feature

Lighter, Stronger, and Space-Ready: How 3D-Printed Magnesium Could Revolutionise Satellites

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What if the key to cheaper, lighter spacecraft is not aluminium but a metal that burns, corrodes, and challenges everything we know about aerospace engineering? **THINK** *talks to* ***Danjel Grima*** *from the* ***Wire Arc Additive Manufacturing of Magnesium for Satellites (WAAMMS) team*** *at the University of Malta to find out the answer.*

In the race to make space travel more efficient, every gram counts. For decades, aluminium has been the backbone of satellite structures. But what if there was a lighter alternative – one that could cut launch costs and revolutionise spacecraft design?

A team of researchers at the University of Malta is testing that theory, exploring how 3D-printed magnesium could be the next game-changer in aerospace engineering. The research team chose magnesium because it offers a strong structural foundation while being significantly lighter than materials such as aluminium. It meets key requirements for aerospace applications, balancing strength, weight reduction, and manufacturability.

The catch? Magnesium is highly flammable, prone to corrosion, and tricky to work with. Yet, if the researchers succeed, this material could reshape the future of satellites, and space exploration as we know it.

MATERIAL BREAKTHROUGHS

The WAAMMS (Wire Arc Additive Manufacturing of Magnesium for Satellites) project brings together expertise from SMW Engineering (Latvia); The Hong Kong Polytechnic University, represented by Prof. Runsheng Li; the University of Malta team, comprising Prof. Ing. Glenn Cassar, Prof. Ing. Ann Zammit, Danjel Grima, and Nejmeddine Layeb from the Department of Metallurgy and Materials Engineering, and Dr Ing. Bonnie Attard from the Malta College of Arts, Science and Technology.

The international collaborators developed advanced three-dimensional metal printing techniques essential to the project, while the UM team focused on post-processing, and the subsequent microstructural and mechanical characterisation of the magnesium and aluminium materials used.

'This process involves analysing the structure of the materials, their composition, and mechanical properties. Specifically, we conduct measurements to understand the material's phase composition, elemental composition, and surface characteristics, which in turn influence the overall mechanical properties of the metal itself,' Grima says.

In their research, the UM team performs heat treatments, exposing the magnesium to high temperatures and then rapidly cooling it (quenching) to enhance hardness. This allows the team to study how the material changes before and after thermal

processing. The key aim is to analyse these alterations, optimise the material's properties, and refine its surface engineering to improve overall performance in satellite applications. This is important both during printing and once a satellite is in orbit.

But how can we 3D-print magnesium? The process begins with a magnesium wire, which is melted using a high-powered heat source – much like welding. The molten material is deposited precisely in a layer-by-layer format to form the part. Tiny air pockets (porosity) may form, affecting strength, so the material is analysed and treated to meet standards. Samples, grossly differing in pore content, have been produced to study the effect of such defects and determine whether the post-processing routine being developed can reduce their impact in application.

At this stage of the research, printing happens on a small scale. 'Right now, the pieces we're printing are relatively small, but the goal is to eventually scale up to larger components while maintaining precision and minimising material waste. One of the key advantages of 3D printing is that it allows us to create complex shapes efficiently, whilst being scalable, and reducing excess material compared to traditional manufacturing methods,' Grima says.

WEIGHT ADVANTAGE

The goal is to determine whether magnesium can replace aluminium in satellite structures. Aluminium remains the primary choice due to its strength, lightweight nature, and resistance to space conditions, though composites, titanium, and specialised alloys are also used for specific components. While an entire satellite made of magnesium is unlikely, replacing select aluminium parts could offer significant weight and cost advantages.

Potential cost-cutting occurs during the satellite's launch. The raw material costs of magnesium and aluminium are relatively similar, so the price difference is negligible at the sourcing stage. However, the manufacturing process – particularly with advanced surface treatments – makes magnesium a highly efficient alternative.

'The real cost advantage comes from the weight reduction. Since launching a satellite into orbit is extremely expensive, with costs ranging between €4,000 and €18,000 per kilogram, any reduction in weight leads to significant savings. For example, if a satellite structure that weighs 100 kg with aluminium could be reduced to around 65 kg using magnesium, that weight difference alone could translate into substantial cost reductions in launch expenses,' Grima says, with reference to findings published by The European Space Agency.

Magnesium's density is approximately 35% lower than that of aluminium, enabling notable weight reductions when it is used in aerospace applications. So a 35 kg weight reduction could result in savings of between €150,000 and €600,000, depending on the specific launch service used.

But does lightness come at the cost of durability? This is another crucial question the UM team is investigating. 'We are actively studying magnesium's durability and have conducted initial fatigue life tests. So far, the results are promising. In one test, before applying surface treatments, the material withstood around 60,000 cycles before failure. After treatment, the fatigue life increased significantly to over 500,000 cycles,' Grima says.

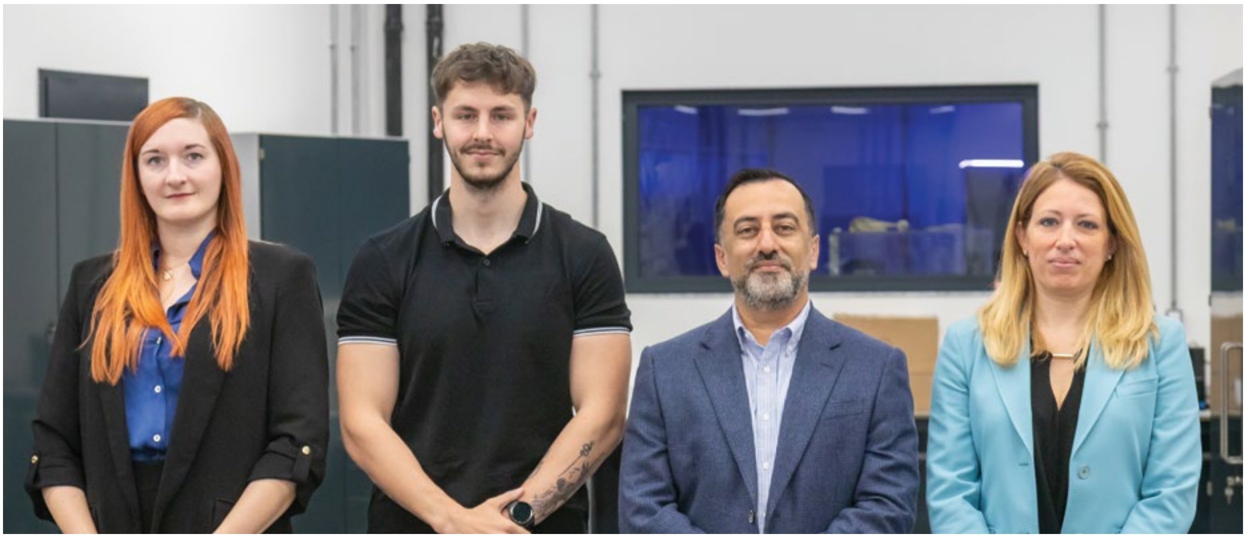
In addition to heat treatment, the surface is strengthened through a process called shot peening, where the material is impacted with small spherical media. This induces compressive stresses within the material that do not dissipate over time. These stresses hinder the formation of cracks, enhancing the overall durability and fatigue resistance of a component.

AZ80 magnesium alloy tensile specimens prepared for mechanical testing.
Photo by Kristov Scicluna

The UM project's early findings suggest that magnesium can perform well under stress, but the team is conducting further tests to confirm consistency and evaluate susceptibility to residual porosity. Another batch of tests is under way to ensure that the observed improvements were not isolated results. While the team is still in the research phase, magnesium shows strong potential in terms of durability.

GLOBAL MOMENTUM

Magnesium is an increasingly prominent material in aerospace research. A collaboration between Mitsubishi Electric Corporation, the Magnesium Research Center at



The WAAMMS Team – Dr Ing. Bonnie Attard, Danjel Grima, Prof. Ing. Glenn Cassar and Prof. Ing. Ann Zammit
Photo by Kristov Scicluna

WAAMMS research support officers, Nejmeddine Layeb and Danjel Grima, running fatigue tests under cyclic uniaxial loading.
Photo by James Moffett

Kumamoto University, TOHO Kinzoku Co., Ltd., and the Japan Aerospace Exploration Agency (JAXA) has developed a high-precision additive manufacturing technology for magnesium alloys using a wire-laser metal 3D printer. This innovation aims to reduce rocket weight and lower launch costs. Additionally, a recent review highlights the increasing use of magnesium alloys in aerospace due to their lightweight properties – crucial for weight reduction in this field.

These studies align with the UM team's findings, reflecting a broader interest in leveraging magnesium's potential to advance aerospace engineering. But the trajectory to lighter satellites is star-studded with challenges.

'One major challenge we faced,' Grima notes of the WAAMMS project, 'is that magnesium is highly reactive and oxidises quickly when exposed to air and moisture. This can cause unwanted surface degradation.
To address this, we switched to alcohol-based polishing solutions instead of water-based ones, which helped prevent oxidation.'

Another challenge was ensuring safety during handling, as magnesium is highly flammable. The team had to take extra precautions to minimise fire risks throughout the process.

The researchers also needed to strike the right balance between improving fatigue life and maintaining surface integrity. Small dimples formed on the surface during post-processing, which could affect durability. 'To counter this, we used composite treatments that helped smooth the surface while strengthening the material. However, increasing strength can also make the material more brittle, so we carefully adjusted the intensity of surface treatments to optimise durability and smoothness,' Grima explains.

With the foundational work mostly completed and aluminium testing finalised, the UM team focused on concluding the magnesium tests in mid-April, aiming to complete the project by the end of May. A gold coating was added to enhance conductivity and oxidation resistance without affecting mechanical properties.

Prof. Ing. Cassar, principal investigator for the WAAMMS project, remarks, 'The WAAMMS project is an excellent addition to our broader effort in advanced materials research, driven by international collaboration, outstanding researchers and state-of-the-art laboratory facilities. Through this and other collaborative projects, we aim to integrate micro-structural control, surface engineering, and additive manufacturing to deliver high-performance, application-driven solutions for aerospace and other demanding sectors.'

Is the manufacturing process implemented in the UM research unique enough to be patented? 'We're still in the research phase, so we haven't explored the potential for patenting the process in depth. However, our techniques, particularly in manufacturing, are becoming more widespread across various industries. That said, there is certainly potential for this technology to be patented and eventually commercialised. Selling it to major aerospace companies could be possible, but for now, our focus is on refining the process and evaluating its full potential,' Grima concludes.

Magnesium may be a challenging material, but if the UM team succeeds, it could redefine satellite construction as we know it – making them lighter, cheaper, and more efficient for the next generation of space exploration. T

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