OVERVIEW OF LASER METAL DEPOSITION

FOR WASTE TO ENERGY PRESSURIZED BOILER COMPONENTS

This document is meant to give a brief overview of recent Laser Metal Deposition (LMD) advances in the WTE boiler industry. Since American Cladding Technologies is a "Service Provider," we are therefore bound by our customer NDAs and our own IP (Intellectual Property). Due to these restrictions, specific details have been omitted to maintain confidentiality.

americancladding.com | 860.413.3098

The purpose of this document is twofold.

1. Provide a fundamental overview to “Non-WTE” professionals why WTE boiler operations can be more severe than other means of electrical power production. The intent is to initiate thinking for potential applications within their own discipline.

2. Provide some basic information to WTE professionals about new advancements within their industry. American Cladding Technologies realizes that some of the information contained within this document is basic knowledge to any Boiler Reliability Engineer who is involved in the WTE industry.

All subject matter within this overview can be discussed in more detail as it pertains to your specific applications if requested.

For more information regarding this topic, please contact:

Scott Poeppel
Vice President
American Cladding Technologies
860.413.3098 | spoeppel@americancladding.com

Overview of Laser Metal Deposition

FOR WASTE TO ENERGY PRESSURIZED BOILER COMPONENTS

OVERVIEW

In the power generation industry, one of the most inhospitable operational environments occurs within the boilers operating at “Waste to Energy” (WTE) facilities. There are many categories of WTE production, but the most common WTE facilities use a fuel source that ranges from wood or construction debris to MSW (Municipal Solid Waste). Within these boilers, pressurized boiler components are subjected to high temperatures (1600°- 2000°F), high pressures (850 – 1200 psig) and fuel that is both highly corrosive and erosive. The principle corrosive component is due to the high chlorine concentration of the flue gas created by incinerating the fuel source.

Depending on the amount of waste being processed, one particular WTE facility we have worked with processes 1,000 tons of chlorine through its boilers each month. Erosion is accelerated due to fly ash impingement and cleaning cycles performed by soot blowers within the operational boiler. To compound this corrosion / erosion effect, as the fly ash debris builds up onto the boiler components, it begins to block flu gas pathways. This build up reduces the heat transfer across the boiler components resulting in thermal “hot spots” within the boiler. As more surface area of the flu gas pathway is choked off, the remaining open pathways experience very high velocity fly ash impingement to nearby boiler component surfaces. Pressure components such as super heater tubes, super heater platens and water wall panels are all subjected to this hostile environment, and must therefore be replaced at regular intervals and at a significant cost to the energy producer.

THE NEED FOR MITIGATION OF WEAR

In an effort to extend component life and reduce replacement costs, the WTE industry has turned to overlaying their boiler pressure components with materials that help minimize the wear rates associated with corrosion and erosion. The most common overlaying alloy used in the power generation industry is Inconel 625. Known as a “nickel based alloy” due to its high nickel content, Inconel 625 also contains elevated amounts of chromium and molybdenum providing a high level of pitting and crevice corrosion resistance caused by chloride contamination. This alloy can be found in generating plants that include coal fired, biomass, nuclear and of course WTE. In this industry, a typical overlay thickness is 0.070” – 0.100” thick for pressurized boiler components. Inconel 625 also offers above average resistance to erosion.

WHY USE AN OVERLAY?

A common term for overlaying a metal component with a dissimilar alloy is known as "cladding." The advantages of cladding are principally economic. The cost of using a less expensive alloy, (common example: SA213-T22) as the primary boiler component material, and cladding a layer of Inconel 625 over the surface, will cost much less than buying the entire component made from a solid piece of Inconel 625. Another advantage of using an overlay is that material properties might be such that complete components are impossible to fabricate, making cladding the only choice.

AMERICAN CLADDING TECHNOLOGIES, INC. BEGINS LASER OVERLAY DEVELOPMENT

In February 2011, American Cladding Technologies (ACT) began working with a North American WTE power producer in an effort to create and apply a laser coating that would outperform Inconel 625 on pressurized boiler components. Though Inconel 625 was shown to be effective, it still fell short of their desired component lifetime performance goals. The typical superheater (SH) lifespan was 16 – 24 months. After this point, usually the entire primary and secondary SH was replaced at significant cost. Working with ACT, the power producer determined that laser cladding offered benefits that could not be realized with the more traditional methods of applying weld overlays. The development process was a collaborative effort between the WTE power producer's "boiler reliability" engineers, ACT "laser process" engineers, a producer of metal powdered alloys and various university materials testing facilities. Eventually, a powdered alloy composition was selected to begin operational testing trials. Testing trials began with individual segments (10 ft. lengths) installed in various boiler pathways on primary and secondary super heater pendants. Periodic boiler inspections were performed on the test samples to track performance.

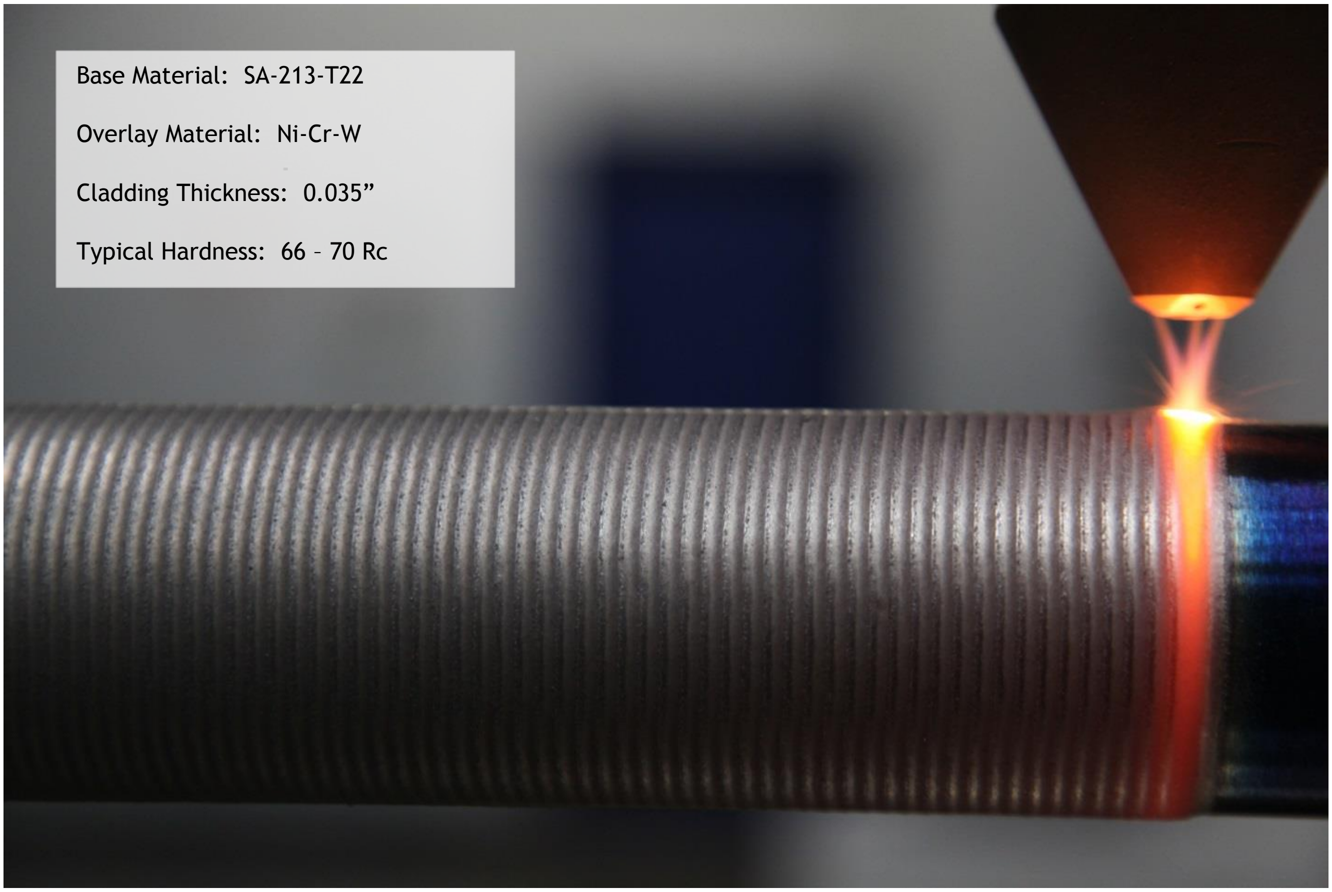
Project goals were as follows:

- Extend boiler pressure component lifetime by a minimum of 2X.
- Eliminate or reduce the use of shielding on the lead SH tubes.
- Optimize laser cladding process to be cost competitive with existing overlay methods.

Photo of a leading SH tube from a test sample inspection. Boiler inspection performed after approximately 14 months of operation. No shielding was installed on test samples. Photo was taken after water wash cleaning of SH tubes. NOTE: Lay lines of the spiral wound laser clad are still highly visible.

By the end of 2011, the performance data on the test samples showed enough encouraging results to warrant moving ahead with continued laser metal deposition of SH tubes. American Cladding Technologies accepted their first purchase order to laser clad a set of 2.5”Ø SA213-T22 superheater tubes for delivery in January 2012.

10 years later, more than 8,000 SH tubes and over 150 SH platens have been laser hard-faced and installed in more than 28 WTE boilers across the U.S. Another boiler component benefiting from this process is the “Soot Blower Lance”. American Cladding Technologies has also begun testing in both the Biomass and Pulp & Paper industries. This performance data has also been encouraging.



Change in the primary alloying element concentration after laser cladding. Comparison is between “Raw Powder Alloy” and the “As Laser Clad” overlay. Coating measurement was taken with Niton XRF analyzer.

Ni (-2.0%)

Cr (-0.2%)

W (-1.1%)

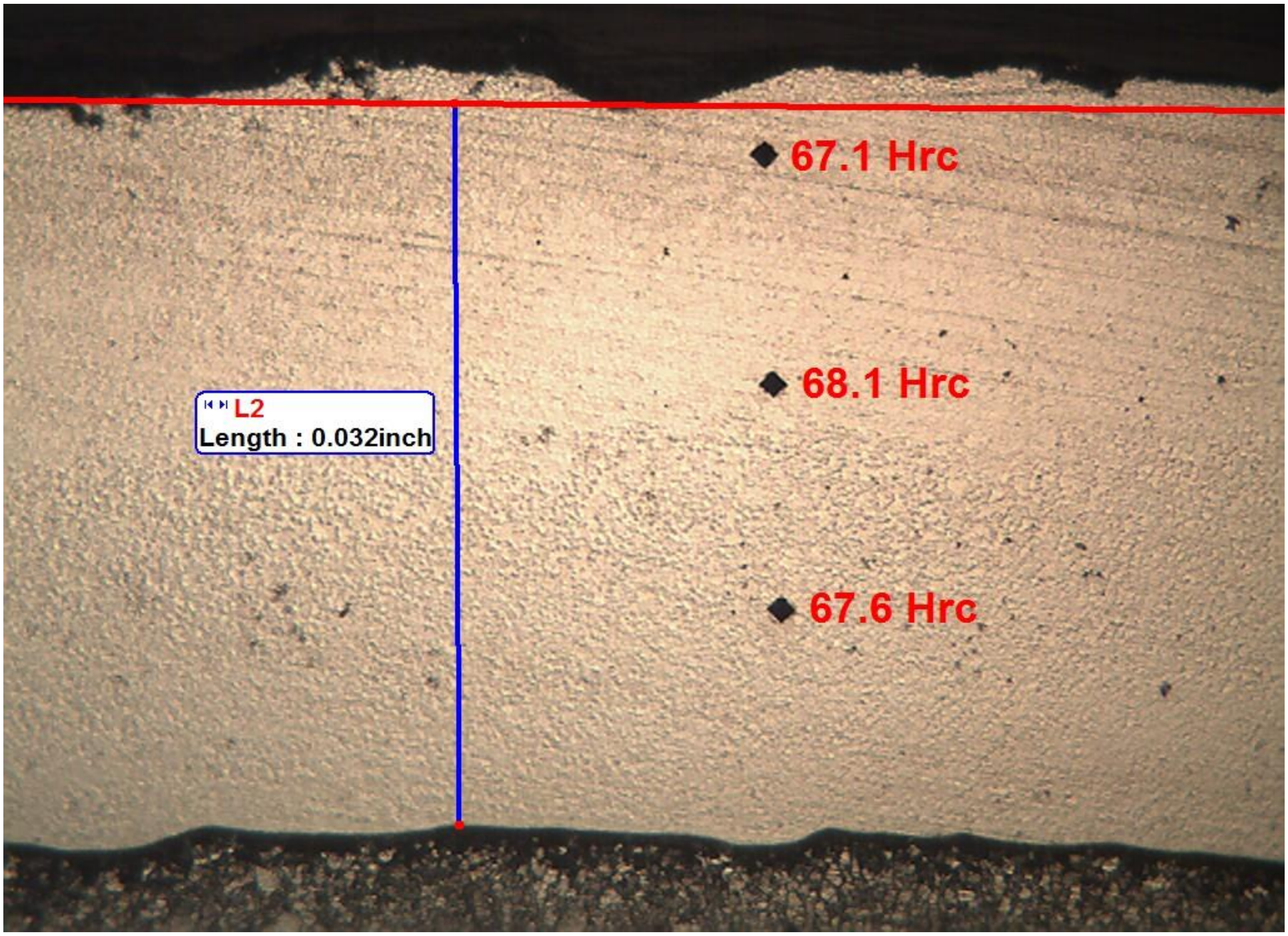
Fe (+0.8%)

A comparison of the raw powder chemistry to the “As Laser Clad” chemistry. The low heat input process allows for very good dilution control. Actual numerical concentration values can be provided as required.

49 MONTH BOILER LIFE IS ACHIEVED

In May 2016, various laser clad SH tubes were removed for evaluation from a local WTE facility. At the time of removal, the SH tubes had been in operation for 49 months. As of January 2022, there are SH tubes that have been in operation for more than 6 years without failure.

Shown above is one of the evaluation tubes removed for metallurgical examination after 49 months of operation.



Metallurgical cross section from one of the “49 month” SH tubes removed for evaluation. Original coating thickness was approximately 0.040” - 0.044” thick.

FINDINGS AND RESULTS

In order to maintain customer confidentiality, American Cladding Technologies will not release or discuss specific values regarding the realized cost savings, power plant operating values or any other data that might be considered sensitive to our customers. However, a general overview of the performance results is provided below.

- **Improved thermal efficiencies compared to the preexisting Inconel overlays.**
  a. Elimination or reduction of shielding on leading SH tubes has reduced ash build up in the low flow areas between the shield and tube face and therefore improved heat transfer.
  b. Reduced heat input of the laser cladding process results in a very low dilution of the base material. This allows for a reduced coating thickness which aids in thermal efficiency.

- **Reduced maintenance costs.**
  a. Reduced or eliminated costs associated with shielding procurement and installation.
  b. Reduced the need for (and costs of) unplanned outages by extending boiler component life.

- **Other advantages of laser hard-facing over preexisting Inconel overlays.**
  a. Reduced fly ash erosion due to the increased wear resistance of the coating. The typical laser applied overlay is 66 – 70 Rc.
  b. By eliminating or reducing SH tube shielding, hot spot formation has been reduced, thereby reducing localized failure points.
  c. Soot blower cleaning cycles have been reduced. Some facilities have reported a 79% reduction in cleaning cycle frequency.
  d. For continuous inline soot blower lances, component life has been extended by up to 6 times their preexisting lifespan.

- **Production cost per linear foot of the laser hard-facing can be equal to or less than the linear foot cost of traditional Inconel 625 overlays. Cost reductions of 40% have been realized. These cost swings are largely dependent on the following variables:**

    a. Total production quantity.

    b. Required coating thickness, which is significantly less than typical Inconel wire overlays and therefore leads to reduced filler material costs and cladding cycle times.

    c. Laser deposition rates, which continue to increase as the development effort continues.

    d. Geographic region within the US. (Overlaying costs vary per region)

A typical cross section photo (50x) of a process qualification sample for ASME Section IX. Base material is SA-213-T22. Photo shows good overlay density, no cracking, no Lack of Fusion (LOF), very low dilution and minimal HAZ.

SUMMARY

- Due to the rapid solidification of the weld pool, microstructure of the overlay is typically superior to traditional overlay methods. Hardness in excess of 66 HRC is readily achieved.
- Minimal heat input from the laser results in very low base material dilution. It is possible to achieve full material properties in as little as 0.005" coating thickness, though this may not always be economical for the end user. It should be said that for a typical SH overlay, a coating thickness of ≥ 0.030" has shown sufficient performance results to be competitive if not superior to traditionally applied Inconel 625 overlays.
- Corresponding with the low heat input, the "Heat Affected Zone" (HAZ) associated with the welding is also minimized.
- Overlay thicknesses ≥ 0.120 have been achieved successfully, but are not always recommended in some applications. Factors to be considered include:
    a. Where the component will be used
    b. Clad geometry of component
    c. Mass of the component
    d. Coating quality requirements.
- Leading and sometimes trailing SH tubes will generally require a thicker coating than the 0.030" normally applied to most SH tubes.
- American Cladding Technologies has recently qualified a weld repair process for this overlay. Coatings can now be repaired with conventional welding equipment in the field.