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Title

Exploring the Benefits and Limitations of Wire-based Direct Energy Deposition of Magnesium Alloys

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Abstract

Magnesium (Mg) alloys offer a unique combination of properties that make them interesting for aviation and space applications: Low density (< 2 g/cm³), high specific strength and stiffness. By using light materials like Mg in space applications, the overall vehicle weight can be decreased, leading to reduced fuel consumption, increased payload capacity and therefore lower operation costs. Another advantage of Mg is its reactivity, which causes the material to thermally disintegrate upon re-entry into the Earth's atmosphere, preventing fragments from reaching the surface.
Mg can be processed by a wide range of methods: In addition to classical casting and forming, excellent successes have also been achieved with additive manufacturing (AM) in recent years. Most additive manufacturing processes use powders as starting materials, e.g., laser powder-bed fusion (L-PBF) and selective laser sintering (SLS). However, typical part sizes are << 1 m, as the processing chamber is subject to size limitations and building speed is comparably low. Another major problem is the feedstock itself: Mg powder is very reactive, and its production is complex, which makes it difficult to handle and hardly available in sufficient quantities.
By using wire-based additive manufacturing methods, these disadvantages can be greatly reduced: The production of Mg wire from cast material is straightforward and the wire itself can be handled without any safety hazard. However, the main advantage of this manufacturing method is the almost unlimited size of parts that can be produced and the high speed at which they can be built. In addition, commercial welding equipment can be used for this process, increasing flexibility, and providing a cost-effective process without high investment.
Particularly in the case of large-volume components, the process represents a clear advantage over conventional production methods, as no molds are required, and high quality can be ensured over the entire volume of the component. Additionally, in comparison to subtractive methods, e.g., milling, no large volume feedstock is necessary. Nevertheless, there are also limitations: the representable resolution and complexity of the parts are comparatively low and, in most cases, post-processing by mechanical machining is required. Furthermore, strength-increasing measures such as grain refinement and work hardening are difficult or impossible to implement.
In this presentation, we show a brief comparison of different additive manufacturing processes for Mg, addressing the differences between powder- and wire-based processes. The wire-arc direct energy deposition (waDED) process is shown in detail and its advantages and limitations are discussed. Finally, microstructure and mechanical properties of waDED parts are presented.