AILEEN - Centers of Vocational Excellence in Aerospace & Defense for Advanced Manufacturing

T5.5 Case study Problem- Based Learning (PBL)

Title of Case Study / Problem-based learning case

Additive Manufacturing of Copper Alloys for Space Propulsion and Thermal Management (CufAM)

Author: Manufacturing Technology Centre (The MTC | Transformative UK Manufacturing Technologies)

AM of Copper Alloys for Space Propulsion | MTC

Background:

Copper and copper alloys are critical to space propulsion and thermal management systems due to their exceptional thermal conductivity.

However, conventional manufacturing methods such as machining or brazing can significantly limit achievable geometric complexity, constraining thermal efficiency and system integration. Additional design features such as cooling channels, complex internal geometries and any additional weight reduction cannot be easily achieved.

Additive manufacturing (AM), particularly powder bed fusion (PBF), offers a transformational route to produce highly complex copper components for space applications. However, copper's high reflectivity makes it difficult to process using conventional infrared laser PBF systems, introducing risks around density, defects and material performance.

- Material: GRCop-42 (Cu-Cr-Nb alloy) and Pure copper
- Method: Laser Powder Bed Fusion
- Motivator: Solving performance bottlenecks in space systems with regards to integrating copper into a wider range of space components.

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Illustration of the case study



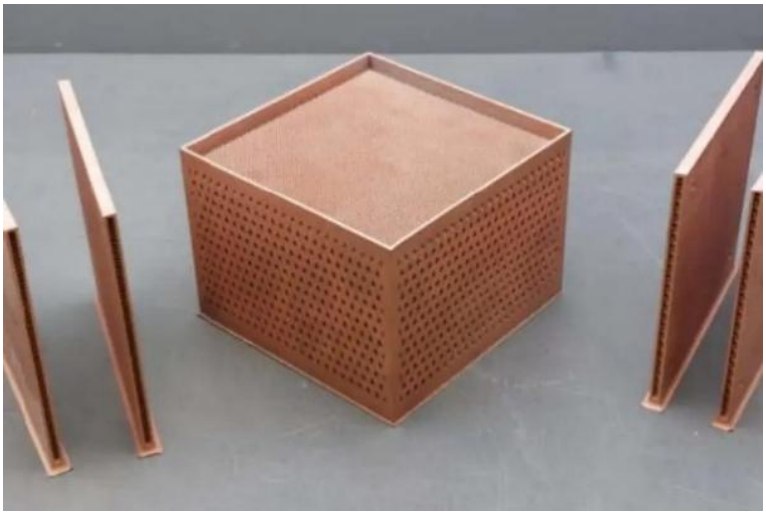


Figure 1. Demonstrator pieces created as part of the research project to address the challenge of copper being integrated into larger volumes of space components. (Manufacturing Technology Centre, 2026)

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Technical challenge

Main technical challenges:

- Interaction between copper and PBF-LB.
  - Copper's high reflectivity causes poor absorption of commonly used lasers.
  - The high-level thermal conductivity of copper leads to unstable melt pools during the powder bed fusion process
- Limited industrial experience with non-infrared AM routes for copper alloys in space-relevant components.
  - Lack of established data and performance
  - High uncertainty in process development
- Lack of validated end-to-end process chain
  - Missing AM process chains for copper including
    - Powder handling
    - Processing
    - Post processing
    - Inspection
- Copper's high material sensitivity
  - Highly sensitive to oxygen and moisture
  - Limitations in terms of ductility

Questions posed:

1. How can the incompatibility between copper and PBF-LB be addressed? What are the current developments which could be implemented?
2. How to address the lack of validated end-to-end AM process chains?

Detailed solution/ process

To address the problem statement and questions, in this case study two representative space materials/applications, a GRCop-42 combustion chamber liner for liquid rocket propulsion, and pure copper phase change material (PCM) thermal devices were investigated for their performance and properties.

To overcome the incompatability between copper and PBF-LB, green laser PBF was implemented which is more suitable due to the short wavelengths provided by a green laser in comparison to traditional routes. This allowed for a more stable melt pool alongside reduced porosity. However, the use of green laser PBF had to be tailored differently to the two different materials; the copper alloy GRCop-42 and pure copper require different parameters. Different alloys versus pure copper will have different absorption levels due to their composition and melt behaviour. Alternatively infra-red laser PBF could be used, but with parameters such as wobble (fast oscillation of the beam) to help with initial absorption into the material.

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To focus on the lack of end-to-end AM process chains, these were focused on and developed during this project through powder characterisation and storage studies, process parameter development and validation and heat treatment optimisation. This experimental and research work allowed for a more comprehensive understanding of what is needed in these AM process chains and their signficance. In particular the heat treatment strategies were important to optimise, resulting in enabling ~300W/mK thermal conductivity whilst maintaining mechanical strength in GRCop-42. Powder handling strategies to minimise oxygen were used as well as using sampling devices measuring oxygen pick-up on the powder using both XPS and Inert Gas Fusion (LECO ONH) methods during different stages in the powder handling and recycling processes. This data could then be fed into industrial processes with guidance on how to minimise oxygen and moisture content, thus improving quality.

Additionally, using the methods developed in the above research, demonstrator hardware was designed, manufactured and tested, including a 20 kN combustion chamber with AM copper liner and novel expansion slots, and PCM heat capacitors. This effectively tested the strategies developed in the research part of the project to answer the initial questions posed and validate the end-to-end process chain.

1 Bibliography

Manufacturing Technology Centre. (2026). *Additive manufacturing of copper alloys for space propulsion and thermal management (CufAM)*. Retrieved from https://www.the-mtc.org/insights/additive-manufacturing-copper-alloys-space-propulsion-and-thermal-management-cufam

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Competence unit coverage:

	AILEEN competence units	Covered CU
AW_01	Welding: Advanced Metallic Materials in Aerospace and Defence Sectors	
AW_02	Welding: Advanced Welding Processes and Equipment in Aerospace and Defence Sectors	
AW_03	Welding: Advanced Welding Applications in Aerospace and Defence Sectors	
AW_04	Welding: Introduction to brazing technology Knowledge for quality brazed joints	
AW_05	Welding: Fundamentals of Industrial Brazing: Main Processes, Quality Standards & Applications	
AI_01	Inspection: Non-Destructive Testing (NDT) in Additive Manufacturing for metals and polymers	
AI_02	Inspection: Metrology in Additive Manufacturing for metals and polymers	
AI_03	Inspection: Inspection of AM parts. Material Quality	X
AAM_01	AM: Qualification, Certification and Standards for AM in A&D	X
AAM_02	AM: Quality Assurance & Quality Control for AM in Aerospace & Defence	X
AAM_02/3	AM: Design of AM parts for A&D (2 courses - for DED & PBF)	X
AD_01	Digital: Introduction to Digital Technologies in Advanced Manufacturing	
AD_02	Digital: Data Acquisition and Analysis	
AD_03	Digital: Industrial Internet of Things (IIoT) and Advantages in Advanced	
AD_04	Digital: Artificial Intelligence and Advantages in Advanced	
AD_05	Digital: Automation and Advantages in Advanced Manufacturing	
AD_06	Digital: Potentials of Advanced Simulation and Modelling in Advanced	
AD_07	Digital: Potentials of Digital Twins and Smart Factory Automation in Advanced Manufacturing	
AD_08	Digital: Unlocking the Potential of 3D Models Beyond Technical Drawings in the Aerospace and Defence Sector	
AG_02	Green: Sustainable Design and Environmental Compliance in Aerospace and Defence	

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