Advances in Boiler Tube Cladding Technology

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Abstract:
Corrosion and erosion of boiler tubes is one of the major issues in boilers and they limit the life of the boilers. In this article we are presenting an engineering solution for automatic weld cladding of the boiler tubes with various alloys and there by extending the life of the boilers.

Introduction:
Cladding is the process of applying one material over other for various reasons such as insulation, corrosion protection, aesthetics etc. In the present context, cladding refers to weld surfacing the components to protect them against corrosion and erosion. Corrosion and erosion of boiler tubes is a common issue in most of the industrial boilers. The present-day boilers are using various types of fuels such as coal, lignite, wood, waste wood, biomass, plastics, industrial waste etc. These fuels invariably contain chlorides, sulphides and hazardous substances that can form corrosive gases and molten salts upon incineration. These corrosive gases and molten salts result in a corrosive medium in boilers and causes damages to boiler tubes and super-heat coils. Apart from corrosion, due to various thermo-mechanical process in a boiler, the components inside the boiler are subjected to erosion. Due to the variability of the fuel used in a boiler it is rather difficult to identify the type of corrosion medium. The corrosion rate of boiler tubes not only depends on the concentration of the gases but also on the temperature and temperature gradient that exist in a boiler. Figure 1(a) shows the effect of temperature on corrosion rate for various types of steel. Whereas figure 1(b) shows the corrosion rate multiplier with respect to concentration. Typical examples of corroded boiler tubes are presented in figure 2(a) and (b).
Frequent repair and maintenance of these components in boilers are time taking and expensive. An efficient operation of boiler demands for few maintenance interventions. This could be achieved through proper selection of alloys for corrosion and erosion resistance coupled with optimized method to apply such alloys on the boiler tubes. This could be done on new components at a workshop or in-situ during a maintenance intervention.

Alloys for corrosion and erosion resistance
As it is rather difficult to control the fuels used in the boilers especially with waste to energy boilers, the corrosion medium that exists in boilers are variable. Hence, Nickel base alloys are prominently used for cladding of boiler tubes. Table 1 below provide the list of commonly used alloys for boiler cladding.

Table 1: Typical alloys used for boiler cladding

<table>
<thead>
<tr>
<th>Alloy Type</th>
<th>Nominal Chemical Composition (wt%)</th>
<th>Phase</th>
<th>Thermal Conductivity (W/m°C)</th>
<th>Coefficient of thermal expansion ($10^{-6}$/°C)</th>
<th>Hardness (HV)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>309L</td>
<td>Fe-25Cr-15Ni</td>
<td>γ</td>
<td>13.8</td>
<td>16.7</td>
<td>170</td>
<td>Cladding of recovery boiler and sub-critical boiler</td>
</tr>
<tr>
<td>Alloy 625</td>
<td>Ni-22Cr-9Mo-3.5Nb</td>
<td>γ</td>
<td>13.5</td>
<td>12.8</td>
<td>220</td>
<td>Refuse incinerator boiler</td>
</tr>
<tr>
<td>Alloy 622</td>
<td>Ni-22Cr-13Mo-3W</td>
<td>γ</td>
<td>15.5</td>
<td>12.4</td>
<td>195</td>
<td>Ultra-super critical boiler</td>
</tr>
<tr>
<td>Alloy 671</td>
<td>50Ni-50Cr</td>
<td>γ</td>
<td>15.6</td>
<td>11.7</td>
<td>220</td>
<td>Possess good sulphide corrosion resistance and erosion resistance</td>
</tr>
</tbody>
</table>

All the above alloys have a single-phase austenitic structure, which provides good corrosion resistance. Alloy 625 is most commonly used material due to its excellent heat and corrosion resistance. This alloy can be used upto a service temperature of 450°C.
One of the most important precaution to be taken while apply the above materials is to control the Fe content in the weld metal. The Fe content on the surface of the weld deposit should be less than 1%. This is achieved through usage of low Fe content filler materials and welding process. In general welding is done by vertical down position.

**Welding Equipment and Process**

As there is a need for rigid control on final weld metal chemistry, Welding Alloys has developed dedicated automatic welding machine and grinding system for boiler tube cladding. These machines can be used both at workshop as well as in-situ. The welding is done in vertical down position to control the dilution and final Fe content in the weld metal. Figure 3 (a) and (b) shows welding equipment and setup at workshop and in-situ respectively.

Figure (4) shows different stages in cladding of fluidized bed boiler. Figure 4(d) clearly demonstrated the quality and appearance of weld obtained by the combination of welding process and equipment. In one of the projects on cladding of a subcritical pressure boiler near de-slugger; the thickness loss of base material; which is carbon steel is observed as 0.14 mm in a year. We have cladded the boiler tubes with Alloy 625 and using our custom-made machines and process. The thickness loss is measured at 0.05 mm in a year. The appearance of these tubes after two years of service is shown in figure 5. This demonstrates an extension of life of the boiler tubes.

**Summary**

Weld cladding of boiler tubes using superior alloys and automatic welding equipment is proven as a successful and economic solution in extending the efficient life of the boilers. This technology is proving to be most cost effective for waste to energy boilers. These boilers are subjected to varied type and concentration of fuels that results in highly corrosive and erosive environment inside the boilers. This technology could also be adopted to other areas such as at steel melt shop, distillation columns etc.

**Acknowledgements:**

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Figures

Figure 1(a) Effect of temperature with respect to corrosion rate in a 0.6 wt% sulphur containing environment. 1(b) corrosion rate multipliers with respect to concentration of sulphur.

Figure 2(a) Appearance of a boiler tube with elephant skin due to sulphide corrosion (b) the cross section of tube showing cracks.
Figure 3(a) Welding setup at workshop (b) welding setup inside a boiler

(a) Appearance of furnace
(b) Automatic welding with Alloy625
(c) Under dye-penetrant examination
(d) Weld bead appearance

Figure 4 Cladding of fluidized bed boiler; (12.5MPa x 515C x 85ton/h, Wood chip + RPF)
Figure 5 Appearance of boiler tubes after two years of service in a sub-critical boiler. The tubes are cladded with Alloy 625 through automatic welding equipment.