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Pressure Points

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HSB, a Munich Re company, is a technology-driven company built on a foundation of specialty insurance, engineering, and technology, all working together to drive innovation in a modern world.

Wire Arc Additive Manufacturing (WAAM)

Author: Phil Gilston, CEng, IWE

In the 2023 edition of ASME Section IX, there will be a new article added to Part QW, that being Article VI. Article VI will address the qualification requirements for WAAM. This new Article incorporates Code Case 3020, originally published in Supplement 1 of the 2021 BPV Code Cases, titled Qualification of Gas Metal Arc Additive Manufacturing (GMAAW).

In addition to Article VI:

- Three new definitions have been added to QG-109.2.
- New variables have been added to this Article.
- P-Numbers have been added to Table QW/QB-422 for weld metals from SFA-5.9, SFA-5.18, and SFA-5.28, along with an explanatory note in new paragraph QW-424.3.

What is additive manufacturing (AM)?

AM is a method where an object is created by depositing material one layer at a time. This is the opposite of traditional manufacturing methods whereby a solid block is shaped by removal of material by machining, cutting, and drilling. This process is known as subtractive manufacturing and creates a considerable volume of waste material.

Background

The use of AM is now well established, and while there are around 18 known different metal additive manufacturing processes, the primary techniques currently used commercially are known as Powder Bed Fusion (PBF). The process uses a roller or blade to spread a thin layer of metal powder on the surface of a work plate. A power beam (normally laser or electron beam welding) fuses the metal powder to the contour determined by the control program. After the fusing of a section is completed, the work plate is lowered by the height of a powder layer, a new layer of fusing is performed, and the process repeated until the entire part is completed.

Initial applications have been used in the aerospace and medical fields. In aerospace, the first Federal Aviation Administration (FAA) approved parts were in Titanium used by Boeing in their 787 Dreamliner, the savings by using these AM parts is in the region of $2-$3M per aircraft. (Moon, 2021)

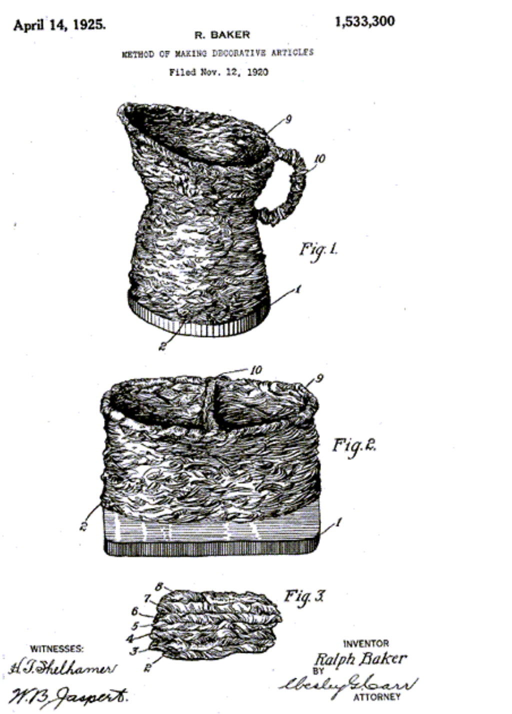
There are limitations for the PBF process:

- It is relatively slow with long print times
- Powder recycling — the powders are expensive
- High power usage — uses a lot of energy to create parts
- Component size — current machines have small print chambers which restrict the size of parts that can be printed

Direct energy deposition (DED)

There is a growing use for additive build manufacturing, also known as DED. DED uses a focused energy source to melt material typically as a wire or powder to make a near net shape part. The most common DED processes are:

- WAAM, typically using:
  - GMAW
  - Gas Tungsten Arc Welding (GTAW)
  - Plasma Transfer Arc (PTA)
- Laser Metal Deposition (LMD)
- Wire Laser Additive Manufacturing (WLAM)
- Electron Beam Additive Manufacturing (EBAM)



Source: R. Baker. Method of making decorative articles US 1,533,300, Filed Nov.12,1920

While powder bed technology is the predominant manufacturing method, wire-arc manufacturing is probably one of the oldest, but least talked about AM processes, and it dates back to at least 1920, when a patent US1,533,300 was awarded to Ralph Baker, who described the use of electric arc and metal electrode to form walled structures and decorative articles.

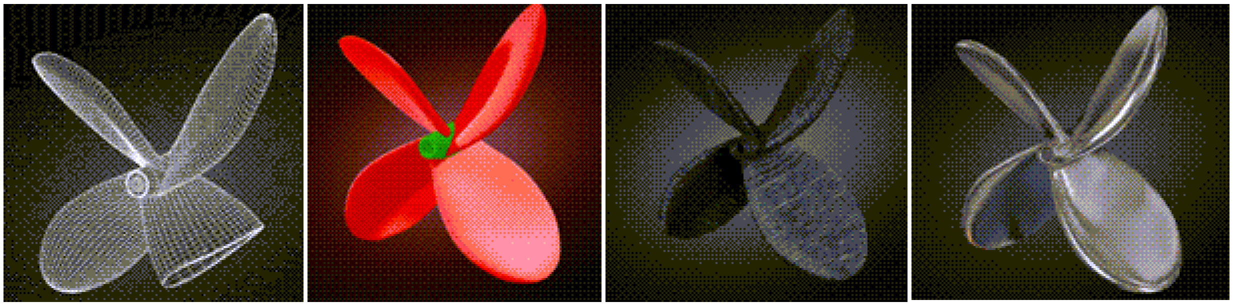
The feed stock for DED can be powder or wire. Unlike the powder bed method, metal powder is fed directly into the fusion beam to print the required layers. This process can work with the Laser, EB, and various arc welding processes GMAW, GTAW, and PTA. Wire feed can be co-axial feeding (GMAW) or off-axis feeding (Laser, Plasma Arc or Gas Tungsten Arc processes).

The advantages of DED are:

- Delivery of higher production rates
- Allows larger components
- Parts produced with minimal waste

Process

For a part to be manufactured, a 3-D model is created using Computer Aided Design (CAD). The model is sliced into layers, each layer representing a layer of deposited weld metal. A program file known as .stl or .AMF is used to control the printing process. Full control over the wire path for each layer allows for optimal process parameters and material deposition.



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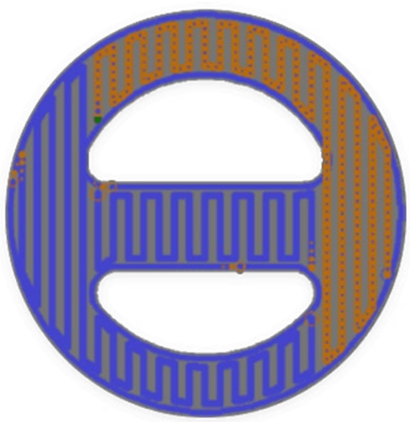

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The file type .stl was developed in 1987 and 30 years later is still the most widely used format for programming the printing process and considered to be the standard file format in 3D printing. Having been around for such a long time, .stl is compatible with most 3D CAD software and other software and hardware in 3D printing, although it does have some limitations. For example, it can only store geometry, while color and texture cannot be addressed — detail is limited (e.g., curved surfaces are approximated, requiring some finishing process after printing). .AMF is considered an updated version of .stl and was developed by the American Society for Testing Materials in 2013 to address the limitations of .stl. .AMF has an advantage over .stl because .AMF can store much more data and address texture and color; the file sizes are smaller than .stl. At this time though, they have limited support and adoption has been slow.

There are other file formats being developed, and this will continue in this emerging market.

Equipment

WAAM systems fall into one of two types:

– Robotics
– Machine tool-based

Integrated systems include manipulation systems and CAD/CAM software. Almost any three-axis manipulator or robot arm and an arc welding power source can be combined to make an entry level WAAM system.

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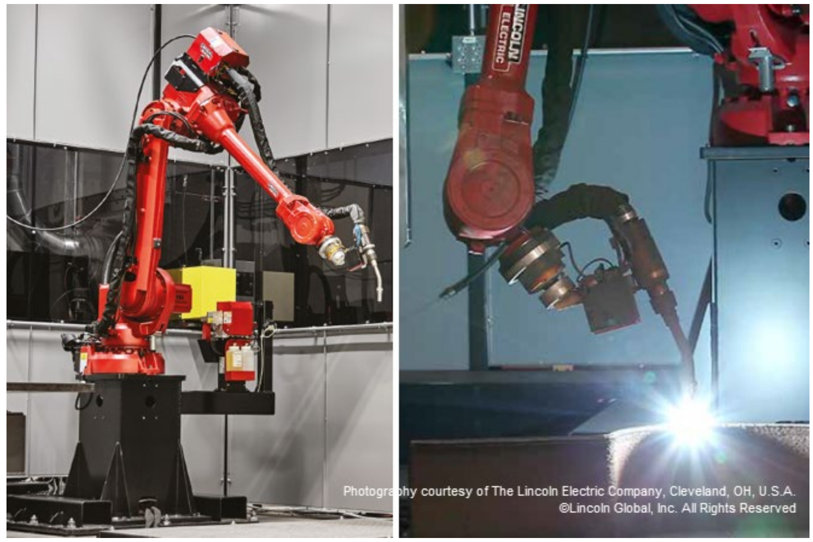
Different arc welding processes can be applied and, to some extent, the material in use will drive the process selected: titanium alloys typically use GTAW, PTA, or EB; most other materials are deposited with GMAW.

Applications for pressure parts



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The American Society of Mechanical Engineers (ASME) is actively working on the use of additive manufacturing. The Board on Pressure Technology Codes and Standards (BPTCS) and the Board on Nuclear Codes and Standards (BNCS) have established a Special Committee on the Use of Additive Manufacturing for Pressure Retaining Equipment.

Already published, is the document ASME PTB 13 2021 Criteria for Pressure Retaining Metallic Components Using Additive Manufacturing. This document provides guidance on the essential elements to be addressed in proposed standards for construction of metallic pressure parts using powder bed fusion additive manufacturing. It is a reference for proposals for Code Cases or additions to codes and standards. Laser and electron beam are permitted by this guideline.

The document can be purchased at:

https://www.asme.org/codes-standards/find-codes-standards/ptb-13-criteria-pressure-retaining-metallic-components-using-additive-manufacturing/2021/drm-enabled-pdf

It addresses:

– Guidance on design, quality control, and NDE of AM components
– Intended to be used in conjunction with a governing design code
– It recommends the use of ASME Section VIII Division 2 Part 5 for design AM components

Following on from the publication of PTB-13, several Code cases are in development.

In Section I, a case for the manufacture of Pressure Relief Valve Bodies and Bonnets or Yokes using the Powder Bed Fusion with Laser or Electron Beam energy sources is currently in Committee.

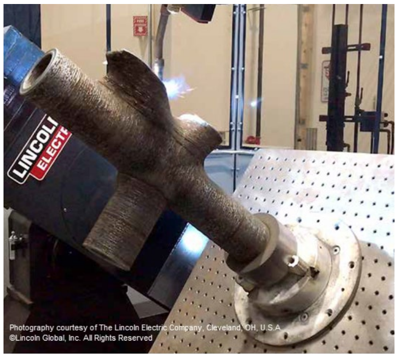
For Section III, Division 1 – Subsection NB/NC/ND, Class 1, 2, and 3 Components, a case for the manufacture of stainless steel products produced using the laser powder bed fusion process, followed by hot isostatic pressed and solution annealed in grade UNS S31603 material is also in Committee.

Section VIII is working on a case for the manufacture of pressure boundary parts in various Titanium alloys using the electron beam direct energy deposition (DED) wire fed process.

As noted at the start of this article, Section IX published Code Case 3020 for the Qualification of Gas Metal Arc Additive Manufacturing (GMAAM) Procedures, and this will be incorporated into the 2023 edition of Section IX. Further in line with the subject matter of this article, a Section I Code Case for Direct Energy Deposit Additive Manufacturing of Pressure parts fully constructed from weld metal is in development. A primary point of discussion in the development of this Code Case is assignment of allowable stresses for parts made from weld metal. Initially, evaluation is proceeding for allowable stresses in the time independent regime. Testing of weld metals is currently ongoing with initial results of mechanical properties at elevated temperatures reported as showing good correlation between weld metal and their equivalent wrought products.
A new project will be initiated looking at the time dependent regime properties for Grade 91 material.

Conclusion, the case for DED additive manufacturing

As has been noted in this paper, DED additive manufacturing allows for manufacture of larger components with advantages of higher deposition rates of weld metal. One of the significant advantages is reduction of lead time; certain components can have lead times of many months, which can impact project schedules significantly. Examples of pressure parts are beginning to be put into service. In early 2022, a replacement header was required for a boiler. Printing of a part for this application was permissible for the application following expert review of API 530 and ASME Code Case 3020 addressing qualification of welding.



The material was Alloy 617, and the component was designed to operate at a temperature of 1500°F, and a pressure of 300psi.

Design was supported by Finite Element Analysis (FEA). This alone generated a part weight reduction based on an additively manufactured part from ~1,200 lbs to ~840 lbs over the convention forging route.

Additionally, based on traditional supply routes, delivery for the header was estimated at 3 months, which would have negatively affected the outage schedule. By using the WAAM process with GMAW, the part from inquiry to delivery was on site in just under 4 weeks.

Summarizing driving values:

– On demand parts reduce the need for expensive inventory
– Improved design, weight reductions
– Performance improvements

References:

Moon, M. (2021, May 13). Boeing uses first FAA-approved 3D-printed parts for the 787. Engadget. https://www.engadget.com/2017-04-11-boeing-faa-approved-3d-printed-metals-787.html

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Phil joined HSB in February 2022. He holds a bachelor's degree in metallurgy and a master's degree in welding technology. Prior to joining HSB, Phil worked for a major power company providing welding and materials support for large industrial boiler projects. Within Codes & Standards, Phil provides technical support and training in the areas of welding and fabrication for boilers and pressure vessels.

Phil is also very active on ASME Boiler and Pressure Vessel Committees. He currently serves as the Vice Chair for Subgroup Fabrication & Examination of Section I, Member SG Materials – BPV I, Member Section I Executive Committee, and Member of Section IX SG General Requirements. Phil is also a member of two NBIC committees, Subgroup and Subcommittee Repairs & Alterations.

Ask the engineer

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SFA-5.18 ER70S-6 is often identified on WPS and PQR as A-No. 1 for filler metal chemistry. However, in the specification for this classification both Manganese (Mn) and Silicon (Si) have allowable ranges that exceed those permitted for assignment as A-No. 1. Section IX QW-404.5 provides the acceptable methods by which A-No. can be determined based on the welding process being used. The conundrum for ER70S-6 can be addressed in several ways:

1. Do not specify an A-Number, just list the ER70S-6 classification. The final paragraph of QW-404.5 permits states: "Designation of nominal chemical composition may also be by reference to the AWS classification…".

2. If the chemistry of the lot of weld wire for ER70S-6 was determined to meet the requirement of A-No. 1 by the acceptable means, then this may be stated on the PQR and WPS. But in this case, controls for the purchasing of the weld wire will need to be established to ensure that the Mn and Si limits are met for the A-No. designation. This approach is permitted in other Code Sections, for example in Section I, Tables PW-39, when a chemistry limit is invoked, it typically states: "…except when further limited by the Purchaser to a value within the specification limits".

By following option 1, welding documents are restricted to the use of ER70S-6 weld wire only, but if option 2 is followed then by assignment of A-No. 1, other wires meeting the same F-No. and A-No. may be permitted for other WPS.

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Take note!

Largest steam drum in the world

Sichuan, China

Pictured: HSB Authorized Inspector, Mr. Wanli He

On May 15, Hongying Dai, Country Manager of HSB China, attended the hydrostatic test of the steam drum at Sichuan CRUN's temporary location in Deyang, Sichuan, China, upon the invitation of our client, Sichuan CRUN. The steam drum, fabricated by Sichuan CRUN in accordance with ASME Code Section I, is to be installed in the Andritz OKI II project located in Sumatra, Indonesia. Once completed, this project will feature the world's largest alkali recovery boiler, capable of processing 13,200 tons of dry solids per day.

The steam drum boasts impressive specifications, with an inner diameter of 2,500 mm, a wall thickness of 150 mm, a length of 34,966 mm, and a weight of 393,643 kg. Constructed from SA-302 Gr. B material, it incorporates a total of 316 nozzles.

The hydrostatic test was successfully conducted, and both the customer's inspector and HSB's Authorized Inspector have signed the test report. This marks a significant project milestone, as the hydrostatic test for this colossal boiler part has been completed. Sichuan CRUN takes great pride in this achievement, and as their Authorized Inspection Agency, we share the same sentiment.

HSB accreditation renewal

HSB renews New Zealand Health and Safety Accreditation

HSB provides manufacturers of pressure equipment with design verification and fabrication inspection services to comply with New Zealand's WorkSafe Department in accordance with Health and Safety in Employment (Pressure Equipment, Cranes, and Passenger Ropeways) Regulations 1999. HSB has also provided cylinder import approvals to comply with regulations 15.15, 15.16, and 15.40 of the Health and Safety at Work (Hazardous Substances) Regulations.

We are proud to share that HSB has successfully requalified as a "Recognized Inspection Body," allowing us to continue conducting fabrication inspections and design verifications of pressure vessels to meet the New Zealand's import requirements. Additionally, HSB has requalified as a "Recognized Inspection Agency," allowing us to continue approving cylinders to US-DOT, Transport Canada, and ISO standards to meet New Zealand's import requirements. A combined effort from our skilled HSB team supported the successful completion of this renewal.

HSB's experienced professionals around the world can efficiently answer technical questions and provide required inspection services to help clients import pressure vessels and cylinders into New Zealand with a high level of assurance.

We are confident our ongoing services will prove to be a valuable and convenient resource for your organization. For more information about this service, please contact getinfo@hsb.com.

Events calendar

2023 virtual technical training seminar topics - click here to register

Month	Topic
September 12&13	ASME Section IX - Welding Requirements (E23)
September 19&20	NBIC Repairs and Alterations (E23)
October 10-12	ASME Section III, Division 5 - High Temperature Reactors and SMR Overview (E23)
November 28-30	ASME Section VIII, Division 1 (E23)
December 5-7	ASME Section I and B31.1 - Power Boilers and Components (E23)

2023 code synopsis virtual training schedule - click here to register

August 16	ASME 2023 Code Synopsis: Section VIII
August 23	ASME 2023 Code Synopsis: Section I & II
August 24	ASME 2023 Code Synopsis: Section V & IX
September 7	ASME 2023 Code Synopsis: Section III
November 7	ASME 2023 Code Synopsis: Section I & II
November 8	ASME 2023 Code Synopsis: Section VIII
November 9	ASME 2023 Code Synopsis: V & IX

2023 on-site Hartford seminar series - click here to register

October 23	2023 ASME (Nuclear) Code and Industry Update Including Advance Reactors
October 24	ASME Section IX (E23)
October 25	2023 ASME Code Synopsis: Sections I, II, V, VIII – Division 1&2, and IX
October 26	ASME Section VIII, Division 1 (E23)

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