Fig 5: XCT actual image (left) vs predicted defects (right)

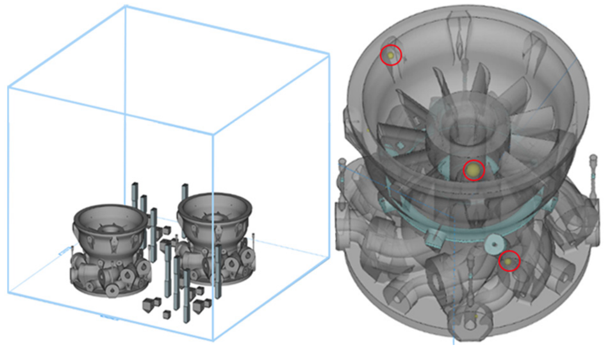

Fig 6: Overall build layout (left) and part B2 with seeded defects shown in yellow and power reduced section in blue (right)

After production, these were de-powdered, heat treated, cut from platform and subject to XCT externally. The result can be seen in Fig 7. Even with the use of an extremely high powered x-ray source (6 MeV, DIONDO D7 3.5-6.0 MeV), the resolution and contrast achievable from XCT was limited, and AMiRIS data was clearly superior in contrast and resolution. Here the XCT resolution of 139µm was achieved, which is 4x less than AMiRIS' 35µm. The difficulties of XCT in large parts are common, in part due to the poor penetration of dense alloys such as IN718.

Detection of seeded defects using XCT and AMiRIS – Practical Example

The MetalFab full scan field capability enables all lasers to operate as one across the entire build area which results in seamless parts without any "stitches". Furthermore, the uniform gas flow ensures optimal process with no spatter being incorporated into the melt and therefore the part.

In order to show that in-process monitoring is a valuable offering, two almost identical parts were built on the same build plate in a MetalFab system at our factory in Eindhoven. The only difference between the two parts was that defects were seeded in one of them (part B2). B1 is the pristine, baseline part. The material used for this build was IN718 and the selected process parameters for this work were our 'Balanced' parmaeters with 80 micron layer thickness.

The defects seeded into part B2 included 10 spherical voids of various sizes between 0.25mm to 10mm in diameter. In addition, a slice of 2mm in the center of part B2 had a separate parameter applied that reduced the power of the in skin by 15%. The parts are shown in Fig 6.

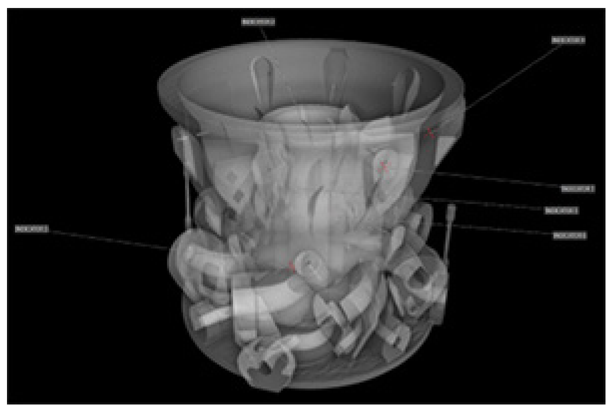

Fig 7: Reconstruction of CT scan of part B2 and location of 6 detected defects as reported by qualified XCT provider

From the XCT only 6 of the 10 seeded defects were able to be detected, and no other anomalies were identified. The smallest defect identified with XCT was 1.5mm in diameter. In contrast, 100% of the identified defects that were seeded in B2 were detected during the build with AMiRIS, along with the remaining 4 defects that were not identified in XCT.

With the 35µm pixel resolution, the defects were able to be detected, flagged and reported during the build, as shown below.

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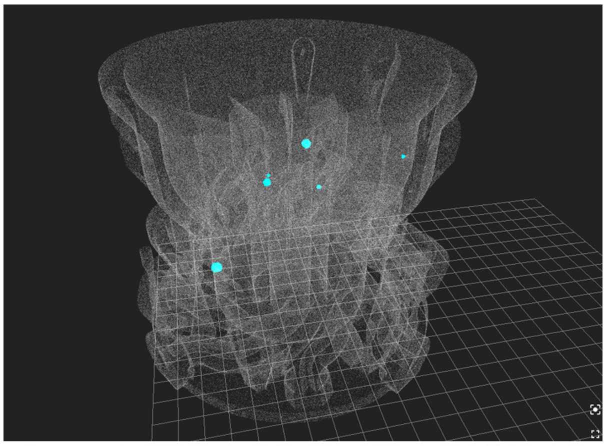

ID	Volume (mm³) ↑	Surface Area (mm²)	Surface Area/Volume (mm⁻¹)	Solidity (%)	Extent (%)
3	15,623mm³	4,093mm²	2mm⁻¹	83%	41%
2	13,899mm³	3,615mm²	2mm⁻¹	87%	53%
1	2,813mm³	1,275mm²	4mm⁻¹	83%	51%
5	2,260mm³	1,083mm²	4mm⁻¹	80%	39%
4	347mm³	333mm²	8mm⁻¹	72%	29%
6	183mm³	195mm²	9mm⁻¹	79%	41%

Fig 8: Reconstruction of XCT Data within the AMiRIS platform and identification of pores

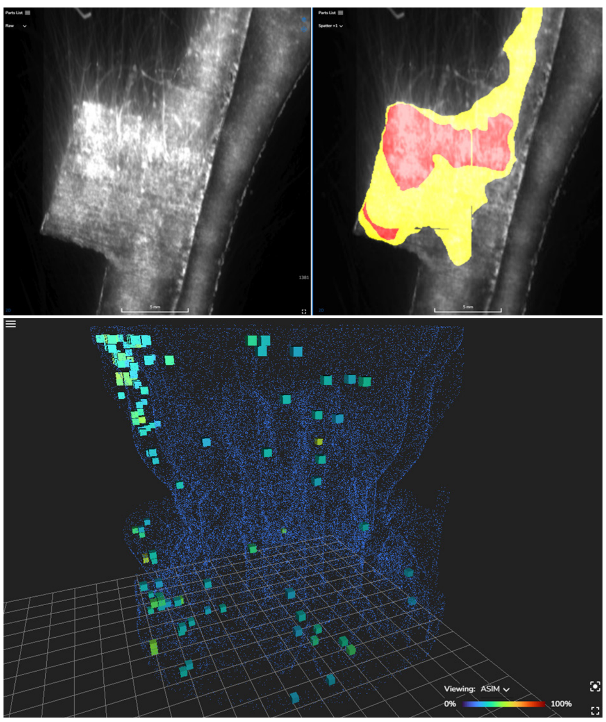

Fig 9: Example of spatter generation and automatic detection in process, separated into high (red) and moderate (yellow) classes and regions of interest identified in the similarity comparison that contain defects detected in process

The two parts in the build (B1 and B2) were run through the similarity module. This is a computational method to determine the level of fit of the parts compared to the gold standard.

In this case the baseline part (B1) was set as the reference part - it is apparent that the defects are not only detected with AMiRIS, but also modeled for their severity on the part's integrity. The similarity score for B2 compared with the pristine B1 part was 80.33%. In this instance, B2 did not pass the similarity check and would in a production setting be flagged for further testing or rejection depending on the quality requirements for that part.

In addition to similarity methods, traditional intensity methods were also applied. Statistical measures of the intensity for each part over all layers and be easily extracted, showing trends over time, such as overheating or laser faults. In part B2 the center section had a 15% lower laser power parameter applied, which is readily observed in Fig 10.

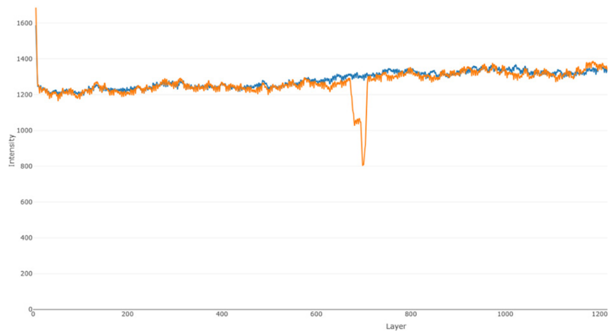

Fig 10: Mean meltpool intensity per layer. Blue denotes part B1 and Orange part B2.

The seeded defects in B2 are easily visible with no other predicted defects present. This is due to the robustness of the IN718 'Balanced' process parameters on MetalFab which self-stabilizes readily giving rise to a highly dense part.

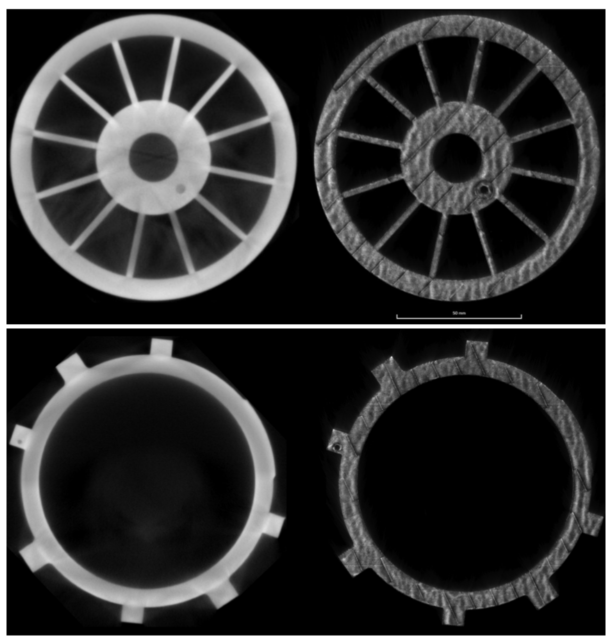

Fig 11: Detection of seeded defects using XCT and AMiRIS in part B2 (above layer 1040, and below layer 1320)

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Benefits

It is clear that the following benefits are achieved when using AMiRIS on your MetalFab machine:

- All common defect types during build process detected
- Higher resolution imaging even compared to high energy CT scans
- Obtain quality assurance information real time to make informed decisions
- End of build reporting to speed up production sign-off

Limitations

It needs to be noted that as AMiRIS is capturing data during the build process, any issues created after the build process is complete will not be captured in the data (i.e. parts damaged during handling or distorted in heat treatment). However, this is a far less critical area of concern for the production environment and accounts for a relatively small percentage of part rejections.
The process for analyzing these post build defects are typically covered in standard production quality testing such a 3D surface scan, CMM, tensile testing etc.

Conclusion

The design of the MetalFab's picture frame viewing window provides the ultimate aspect for AMiRIS to operate without sacrificing any other sensor real estate of the machine. It's the perfect pairing. All seeded defect types were detected using AMiRIS. This provides real-time feedback to the operator, empowering them to make the best decision of how to manage a quality issue in process. Not only is the information presented proving decision-making opportunities at the time that the quality issue is detected, it is also far higher resolution than the gold standard CT scan technique. In an environment where CT scans are reduced or eliminated, AMiRIS will also offer a most cost effective solution. Quality reporting at the end of the build can allow for sign off of production much earlier than previously experienced to dramatically reduce the production cycle and unlock revenue much faster.
When taking into account all of the benefits: AMiRIS is faster, cheaper and better than relying on CT scanning alone - time to get one on your MetalFab.

White paper

For more information on AMiRIS process monitoring system please contact Additive Assurance at: hello@additiveassurance.com

At Additive Industries, our objective is the success of our customers in achieving the lowest cost per part at market leading quality.

We pride ourselves on our flexibility to work with our MetalFab users in achieving their industrial goals.

To find out more, contact us at:
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