MX3D

ROBOTIC 3D METAL PRINTING

Alloys, Performance & Properties

WHITEPAPER 2026



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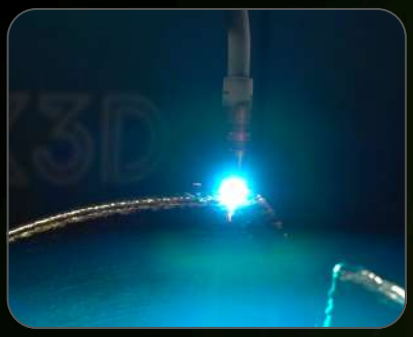
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The WAAM Feedstock Advantage

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Wire Arc Additive Manufacturing, classified under Directed Energy Deposition with an electric arc (DED-arc), represents a fundamental shift in how heavy metallic components are engineered and fabricated. By depositing molten metal wire layer-by-layer using a digitally controlled electric arc, WAAM bypasses the physical constraints of traditional manufacturing and offers a strong alternative to casting and forging.



The WAAM Advantage

- **Subtractive Manufacturing:** Traditionally relies on machining solid billets, which results in excessive material waste and highly inefficient buy-to-fly ratios.
- **Casting:** Requires expensive dedicated molds, complex internal cores, and lengthy lead times.
- **Additive Manufacturing:** Places material strictly where structural loads require it, producing near-net-shape geometries ready for minimal post-machining. Furthermore, for highly reflective metals such as aluminum and copper alloys, electric arc power sources provide direct, highly efficient thermal transfer without the operational hazards or thermal losses associated with laser-based additive systems.



About the author

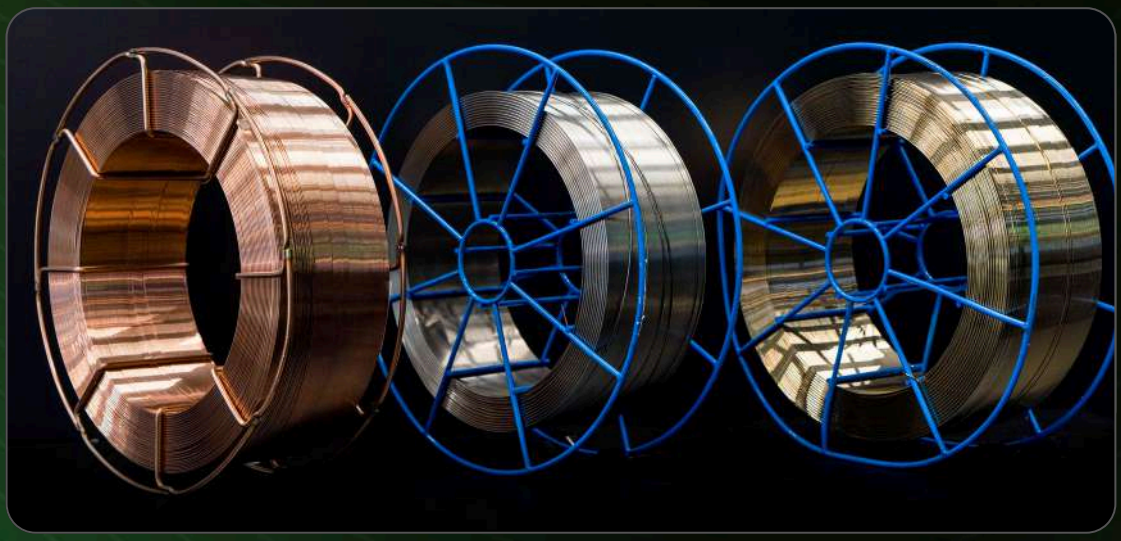
Kevin Affari, Materials Expert at **MX3D**. As a key member of the engineering and technical team, he focuses on the development and integration of cutting-edge robotic 3D metal printing technologies. His materials expertise helps ensure that MX3D's printed parts are highly reliable and can meet or exceed traditional forged and cast benchmarks. Additionally, Kevin supports clients in implementing custom WAAM solutions, facilitating a seamless transition from initial concept to full in-house production.

The Shift to Wire

While powder-based metal additive manufacturing technologies have established a footprint in small-scale, high-precision components, their economic viability degrades rapidly when scaled to large industrial parts. WAAM avoids these scalability issues by utilizing standard, commercially available industrial welding wire.

Transitioning from powder to wire provides economic and operational advantages:

- **Feedstock Economics:** Across all major alloy families, including stainless steels, nickel superalloys, and high-strength steels, solid wire remains significantly cheaper and far more economically scalable than gas-atomized metal powder.
- **Capital Efficiency:** WAAM uses a standard industrial arc-welding power supply, which costs a small fraction of an equivalent industrial laser transmitter or electron beam generator.
- **Operational Flexibility:** WAAM delivers substantially higher deposition rates without requiring massive vacuum enclosures, specialized powder-recycling infrastructure, or hazardous atmospheric explosion protocols.
- **Standard Availability:** A much larger group of alloys is available in standardly supplied wire than in powder. Increasing the flexibility and choice for the end user.



Picture of wire spools used by MX3D for WAAM prints

Because WAAM involves rapid, localized melting and repeated thermal cycling, the mechanical integrity of the final component is dictated entirely by feedstock chemistry, arc physics, and toolpath strategy. Therefore, understanding how to source, evaluate, and control wire feedstock is the critical first step in producing high-performance, defect-free WAAM components.

Sourcing and Evaluating High-Quality Wire

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First, it is important to define a baseline. A reliable WAAM process depends entirely on the quality and delivery mechanics of the wire feedstock.

Coaxial Feeding:
GMAW and CMT systems feed wire directly through the center of the torch. This allows for omnidirectional toolpaths, significantly simplifying robotic path planning.

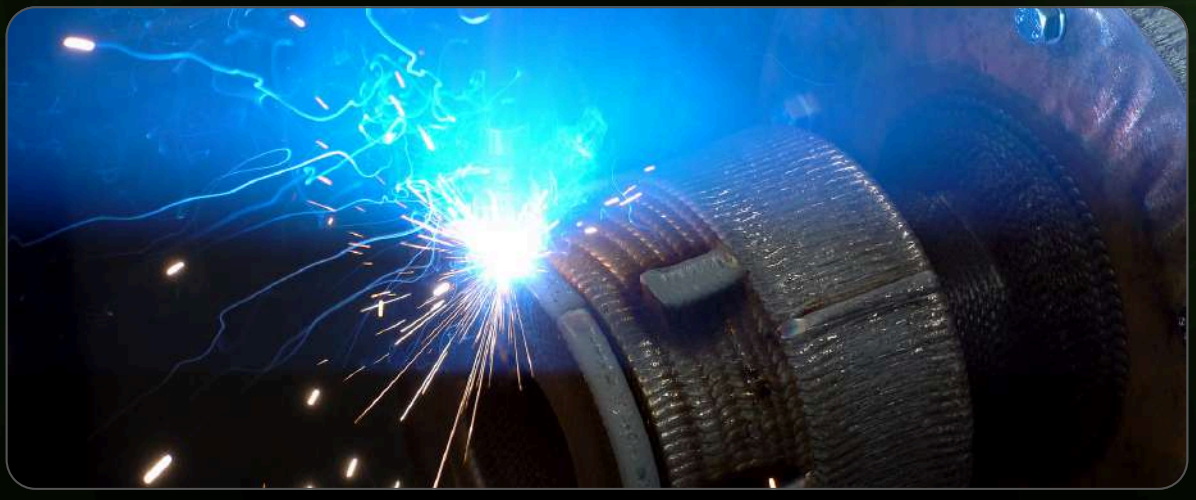
External Feeding:
GTAW and PAW systems feed wire externally. This requires precise multi-axis rotational alignment to maintain the correct entry angle, adding complexity to the process

Process Compatibility: How the wire interacts with the electric arc dictates thermal dynamics and deposition efficiency.

- **Arc Power and Wire Feed:** The wire feed rate directly correlates to arc power. Higher power yields deeper base penetration and smoother weld beads, but excessive power causes melt pool overflow and dimensional inaccuracy.
- **Chemical Composition:** The wire's elemental makeup must be tightly controlled to ensure stable flowability, predictable cooling rates, and consistent melt pool behavior.

Avoiding Defects: Selecting pristine feedstock is the primary defense against structural defects.

- **Porosity:** Surface contamination on the raw wire (such as moisture, oil, or oxides) introduces trapped gases into the melt pool during rapid solidification. Utilizing wires with flawless surface finishes is critical to preventing voids.
- **Cracking and Delamination:** Heat-sensitive alloys are highly prone to solidification cracking under high thermal stress. Feedstocks must be carefully paired with low-heat-input deposition strategies to preserve structural integrity.



Picture of the electric arc and deposition of a WAAM part in the printing process

Designing for Strength, Speed, and Durability

WAAM can process nearly any commercially available, weldable wire. Selecting the right alloy requires balancing mechanical demands with the material's thermal behavior and deposition speed. Here are some examples that MX3D uses when selecting the right material.



What material can be used in which situation?

- **Duplex Stainless Steels (Strength & Corrosion):** Alloys like ER2209 deliver extreme yield strength and resistance to pitting in chloride-rich environments. The primary engineering challenge is maintaining the 50/50 ferrite-austenite phase balance. Low-heat-input arc variants, like Cold Metal Transfer (CMT), tightly control the thermal cycle to prevent phase imbalances and hydrogen embrittlement.
- **Aluminum Alloys (Deposition Speed):** WAAM processes highly reflective aluminum (e.g., 2219, 5183, 7075) with exceptional efficiency, bypassing the oxidation risks of powder-based AM. WAAM achieves massive deposition rates, upwards of 2 kg/hour, for the rapid fabrication of large, lightweight frames. Strict interpass temperature control ensures fast cooling, preventing trapped hydrogen gas bubbles and internal porosity.
- **Nickel Superalloys (Extreme Environments):** Inconel 625 and 718 provide incredible structural stability, toughness, and corrosion resistance for cryogenic tanks and heavy-duty turbines. WAAM's near-net-shape deposition mitigates the rapid tool wear and high machining costs associated with these tough alloys. Heat input must be strictly minimized during deposition to prevent liquid-film solidification cracking (Laves phase formation).
- **Carbon Steels (Structural Versatility):** These materials provide cost-effective solutions for heavy-duty structural nodes and large spaceframes. Structural success in these dense, volumetric builds relies heavily on arc power management. Higher arc power ensures deeper base penetration and creates a smoother weld bead toe angle, which is essential for preventing inter-bead lack of fusion.
- **Bronzes (Maritime Durability):** Bronze alloys are selected for their robust performance in maritime and energy applications. They offer a highly cost-effective alternative to more exotic alloys while delivering the excellent corrosion and cavitation resistance required for heavy marine components, such as ship propellers and marine hardware.

Quality Assurance: Testing, Monitoring, and Verification

Guaranteeing the structural integrity of a WAAM component requires a dual approach: rigorous offline physical testing combined with continuous, real-time digital monitoring. By maintaining a strong QMS and having qualified staff, MX3D follows the highest industry standards successfully.

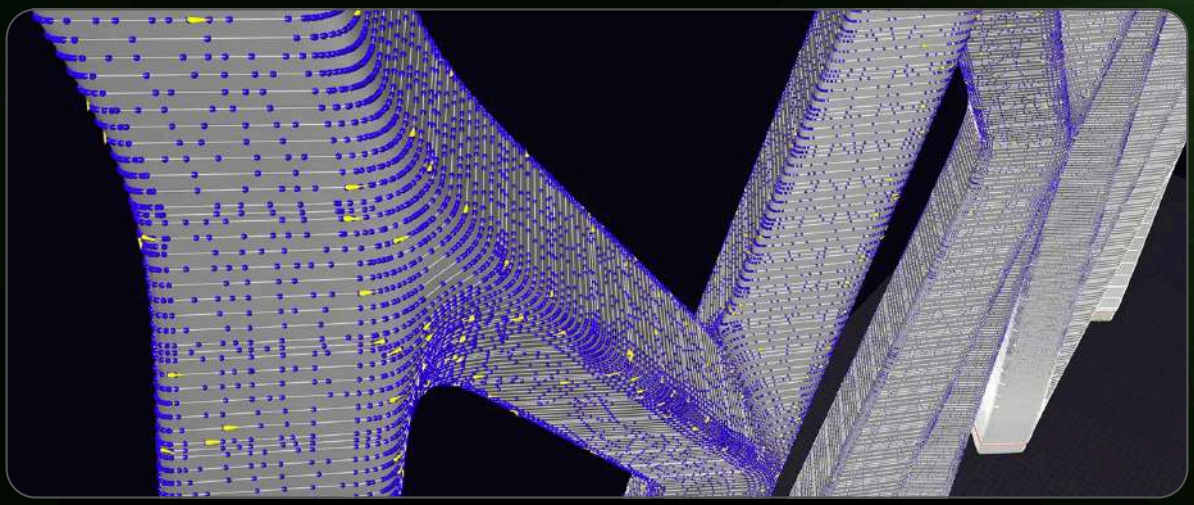
Toolpath Verification:
Quality assurance begins digitally. To prevent internal voids or interlayer material bulging, CAM software dynamically adjusts the distance between adjacent weld beads to maintain a strict 15% to 50% overlap tolerance window.

Offline Physical Testing:
A certified material baseline is established through tensile and Charpy V-Notch testing (guaranteeing strength and toughness), multi-directional testing (to manage anisotropy), and cross-sectional analysis (verifying grain size and porosity limits).

Inline Process Monitoring:
Multi-sensor digital logging allows for immediate anomaly detection. This integrates optical sensors (for dimensional accuracy), thermal cameras (to track cooling rates), and spectral/acoustic sensors (to detect internal void formation instantly).

Fit for purpose:
By combining non-destructive testing (NDT), precise dimensional checks, and continuous digital logging, manufacturers are able to prove that every area matches the physical baseline, ensuring safe, ready-to-deploy industrial 3D-printed components.

Ultimately, this comprehensive QA framework does more than just prevent defects. By combining physical baselines with real-time digital logs, manufacturers create a fully documented digital thread, the exact proof required by regulatory bodies to certify WAAM components for deployment in critical, load-bearing infrastructure.



MetalXL software interface showing a CAM toolpath of a WAAM part

Manufacturing to DNV AMC 3 Standards

To deploy WAAM components in the most demanding maritime and energy environments, the parts must be certified to stringent international regulatory standards. The global benchmark for qualifying metallic additive manufacturing is DNV-ST-B203.

The DNV-ST-B203 framework and its significance within the WAAM industry

- **The DNV-ST-B203 Framework:** This standard governs the qualification and production of metallic AM parts for the maritime and oil & gas sectors. It outlines the exact destructive testing, non-destructive testing (NDT), and process controls necessary to prove a printed part is as reliable as a traditionally forged or cast component.
- **Achieving AMC 3:** Components are graded by their operational criticality. Additive Manufacturing Class 3 (AMC 3) is DNV's highest classification, reserved for critical, load-bearing, and pressure-retaining parts such as pump impellers, valves, and heavy-duty flanges. Reaching AMC 3 requires flawless parameter control, 100% NDT inspection, and absolute process repeatability.
- **Chemistry and Traceability:** Certification demands a fully documented digital thread. Material inputs and thermal parameters are strictly logged to ensure the as-built chemistry perfectly matches the rigid material guidelines required for deployment into harsh, highly corrosive environments.



MX3D Case Study:
To validate our materials and process, MX3D successfully prints and qualifies parts in accordance with this standard. An example is this heavy-duty flange printed in line with the DNV AMC 3 standard. This certification serves as hard proof that WAAM is not just a prototyping tool, but a fully viable production method for critical, load-bearing infrastructure.

Application & Use Cases

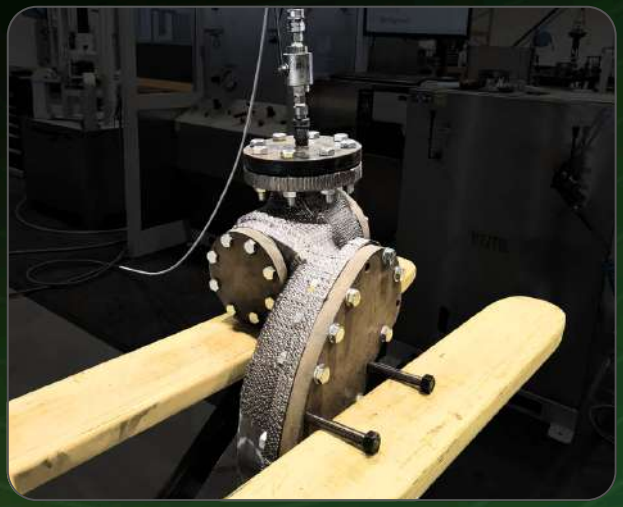
With materials tested, monitored, and certified, WAAM is actively replacing highly machined forged billets and cast components used in the field.



Fluid Handling & Pressure Systems: Complex, high-wear components like closed impellers and pump housings are frequently printed in duplex stainless steels and bronzes to withstand severe cavitation and high-pressure fluid dynamics. WAAM bypasses the extreme lead times of complex casting molds, delivering corrosion resistance for continuous, high-flow operations, according to PED and ASME-9 standards.



Valve Bodies: Critical for high-pressure fluid control, heavy industrial valves demand absolute structural integrity. WAAM eliminates the massive lead times and internal porosity risks of traditional casting. As a benchmark, a massive 750 kg carbon steel valve body was continuously printed in just 180 hours, achieving mechanical properties that exceed conventional castings and rival forged components.



Critical Spares & Reverse Engineering: Replacing damaged or obsolete components for legacy equipment usually means long lead times. By combining 3D scanning with WAAM, operators can reverse-engineer and print direct replacements. For instance, a 97 kg steam-turbine spare part was continuously printed in just five days, passing comprehensive NDT and hydrostatic pressure testing for immediate, fully certified reinstallation.

Conclusion

Wire Arc Additive Manufacturing has moved beyond its experimental phase and into heavy industrial production. By transitioning from expensive metal powders to commercially available welding wire, WAAM drastically improves material utilization and drives down capital expenditures.

The success of WAAM lies in the metallurgy. By strictly sourcing high-quality wire, optimizing overlap algorithms during path planning, and controlling thermal inputs via advanced arc variants like CMT, manufacturers can consistently deposit defect-free material. Backed by rigorous physical testing, real-time digital monitoring, and DNV AMC 3 certification, WAAM stands as the ultimate production method for rapidly delivering high-strength, heavy-duty metal components.



The MX, M1, MD and MB WAAM systems of MX3D

If you would like to know more about material properties of WAAM for your own part or if you have a system inquiry, reach out to MX3D to evaluate feasibility, performance, and business impact based on your specific application.

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