In-Process Weld Rework Reduces Cost and Lead Time for Aluminum Castings

Recently, an aluminum casting supplier to a prime contractor for the U.S. Department of Defense was allowed to incorporate In-Process Weld Rework (I-PWR) into its production of high-specification aluminum castings. As a result, the prime contractor realized substantial lead time savings and the casting supplier saved money by eliminating scrap castings. This is because I-PWR offers substantial process efficiencies while also maintaining compliance with the high quality standards required of defense castings.

Background

In May 2018, the Aviation Forging and Casting Assistance Team (AFCAT) received a report of high casting scrap rates at an important aviation cast parts supplier. AFCAT was directed to look into potential causes for the high scrap rate. The AFCAT and CAST-IT teams discovered that this foundry, and many other DLA suppliers, were not permitted to perform In-Process Weld Rework (I-PWR) on castings.

In-Process Weld Rework (I-PWR) is a common finishing process within the metalcasting industry. I-PWR brings indications of potential surface or sub-surface nonconformances into compliance so that the cast part will meet customer specifications for solidification integrity for mechanical properties or surface appearance. Using defined weld procedures, qualified welders apply I-PWR to every weldable casting alloy produced in virtually every mold cavity making process.

I-PWR has been shown to enhance the mechanical properties, cyclic life, and fracture toughness among A357 and A201 cast aluminums (documented by Northrop Grumman in 1987)[1] and the mechanical properties and cyclic life for E357-T6 aluminum castings (documented by the American Foundry Society in 2012).[2] The American Metalcasting Consortium highlighted the value of I-PWR in a 2018 Casting Quality Tip.[3] Indirectly reflecting the efficacy of I-PWR, one of the most stringent specifications for critical military, aerospace, and commercial vehicle castings, AMS 2175 Rev. A is silent regarding in-process welding on castings. AMS 2175 applies to all metalcasting alloys and mold cavity making processes except die casting

Despite the benefits of I-PWR, engineering authorities in original equipment manufacturers (OEM) and defense prime contractors may unnecessarily limit or prohibit welding due to an incomplete understanding of I-PWR. However, prohibiting I-PWR can increase the cost and lead time required to produce critical cast parts.

A Defense Prime Contractor's Prudent Choice

David Weiss, Vice President of Sales and Engineering at Eck Industries, described the advantages of utilizing I-PWR and its applications for high-specification aluminum castings at the 2019 American Foundry Society CastExpo. In the audience was one of Eck Industries' customers, a U.S. defense prime contractor that had barred the use of I-PWR on any of its aluminum castings due to the critical applications of its products. As a consequence, Eck Industries was incurring the unnecessary cost of scrapped, repairable castings, and the prime contractor suffered unnecessary delivery delays while scrapped castings were being remade.

Impressed by Weiss's presentation, the contractor arranged for its design, materials, and manufacturing engineering colleagues to meet with Eck Industry representatives. At the outset, the contractor's engineers were not inclined to lift the ban on I-PWR for their aluminum castings. However, when they saw the commonly accepted metalcasting industry process of welding plugs into coreprint windows, they began to reconsider.

Using a process similar to I-PWR, welded plugs are common in complex, sand cast structural and functional geometries, including pumps and valves. This process involves plugging openings in casting walls used to support complex internal cores. It applies to most weldable ferrous and non-ferrous alloys and is a complete, through-wall, butt-weld. For both I-PWR and plug-welding, all welding is done before the final heat treatment.

Cosmetically dressing the weld bead involves light manual grinding and grit blasting. How close the surface matches the neighboring as-cast surface varies according to customer preference.

Shown below is a complex sand-cast aluminum exhaust manifold, which has separate cored passages for water cooling. Supports for the water passage core require windows in the manifold walls that must be welded shut with plug castings. The plug castings are cast with the manifold in its gating system. The plugs and the core-print windows are beveled for complete, through-wall butt-welds.

The photo above illustrates the as-welded condition before manual grinding, post-weld heat treatment, and grit blast to smooth the surface per customer requirements.

Welding plugs into coreprint windows is not only common, but rarely questioned by responsible engineering authorities. In contrast, I-PWR typically involves much less of the casting wall thickness (typically 20% or less) and a far smaller area of weld bead. The contractor's engineers realized that if large-scale plug welding is allowable, small-scale I-PWR could also be used without harming the quality of its cast parts.

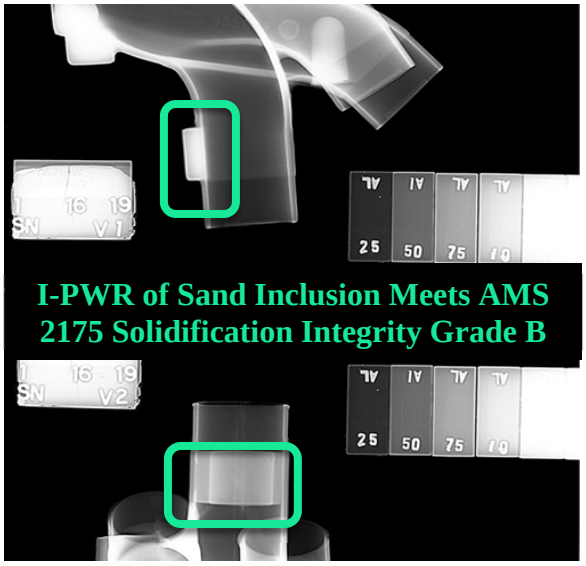
I-PWR Produces High-Quality Results in Defense Applications

I-PWR has been shown to meet the same stringent quality standards required for cast defense materials. To ensure that I-PWR meets these requirements, only welders that have been specially qualified for I-PWR (and in-process welding of coreprint window plugs) are allowed to make these welds. This qualification is alloy-specific, as some alloys are more difficult to weld at a high integrity than others. Moreover, the weld procedures used must be approved, ensuring that the final part will conform to applicable standards.

I-PWR meets the same AMS 2175 Rev. A solidification integrity grade as the parent cast metal, shown by the above sequence of I-PWR of a sand inclusion defect, finish grinding, heat treatment, and grit blasting to match the surrounding parent metal surface. Finally, radiographs (shown below) demonstrate the weld's solidification integrity at AMS 2175 Grade B.

The sources in footnotes 1 and 2 confirm that the yield strength medians and elongation percent medians among welded and unwelded specimen comparisons for A357, E357, and A201 are virtually indistinguishable (within 8

MPa or 1 percent, respectively). Elongation percent standard deviations in the more recent E357 study are even smaller for the welded test plates compared to the no-weld test plates.



Recognizing that I-PWR could reduce the cost and time required to produce cast parts without sacrificing quality, the contractor's engineering and quality authorities decided to reverse their ban on welding anywhere on their aluminum castings. The prime contractor now permits I-PWR where its casting producers demonstrate compliance to specifications. The engineers embarked on a program to revise all of their aluminum casting solid model data files to allow in-process welding for rework or plugs, with the exception of a few critical service castings. Among those critical service castings, welding is only restricted for defined zones where transformed stresses are high.

Conclusion

In short, using I-PWR in the production of weldable defense castings can eliminate the high cost and delays of scrapping repairable, conforming cast metal components. As David Weiss explains, "In this case, the data supported that a complete ban on welding was not justified, given the language of the specifications and the practical examples presented." I-PWR is a valuable tool enabling suppliers to rapidly deliver high quality, cost-effective cast metal components that contribute to warfighter readiness.

Footnotes:

1. Manufacturing Methods for Process Effects on Aluminum Casting Allowables; Northrop Grumman, Aircraft Division, Hawthorne, CA; Approved for Public Release, 8 Oct 1987; Pages 251-259; Kermit J. Oswalt, Program Manager.

2. Effect of Weld Repair on Static and Dynamic Tensile Properties of E357-T6 Sand Castings; Gegel, Hoefert, Hirvela, Oehrlein; 2012; American Foundry Society.

3. American Metalcasting Consortium Casting Quality Tip: https://amc.ati.org/wp-content/uploads/2018/09/In-Process_Weld_Rework-w-new-web-link.pdf

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