

Casting Quality Tip: In-Process Weld Rework

Problem

In-process weld rework during finishing of as-cast surfaces on many kinds of castings is widely misunderstood by casting materials engineers, manufacturing engineers, and inspectors.

Background

Castings are susceptible to having small surface *imperfections* such as inclusion pits, gas microporosity, cold laps, misrun edges, or dents from handling damage that are cosmetically unappealing, or cosmetically non-compliant. In-process weld rework of castings, also referred to as “cosmetic weld repair,” is a routine casting finishing activity that is used to mend such casting surface imperfections across almost all alloy families and mold cavity-making processes. In-process weld rework is also performed on surface and near-surface *discontinuities*. These discontinuities are typically harmful to the structural performance of a casting. They are hot-tears (pre-existing cracks from the nature of the alloy, mold cavity geometry, and/or the mold cavity material), cracks from heat treating, and near-surface voids revealed by radiography or ultrasound. For commercial castings, the extent of *discontinuities* is typically classified by radiographic standards.

Solution

This Casting Quality Tip aims to correct misconceptions about in-process weld rework of legacy weapon system castings to enable faster deliveries of quality castings to the warfighter at lower costs.

Specification Scenarios

Most Common Scenario - In-process weld rework is NOT noted in specifications: A casting that has been welded, blended, heat treated, and has passed all drawing specified inspections will generally be dimensionally, physically, chemically, metallurgically, and structurally compliant to drawing requirements. Therefore, specifications to limit or document in-process weld rework of surface imperfections are rarely noted in commercial castings. Similarly, military or aerospace castings not classified for service severity also typically have no specifications limiting or documenting in-process weld rework.

Scenario in which AMS 2175 (Classification and Inspection of Castings) is specified: For military and aerospace castings, in AMS 2175, severity of cast component service is classified as Class 1 through 4, and surface and/or internal integrity is specified as Grade A through D. Classes require different levels of sampling for non-destructive tests to verify compliance with the specified integrity grade. Significantly, grades directly correlate to the cyclic life of a classified casting’s highly stressed surfaces. AMS 2175 covers almost all casting processes and the full range of casting alloys, so it is also adopted as a commercial standard for safety critical castings, SAE 2175 being identical.

Importantly, AMS 2175 is silent regarding in-process weld rework, only specifying the extent of imperfection in Grades A through D as “graded” in radiographic, magnetic particle, die penetrant inspection and/or visual inspections. This is inspection after all casting finishing processes are complete including final heat treatment. Those finishing processes include in-process weld rework, if applicable. Welded or not, passing the specified grade indicates that the allowable transformed stress for which the casting was designed will enable the intended cyclic life. Conversely, poor in-process weld rework will result in surface and/or subsurface indications that would not pass testing for the specified integrity grade.

Click this link, [In-Process Weld Rework Specifications and Properties Data](#), for static, cyclic, and fracture toughness data, welded versus as-cast parent alloy, after final heat treatment for aluminum and magnesium alloys.

Scenario when in-process weld rework is limited or must be documented: With AMS 2175 to assure surface and internal integrity that correlates directly to the design intent for cyclic life, limiting or requiring documentation of in-process weld rework is an unnecessary “belt plus suspenders” precaution. An example is AMS-A-21180 (High Strength Aluminum Alloy Castings) that allows call out of “no-weld zones” or “in-process weld rework only upon written permission of the purchaser.” Maps may be required showing location, size, and depth of welds

to be approved by the cognizant design authority in advance for each casting to be welded. Applying AMS-A-21180 implies that the cognizant design authority doesn't have faith that the non-destructive testing specified in AMS 2175 for aluminum structural castings will assure safe performance in Class 1 or 2 severe service. That should be a rare requirement, and if required, should only be applied to casting surfaces that really are critically stressed.

Recommendations

Sometimes "no weld" specifications or "in-process weld rework" limitations have been specified incorrectly for legacy weapon system castings on the original drawing or in the Technical Data Package (TDP). The consequence of misapplied in-process weld rework specifications can be lack of metalcasting supplier team responses to solicitations, excessive costs, and/or excessive delivery delays.

Mechanical properties of welded surfaces, especially cyclic life and fracture toughness, have been well-documented to be the same as the cast parent material, heat treated. In-process weld re-work that meets AMS 2175 surface and internal integrity grade for the class of service is just another casting finishing process prior to final heat treatment and final net-shaping processes.

In order to meet the specified grade for surface and internal integrity, the metalcaster will have to use qualified welders, approved weld procedures, and approved weld filler chemistries. If the metalcaster doesn't have those in-process weld rework manufacturing capabilities, then AMS 2175's non-destructive testing requirements will reject each casting for flawed welds or the whole lot of castings based on a flawed weld sample. So, specifying "no weld zones" or "in-process weld rework only upon written permission of the purchaser" should be a rare, super-safe requirement on only the most severe service applications.

An effective specification strategy for "in-process weld rework only upon written permission of the purchaser" is to define, *in advance*, zones on specific critical casting surfaces for which there are limitations for in-process weld rework. For example, specify "In zone A, in-process weld rework is permitted per 'X' square centimeters: 'N' welds of 'L' maximum length no closer than 'S' spacing." Then, allow the metalcaster to certify compliance with the specification when the finished castings are shipped. A higher level of compliance can be required with both the certification and a map of the weld sizes and positions in the defined zones. This compliance strategy can save many weeks of lead-time by eliminating requests to weld specific castings and the waiting time for approval.

Another effective strategy to simplify and expedite finishing of castings with minor surface *imperfections* is to allow blending of such imperfections of a maximum depth with light grinding as a practical alternative to in-process weld rework. A common maximum depth that is helpful is 1.5mm. In addition to a note allowing blending of such shallow imperfections, is a note to exempt the specific blend area from dimensional compliance.

Misapplication of in-process weld rework limitations can be readily superseded with a drawing revision, TDP revision, or a purchase order requirement to enable faster deliveries of quality castings to the warfighter at lower costs.

We welcome your feedback on this information. Please send your comments to amc@ati.org.

