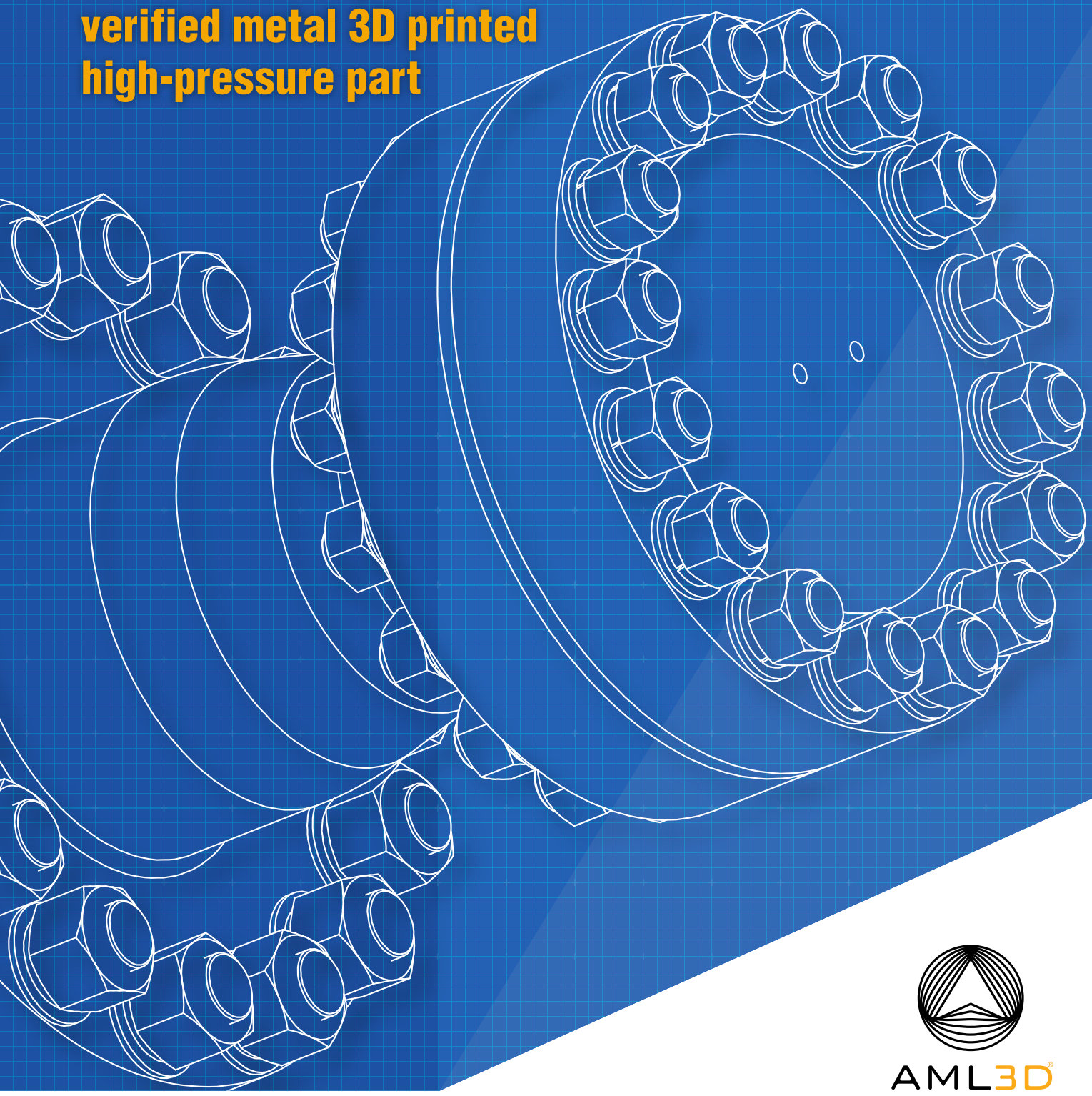
ARCEMY® CASE STUDY

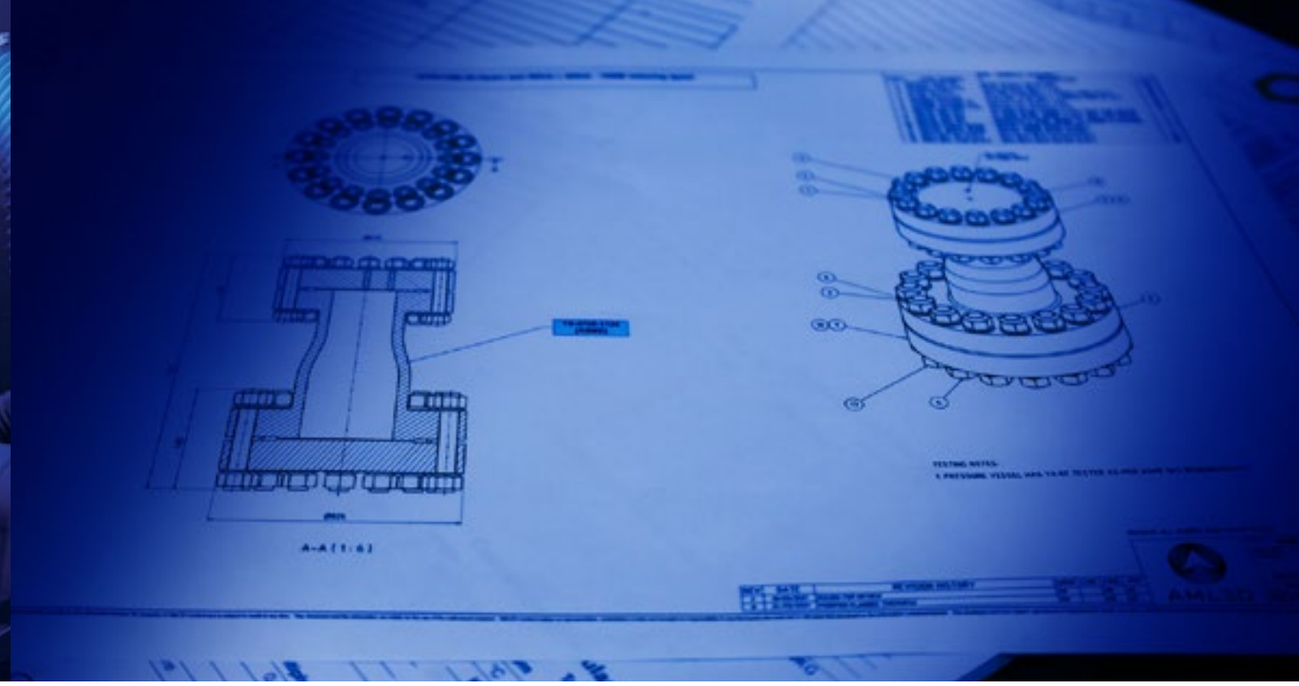
PRINTED TO API 20S STANDARD

ADDITIVELY MANUFACTURED METALLIC COMPONENTS FOR USE IN THE PETROLEUM AND NATURAL GAS INDUSTRIES

The world's largest, verified metal 3D printed high-pressure part



AML3D®



CASE STUDY

Customer
AML3D

Industry
Manufacturing for Aerospace, Defence, Maritime, Mining, Oil & Gas.

Method
Wire Additive Manufacturing (WAM®)

Material
70ksi Wire Feedstock

Application
Using its patented WAM® technology, AML3D is disrupting traditional billet machining, forging and casting manufacturing methods.

Advantages

- **Greener –** AML3D's WAM® provides an environmentally sustainable manufacturing solution, reducing material waste compared to billet machining. Additionally, WAM® uses an order of magnitude less energy per kg of printed metal when compared to per kilo of casting produced.
- **Faster –** AML3D offers a faster manufacturing solution when compared to machining billet, forging and casting methods.
- **Stronger –** AML3D's patented WAM® process results in enhanced material properties.

LEARN MORE

www.aml3d.com

Background

AML3D Limited, founded in 2014 and a publicly listed technology company since 2020, utilises its new advanced 3D printing technology to pioneer and lead metal additive manufacturing globally. Disrupting the traditional manufacturing space, AML3D has developed and patented a Wire Additive Manufacturing (WAM®) process that metal 3D prints commercial, large-scale parts for Aerospace, Defence, Maritime, Manufacturing, Mining and Oil & Gas.

AML3D has created and patented a Wire Additive Manufacturing (WAM®) process and developed proprietary software, WAMSoft® and AMLSoft™, that drives ARCEMY®, AML3D's industrial metal 3D printer. ARCEMY® provides industry point-of-need additive manufacturing solution that is faster, greener and leaner than conventional manufacturing methods, improving supply chains and enabling metal part suppliers to become globally competitive.

AML3D also provides metal 3D printing design engineering services, software licensing, technical support, consumable sales and contract manufacturing services.

Using AML3D's ARCEMY® and patented Wire Additive Manufacturing (WAM®) process, this high-pressure piping spool was fabricated in a monocoque form, using easily sourced wire feedstock.

The process significantly reduced lead times and eliminated any joint defects while improving material properties with WAM® optimised process procedures exceeding industry strength standards.

Challenge

Research into Metal Additive Manufacturing, or metal 3D printing, has highlighted several advantages when compared to conventional manufacturing methods such as billet machining, forging and casting. AML3D looked into how ARCEMY® and it's patented Wire Additive Manufacturing (WAM®) process can contribute to high-pressure industries and push existing boundaries when it comes to producing greener large-scale or exotic material parts faster.

The first of its type to be metal 3D printed globally, AML3D's 940 kg high-pressure pipe spool was fabricated as a "one-piece" part instead of using three separate parts as required with traditional fabrication.

At 850mm high, featuring raised face flange faces of 825 mm and 675 mm in diameter, the 41mm thick Class 1500 high-pressure pipe had a deposited mass of 1,120 kg with a machined mass of 940 kg.

Typically, a high-pressure pipe spool like this would be fabricated from three pieces and welded together using a DN400 to DN300 reducer and two weld neck flanges to ASME B16 schedule 160 specifications.

Conventionally manufactured, the components used in constructing a typical high-pressure piping spool of this size will utilise flanges manufactured from a forged material. The process of forging concentric reducers and weld neck flanges involves heating, shaping and cooling billet material, which can be slow to source from overseas suppliers and features both high energy and carbon footprint to produce. Once these forged weld neck flanges are made, two circumferential welds are used to join them to the forged concentric reducer.

Using AML3D's ARCEMY® and patented Wire Additive Manufacturing (WAM®) process, this high-pressure piping spool was fabricated in a monocoque form, using easily sourced wire feedstock. The process significantly reduced lead times and eliminated any joint defects while improving material properties with WAM® optimised process procedures exceeding industry strength standards.

70ksi
wire feedstock

1,120kg
deposited material

940kg
part weight

216hrs
print time

It was amazing to see something of this size 3D printed; it was very accurate, straight and faces parallel to each other before machining; many of the surfaces could be left unmachined.

– Mark Cavanagh, Caman Engineering

Solution

The Material

While AML3D can fabricate parts using a wide range of wire feedstock, we opted to manufacture the high strength piping spool from certified ASME Section II / AWS A5.17 ER70S-6 wire feedstock. This feedstock is a medium strength carbon steel that features increased manganese, reduced carbon percentage, and silicon content that assists with deoxidising the base material. ER70S-6 is best suited for additively manufactured parts that are subject to high-pressure applications such as this.

Through testing with NATA recognised labs and collaboration with our University research partners, we have found that our patented WAM® process can greatly improve material properties due to the ability to control and optimise the WAM® process parameters.

There are a large number of metal alloys that can be used to create parts with WAM®. Typical material properties of WAM® printed parts are above the minimum requirements of industry standards.

Our process is highly adaptable to virtually any metal alloy, often resulting in superior property outcomes as a result of our WAM® process optimisation procedures.

For additional properties, parts can be heat treated or have a corrosion-resistant overlay to increase service life.

ER70s-6 Chemical Properties

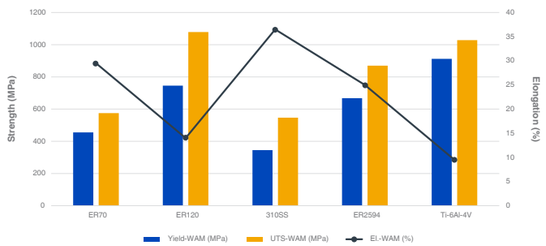
Chemical composition (%)									
C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V
0.07	0.88	1.49	0.022	0.017	0.31	0.02	0.04	0.01	0.01
0.06 ~0.15"	0.80 ~1.15"	1.40 ~1.85"	≤ 0.025	≤ 0.035	≤ 0.50	≤ 0.15	≤ 0.15	≤ 0.15	≤ 0.03

ER70s-6 Mechanical Properties

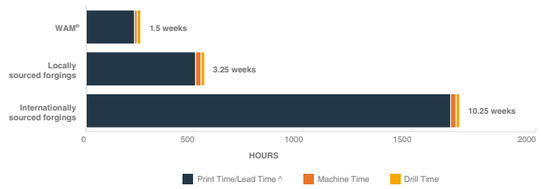
Mechanical Properties*					
Test No.	Orientation	UTS (MPa)	0.2% Proof stress (MPa)	Reduction in area (%)	Elongation (%)
T21351	Longitudinal	579	481	76	31
T21352	Transverse	575	455	72	24

** Mechanical property values for the 'as-deposited WAAM' values are based on the median value and repeatability testing.*

Typical WAM® Material Properties



Fabrication Time: WAM® vs. Traditional



The Machining

The machining process takes the raw material, cutting it to shape, ensuring it is fit for purpose. A WAM® printed part may still require machining on specific surfaces, surface area machined will largely depend on the parts requirements and intended use. With contract manufacturing services that we provide to our customers, we select from a range of specialised precision machinists to suit the specific industry application we are producing the part.

Equipped with large CNC vertical lathes, Caman Engineering had the experience and capability required for this specialised 940 kg pipe spool. An approved PED material supplier, Caman Engineering, is an Australian manufacturer of pipeline flanges, heat exchangers and pressure vessel components to mining, petrochemical and oil & gas.

Typically, parts manufactured with WAM® have lower machining time with significantly less material waste than conventional equivalents.

Turning time on the borer was 12 hours, a significant reduction compared to the estimated 25 hours of machining time of a comparative traditionally forged part.

Drilling operation for the flanges where completed via a manual radial drill due to the pipe spools 850 mm size. A spool under 700 mm would be drilled in situ on the CNC.

The Standards

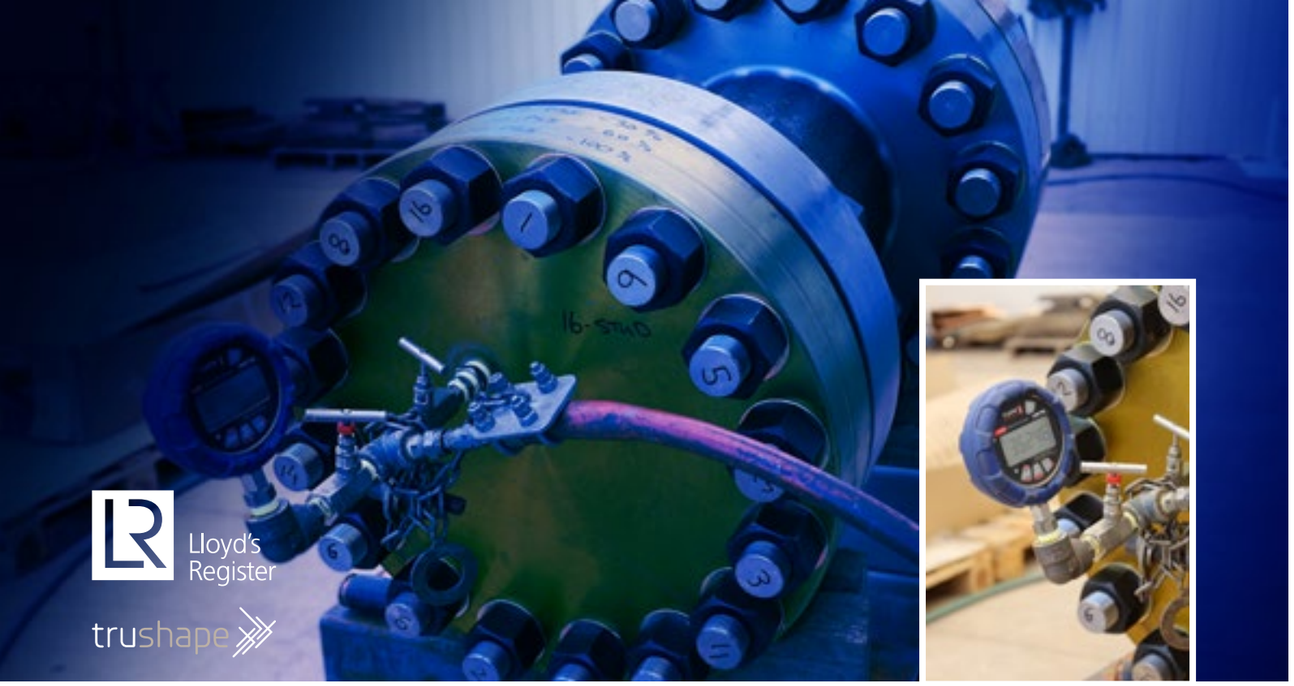
The high-pressure pipe spool was 3D metal printed, and tested, to the following industry standards:

- API 20S, Standard for Additively Manufactured Metallic Components for use in the Petroleum and Natural Gas Industries
- AWS D.20, Specification for Fabrication of Metal Components using Additive Manufacturing
- ASME B31.3 2020 Process Piping
- ANSI Class 1500
- ISO 9001:2015 QMS

12hrs
Machine Time

MACHINING TIME
◀ WAM® | FORGED ▶

26hrs
Machine Time



Solution

The Testing & Witnessing

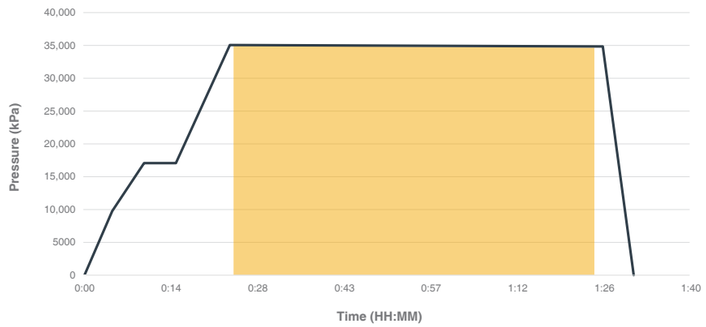
The WAM® produced high-pressure pipe spool underwent two rounds of non-destructive testing. As part of our production process, the first round of NDE (Non-Destructive Evaluation) included 100% Dye Penetrant testing to detect surface-breaking defects. 100 percent Radiographic testing was performed and found compliant to AWSD20.1/D20.1M:2019 Table 8.4 (Class A) based upon inspection methods outlined in AS 2177 – 2006 and AS 2314 – 2006.

The second round of NDE required the high-pressure piping spool to undergo part-specific hydrostatic testing for the high-pressure market. Following the same approach as machining, our selected testing partner TruShape Engineering, are specialists in manufacturing and testing pipework for petroleum, gas, and water industries.

The team at TruShape set the hydrostatic testing as per ASME B.16 & B31.3 standards for valve testing and incorporated particular requirements experienced by their high-value customers, such as torquing the blind flanges in a specific order and to industry specification.

To successfully pass the industry standard, the reducing spool was required to hold a pressure of 34,790 kPa for a minimum of 60 minutes without any leakage or evident pressure loss, complying with minimum industry standards. This was witnessed by the third party classification society, Lloyd's Register, who provided written verification of compliance.

Witnessed by Lloyd's Register, the high-pressure pipe spool passed the industry-standard hydrostatic test requirements with no leaks or significant pressure loss.



SEE THE PRINT

Founded in 2014, AML3D is a technology company that is focused on improving manufacturing supply chains by using a proprietary WAM® Process.

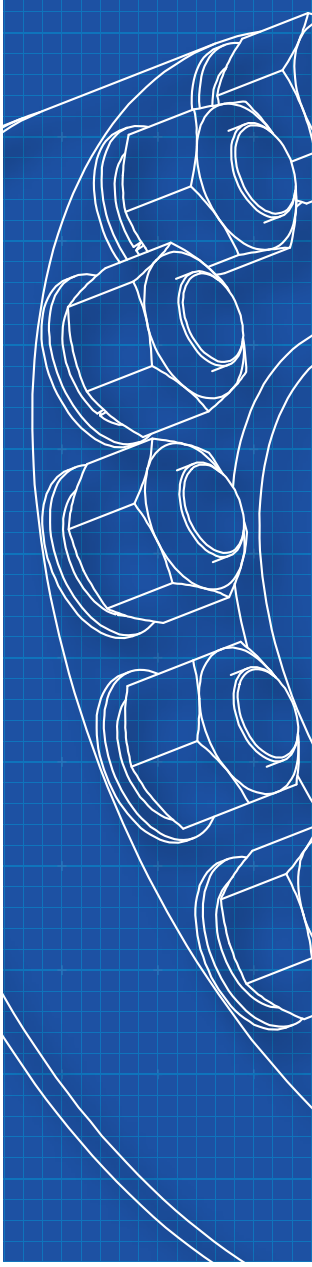
AML3D uses new technologies to pioneer and lead metal additive manufacturing globally, enabling our customers to become globally competitive.

We achieve this by combining our patented Wire Additive Manufacturing (WAM®) process with Industry 4.0 capability that is driven by the Industrial Internet of Things (IIoT).

> **The 3D printing of the Panama Chock shows that large components can be made available with shorter lead times and with equal standards of quality and performance.**
>
> *– Aziz Merchant, Keppel Marine & Deepwater Technology*

> **Wire Arc Additive Manufacturing, or WAAM, has the potential to enable a productivity step change in shipbuilding, able to 3D print marine grade metal structures at a scale well beyond other commercially available metal 3D printing technologies.**
>
> *– Andrew Malcolm, Austal*

> **Toolcraft looks to partner with AML3D whenever there is scope for their process – when manufacturing parts larger than commonly available materials or when sourcing exotic metals is cost prohibitive.**
>
> *– Greg Stevens, Toolcraft Australia*



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Japan Patent 7225501