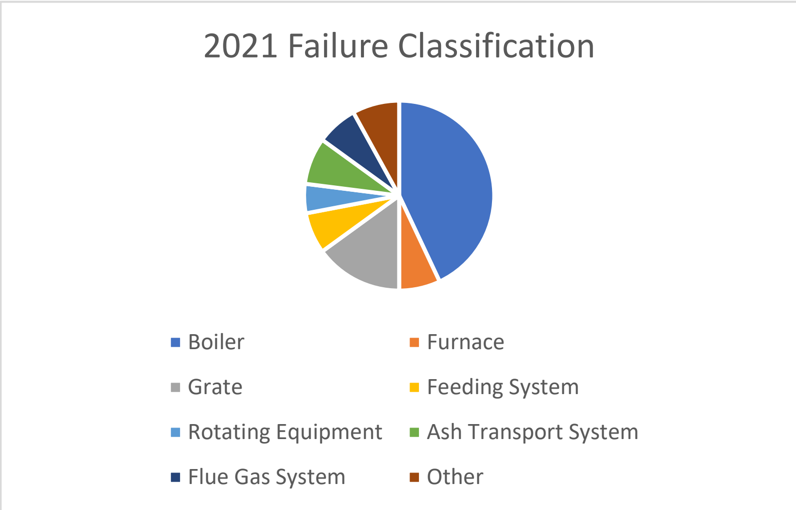
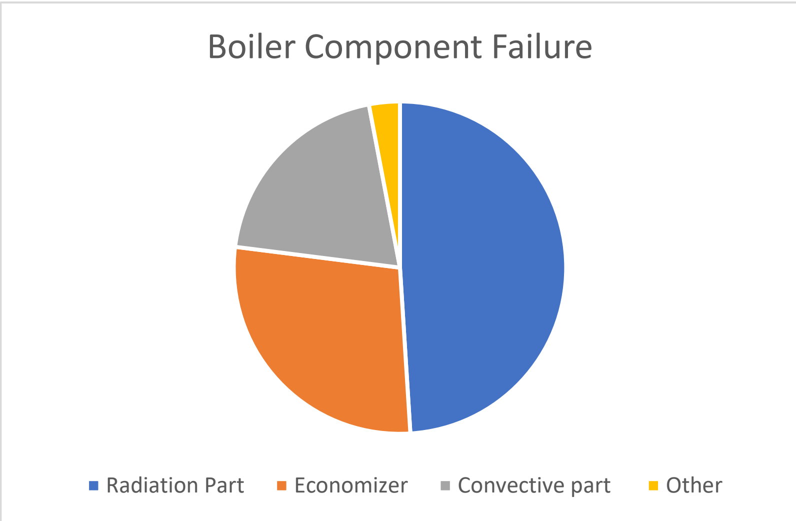
Waste to Energy Plants Suffer from Unplanned Shutdowns Caused by Boiler Failure

A 2021 Prewin Network Unplanned Shutdown Survey has revealed that equipment failures in Waste to Energy (WtE) and Biomass plants were responsible for a total of 22.9 days of unplanned shutdowns in 2021, and 43% of equipment failure classifications were boilers.





Furthermore, boilers alone were responsible for an average of 9.9 days of unplanned shutdowns in 2021, with the radiation part accounting for 49% of boiler failures, followed by the economizer (28%), the convective part (20%) and other (3%).

These latest statistics provide an insight into asset performance and reliability, highlighting boilers as one of the most problematic pieces of equipment for plant owners to manage. This article discusses one of the most common contributing factors behind boiler failure: corrosion.

The Boiler Problem

Typically designed for medium or large installations, boilers produce steam by burning biomass, recycled biomass, or pre-treated industrial or urban waste. Fuel flexibility offers related cost reduction, but results in boiler corrosion.

However, mixed fuel environments create extreme conditions that can predispose equipment to damage. There is a wide variety of boiler design: horizontal grate, inclined grate, bubbling fluidized bed, circulating fluidized bed, and so on. If the fuel contains plastics and other chemicals then chlorine, sulphur, and other alkali and heavy metals can be generated, dramatically increasing the thickness loss rate through corrosion mechanisms.

Without proper preventative care, these conditions can lead to unexpected outages and high maintenance costs, reducing the efficiency and emission benefits of these boilers.

ella@thewriteimpression.co.uk

Boiler Corrosion Mechanisms in WtE and Biomass

Increasing efficiency of WtE boilers means increasing pressure and temperature inside the boiler tubes. The combination of new fuel types containing higher levels of corrosive agents with these higher temperatures and pressures can lead to material softening. Accelerated fireside boiler corrosion starts on the unprotected steel heat exchange surfaces of the super-heaters and erosion resistance declines.

Most corrosion protection mechanisms consist of generating a corrosion barrier on the base metal by forming an oxide layer. The challenge inside WtE boilers is that this layer is quickly eroded, forcing the formation of another layer, and consequently leading to the erosion-corrosion phenomenon. Erosion-corrosion thinning can happen quickly when harsh conditions are combined with soft or poor erosion resistance materials.

WtE Boiler Corrosion and Erosion Protection

Refractory protection is the first defence against corrosive flue gases and can also have excellent erosion properties. However, it's heat exchange properties are limited as the thermal efficiency is low. Refractory alloys can be used, but due to the excessive material costs and limited erosion resistance, the implementation of a surface protection layer is often a more cost-effective solution.

The use of thin ceramic coatings seems like an attractive approach, although often, the thermal expansion mismatch and the fragility of such coatings make this solution unreliable. The coatings tend to crack, and corrosion can develop underneath the protective layer which is then likely to peel off.

The Solutions

Weld Metal Overlay (WMO)

Many boilers are designed and fabricated with weld metal overlay (WMO) installed in critical areas at risk from erosion or corrosion.

Often, over time and during continued operation, accelerated corrosion is then observed on the unprotected tubes beyond the WMO section, for example in the second pass (this is commonly referred to as 'corrosion creep'). In this case the scope of tube area protected by a corrosion barrier needs to be extended.

Corroding boiler tubes, Drax, 2018

In many instances, the conventional solution is to have the affected sections removed and replaced with new tube panels which are protected with a WMO corrosion barrier applied in the shop. However, replacing water wall sections can cause long downtimes and additional problems, such as distortion and surface geometry irregularities at the butt weld, among others. WMO is particularly challenging in instances where external furniture is involved.

The alternative of field WMO application on-site is difficult to manage from a quality perspective, may not be possible on thinner tube sections, and is time consuming, extending plant stoppages.

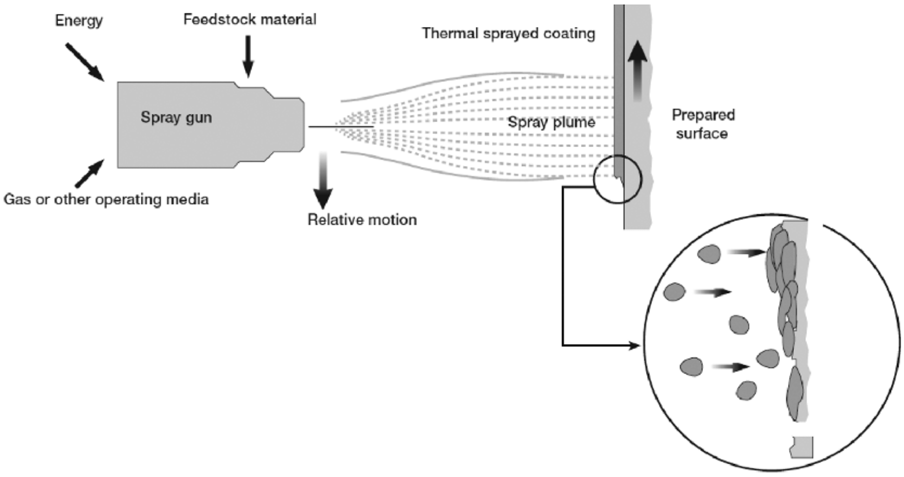
In other cases, in certain parts of the boiler the applied WMO can start to show signs of accelerated wastage due to corrosion after only one or two years in service. This original investment needs to be protected from further rapid degradation which risks the integrity of the underlying water wall.

Ageing Weld Overlay, Renergia, 2017

Thermal Spray

Thermal spray technology has been used for the application of corrosion resistant alloys (CRAs) in the power industry since the 1980s, spraying metal alloys widely used in the WMO process. However, it was quickly understood that the thermal spray process itself negatively affects the properties of the alloy being sprayed.

The resulting as-applied cladding, when using off-the-shelf metal alloy wires and conventional thermal spray equipment, was permeable. This permeability due to porosity, high internal stress, encapsulated oxides, and lower bond strengths with the base metal created a perfect pathway for corrosion and premature failure. Quite the opposite of the desired result.



Thermal spray process

These early failures resulted in a universal distrust of thermal spray technology. At the same time, this provided a huge opportunity: is it possible to improve the bond strength and reduce the permeability, porosity, oxides, and internal stress of the as-applied thermal spray coating?

High Velocity Thermal Spray (HVTS) Alloy Cladding

engineers and material scientists at Integrated Global Services (IGS) successfully developed a solution to this problem by redesigning both the conveyancing equipment used to apply the metal alloy and the metal alloy feedstock material itself.

Bond strength

The problem of the bond strength between the thermal spray applied metal particles and the substrate was solved by increasing the spray velocity and improving the quality of the substrate surface preparation.

When the atomized molten metal particles propelled by the supersonic air flow hit the suitably prepared substrate, they splat like a pancake and are embedded into the substrate, forming very tight bonds.

Creating an impermeable barrier

When the atomised metal droplets leave the thermal spray gun, during their flight to the substrate, they are exposed to the atmosphere and 21% oxygen. As a result, these high temperature molten droplets experience in-flight oxidation. If not controlled, when the metal droplets land on the substrate, they are deposited with a thin accompanying layer of oxide, compromising the permeability of the applied microstructure.

IGS has solved this issue of macro porosity with its High Velocity Alloy Cladding. Off-the-shelf alloys have been modified with unique alloying components to prevent inflight oxidation. By mitigating oxide formation, the corrosion performance, and permeability of the protective barrier has been greatly improved.

HVTS Case Study: Weld Overlay Corrosion in a WtE Boiler in Switzerland

Overview

The Hitachi Zosen Inova (HZI) furnace installed at Renergia is an inclined moving grate four-pass waste to energy boiler with an external economizer. The boiler's thermal capacity is 47MW with the steam flow of 58 t/h and steam pressure of 41 Bar at 410°C.

Alloy 625 weld overlay was shop-applied on the fireside water wall panels to protect the WtE boiler tubes from fireside corrosion. After months of operation, an inspection revealed accelerated degradation of the Alloy 625 just above the grate.

Several solutions were considered to manage the boiler tube metal wastage and improve both the reliability and lifetime of the water walls, including replacement, field applied weld overlay and thermal spray.

Top half: unprotected Alloy 625 weld overlay section showing wear and degradation.

Bottom half: Area protected with IGS HVTS

The Solution

The HVTS application took place in 2017 on a 20m^2 area located on the left membrane wall at the very low furnace of the moving grate WtE boiler above the refractory. The plant also had a thermal Spray (TS) coating applied by a different vendor on the right-hand side of the membrane.

The Results

These areas were then inspected in 2018 to determine whether HVTS and other vendor's TS were successful at stopping the weld overlay (WMO) degradation. The inspection of the HVTS/WMO interface showed that the area clad with IGS HVTS was no longer affected by corrosion. Unprotected Alloy 625 WMO and other vendor's TS, on the other hand, both continued to degrade.

It was decided that the scope would be extended and that HVTS alloy cladding would be applied to a further 20m2 area in 2019. An inspection later that year, in August 2019, confirmed the following. The areas protected with high-velocity thermal spray (HVTS) alloy cladding were not exhibiting any pitting corrosion or wastage. Adjacent unprotected Alloy 625 weld overlay sections were showing signs of wear and degradation.

A further inspection in 2020 has confirmed that HVTS IGS5470 is performing in line with expectations and is protecting weld overlay areas from further corrosion.

Client Comment

Markus Benz, head of maintenance at Renergia Zentralschweiz AG, commented: "IGS has been selected in November 2017 to apply ~20m² of their IGS material using their HVTS technology. They mobilized efficiently and performed within the tight requested schedule the expected scope of work.

After ten months in operation, a short inspection of the waste to energy boiler was performed in September 2018 confirming the good performance of the coating. As a result, another area was ordered for application in January 2019. In early January, aa deeper inspection confirmed the good overall behavior of the cladding after 14 months in operation.

The protected area has been doubled so that we expect to operate safely until our next turnaround in 18 months. IGS has successfully applied the contracted scope within the critical path in a highly professional manner, with reliable and transparent communication."

Summary

The findings outlined in the 2021 Prewin Network Unplanned Shutdown Survey emphasize the importance of asset maintenance and protecting process materials from degradation and loss of performance. Unplanned shutdowns can have a significant financial impact both in lost productivity, and emergency remedial works.

There are several solutions available on the market, namely Weld Metal Overlay (WMO) which is a reliable albeit time consuming and costly method. Thermal Spray is another solution which in theory is a better alternative to WMO but can lead to premature failure. HVTS is the next evolution of thermal spray coatings which provides reliable, long-term protection from corrosion.

As asset failure, particularly boiler failure, continues to be a costly problem for WtE plant managers, it is crucial that preventative measures are taken to improve asset life, reduce downtime, and deliver significant savings.