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Materials Science and Technology Division

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ABSTRACT

ORNL (Contractor) and Magna Services of America Inc. (Participant) collaborated to determine the feasibility of binder jet additive manufacturing (BJAM) for the fabrication of copper components for automotive heat sink applications. This Phase 1 collaboration focused on printing copper heat sinks that rely on capillary effect to move fluids rather than mechanical pumps in electric vehicles to extend the battery range and life. Partial sintering of copper powders deposited via BJAM was hypothesized to aid capillary effect to improve the heat transfer. Further, BJAM offers the potential for scalability at a production level.

1. EXPLORATION OF BINDER JET ADDITIVE MANUFACTURING FOR AUTOMOTIVE HEAT SINK COMPONENT FABRICATION

This Manufacturing Demonstration Facility (MDF) technical collaboration project was started on September 27, 2021 and ended October 31, 2022. This project was in collaboration with Magna Services of America Inc. In this project, ORNL and Magna evaluated the potential for using binder jet additive manufacturing (BJAM) to deposit copper powders in desired geometries conducive for eventual use for heat sink applications.

1.1 BACKGROUND

With the automotive sector undergoing electrification, battery range and life are the most cited barriers for widespread consumer acceptance of electric vehicles (EVs). In the absence of waste heat from an internal combustion engine, EVs utilize the battery power to heat and cool the vehicle cabin that can negatively impact the vehicle range in between charges. The aim of this technical collaboration was to develop 3D printed porous heat sinks that rely on capillary effect instead of mechanical pumps to move liquid. BJAM was selected as the 3D printing technology owing to its scalability potential as well as the ability to leverage the process inherent porosity to aid capillary effect to enable evaporation and condensation of fluids for heat sink applications.

1.2 TECHNICAL RESULTS

Figure 1 shows the particle size distribution of the copper powders used in this project. The d_{10}, d_{50}, and d_{90} of the powders was measured to be 6.32 μm, 9.43 μm, and 24.24 μm respectively.

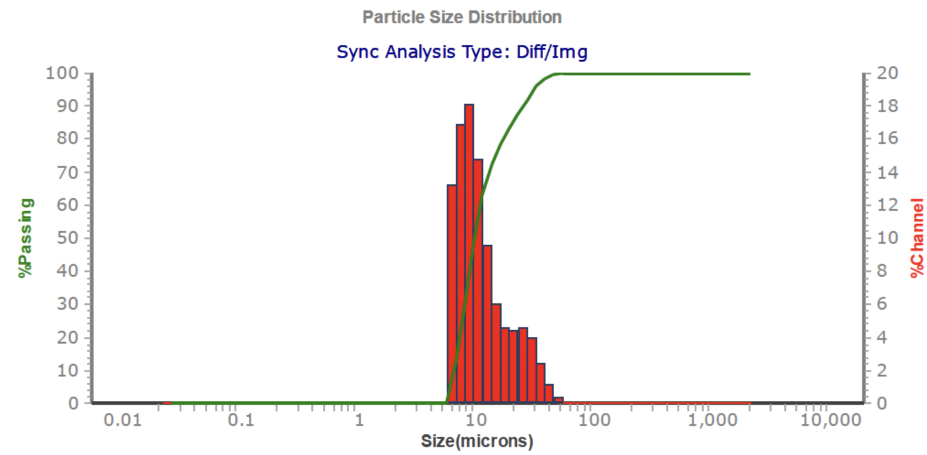

Figure 1 shows the powder size distribution of the powders used in the study.

An ExOne Innovent binder jet system was used with AquaFuse binder to deposit and print the powders in thin plate structures as shown in Figure 2. While the green parts were printed without concerns as shown in Figure 2(a), curing the parts in an open air furnace at 200°C resulted in oxidation and notable coagulation of the powder bed, shown in Figure 2(b). The completed prints were impossible to clean and separate from unprinted material due to the powder bed coagulation.

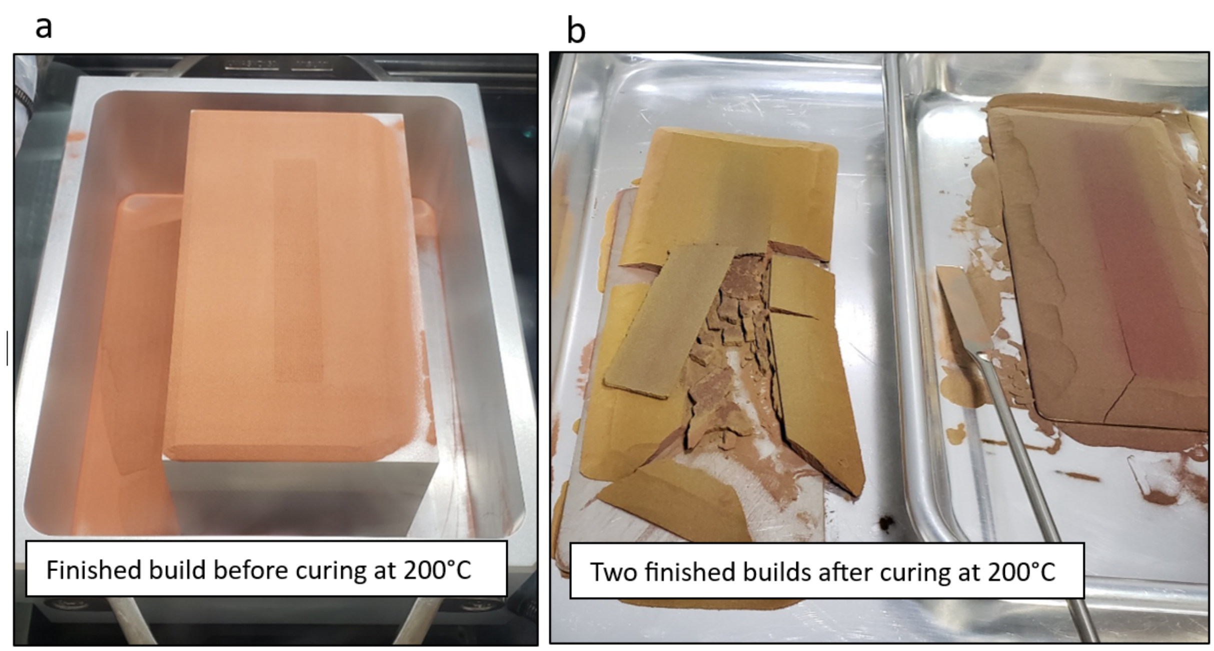

Figure 2 compares the printed geometries before and after curing at 200°C.

A thin lattice geometry was printed to determine the feasibility of printing the heat sink geometries. Figure 3 shows a closeup of the powder clogs from the coagulated powder bed. The clogs could not be removed.

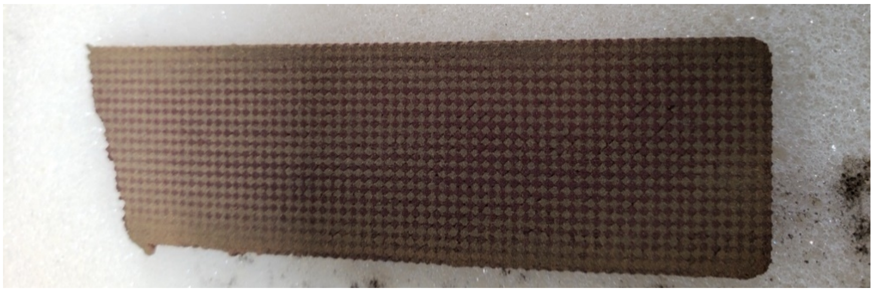

Figure 3 shows the lattice structure clogged with powders post curing.

Several supply chain delays related to the Covid-19 pandemic combined with challenges in printing the finer powders while achieving the desired channel spacing resulted in a premature termination of the project.

1.3 CONCLUSIONS

In summary, this CRADA between Magna Services of America Inc. and ORNL explored the possibility of using binder jet AM to print components for heat sink applications using pure copper. However, we found that the interaction between the powder and the binder possibly results in the oxidation of the powders during curing that results in non-printability due to powderbed coagulation. Although copper has been printed and sintered via binder jet AM, the effect of fine size distributions on high aspect ratio geometries need to be investigated further.