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Review Article

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A Review on effect of Nano Composite Coated on Boiler tubes and coated methods

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Abstract Nano technology, offers an enormous chance to improve the materials or to adopt or identify a life enhancement strategy of boiler tubes, to the modern engineers because of the outstanding properties Carbon nano tubes (CNT'S) exhibits. Recently scientists or engineers are considering the nano structured composite coatings as these coatings shows great oxidation and corrosion resistance with high heat transfer coefficient at high temperatures to prevent tube failures, increases available operating hours and optimize planned outage cycles. This study focuses on how a nano-structured composite coating can be developed using conventional thermal spray systems. These sprayed coatings are found to generate an amorphous matrix structure containing starburst shaped crystallites with sizes ranging from 60 to 140 nm. And after heating to temperature in the range above 600 ^{0}C, a solid state transformation occurs which results in formation of phases inter dispersed on a structural scale from 60 to 110 nm. The nano-composite microstructure contains 'clean' grain boundaries which are found to be incredibly stable and resist coarsening throughout the range of temperatures found in boilers. The sprayability, "forgiveness", and repair ability of the coatings are explained in detail with the emphasis on field applicability in boiler environments. Additionally, the properties of the coating are studied including the bond strength, hardness, bend resistance, and impact resistance. The revolutionary performance of these composite coatings in boiler environments are studied at elevated temperature at around 600°C.
It is also found that these nano- structured coating can be applied to enhance the corrosion performance of boiler tubes with improved high temperature creep strength.

Keywords Bodo Creek, intertidal flats, tide, recommended levels and temporal variations

1. Introduction

Engineers are constantly under pressure to raise the plant's efficiency, i.e. more power with less fuel usage, due to the growing demand for electricity and the regular economics of power stations. Engineers have the option of designing boilers that can generate steam at extremely high temperatures and pressures in order to attain higher efficiency. The materials of the tubes and their ability to withstand such high temperatures and pressures are a fundamental constraint when working at such high temperatures and pressures. In order to ensure optimal availability and trustworthiness of power plants, "Boiler tubes are constantly a hotspot for researchers, whether in terms of materials or mechanisms" [3], to increase the life of tubes, to lower the chances of failure in order to widen the gap between scheduled maintenance.

1.2 Importance and technical aspects of Nano Composite coating on Boiler tubes

Carbon nano tubes (CNTs) were initially developed and introduced [8], it shows exceptional properties in all scientific area's like physics, chemistry, mechanical or electrical engineering small size, low density, high stiffness, high strength and excellent electronic and thermal properties [12]. These exceptional mechanical and physical properties Along with low weight of CNTs and recent improvements in their synthesis and purification techniques make CNTs excellent candidates for use in tailoring properties of composites [13].

1.3 Nano composites

Nano composites can be defines as "material made of two or more uniquely unrelated material existing at different phases, among them at least one component has a nanometer scale dimension, (length, width, thickness)" [10].

Nanocomposites attracting the attention of researchers because of the extraordinary properties, resulting the mixing of properties of parent component and interfacial interactions. Compared to conventional ones "these materials have very unique properties and modification in properties may be achieved" [14-15] with a great ease.

There are "basically three mechanisms to which the exceptional properties of nanocomposites are associated" [16].

- Polymer chains must be confined by nanoscale particle which are in the size of radius of gyration of composite chain.
- The nanoscale particles themselves have unique properties better than their macroscopic particles.
- Way in which the nanoscale constituents are arranged.

The nanocomposites' unique properties have helped not only to improve existing products, but also to extend their applications into the areas formerly dominated by metal, glass and wood in the appliance, construction, electrical, food packaging and transportation industries [14].

After seeing these benefits in terms' of properties, which are found in general or may be fabricated in these composite. Consideration of researchers to use them as coating material is attracting a great interest. There have been a some commercial application already found and used recently for example, they are used as scratch resisting painting for automobile, anti- corrosion coating for metal, flame retardant reinforced material (the Applications which are most useful in this study to protect boiler tubes), sharpen memory materials and medical implant materials.

2.1 Nano Composites Coatings

Nanostructure coatings have recently attracted increasing interest because of the possibilities of synthesizing materials with unique physical–chemical properties. Advanced nanostructure coatings can achieve highly sophisticated surface related properties such as mechanical, magnetic, catalytic, electronic, optical and chemical properties, making them appealing for industrial applications in high temperature applications such as boiler tubes due to their unique electronic, mechanical and magnetic properties due to the size effect [15]. Nano composite coatings, nano-graded coatings, nano-scale multilayer coatings, super lattice coatings, and other design models for nano-structured coatings exist.

"Designing of nano-structured coatings needs consideration of many factors, e.g. the interface volume, crystallite size, single layer thickness, surface and interfacial energy, texture, epitaxial stress and strain, etc., all of which depend significantly on materials selection, deposition methods and process parameters" [17]. Temperature stability, erosion resistance, corrosion, and other high-temperature phenomena features of nano-composite coatings far exceed those predicted by the mixing rule.

2.2 Development of nano structure coating

Thermal spray coatings are a method that has a number of advantages when applied to boiler tubes since they permit in-situ recoating of the tubes as well as the capability to remedy isolated problems within the boiler. The ability to recoat boilers during a planned outage is particularly appealing because downtime is reduced, resulting in significant operating cost savings. Several types of thermal spray coatings are commonly used in boilers today including nickel chrome, iron chrome [18]. There has recently been a big push in the thermal spray business to develop nanostructured coatings. There have been two ways that have been widely employed.

- The first way is to start with a micron-sized powder that has been extensively distorted, physically processed and has a nanoscale structure.
- The second method involves spraying nano-size particles or nano-powder precursors directly.

Both approaches rely on maintaining the existing nanoscale structure during spraying and subsequent impact on the substrate [16].

"Nanoscale coatings have been developed using an unique method that involves processing through a solid/solid state transformation, which can happen during spraying or during a secondary post-heat-treating anneal. This route to nanoscale coatings has been enabled by developing alloys that readily form metallic glass structures at cooling rates in the range of thermal spray processes (10^4 to 10^5 K/s)" [18]. When heated to its crystallization temperature throughout the diversification course, the glass precursor quickly converts into a nano size composite structure. "This refinement is due to the uniform nucleation and extremely high nucleation frequency during crystallization, resulting in little time for grain growth before impingement between neighboring grains. By this route it is possible to develop very stable nanostructures which resist coarsening at elevated temperatures" [20].

2.3 Experimental Procedure of Coating

"Cryo-milling, the mechanical attrition of powders within a cryogenic medium, is a recently developed method to synthesis nano-structured metallic or cermets powder" [21]. Nano-structured bulk and coating materials using the cry milled powders as precursors have exhibited encouraging results in improving material properties [22]. The high velocity oxy/air-fuel (HVOF/HVAF) process is one of the most popular thermal spraying technologies and has been widely adopted by many industries due to its flexibility, cost effectiveness and superior quality of the coatings produced [23]. The characteristics of ultra high flying velocity and relatively low temperature for injected feedstock powders favor depositing of nano-structured coatings as the nanofeatures of the powders could remain well after the spraying process [24]. HVOF/HVAF sprayed nano-structured coatings have prove great success in improving the performances of existing material systems, and are believed to be one of the most possible ways for commercial applications of nonmaterial's High chromium content nickel based alloy, as a widely used corrosion resistant coating material, possesses good ability against oxidation, sulfur induced corrosion and hot corrosion [25]. Once the chromium content touches the critical threshold, a nonstop Cr_2O_3 scale builts on external layer of alloy with strong binding strength, protecting the alloy against deterioration. Furthermore, chromium has a high potential to generate the chromium carbide that is responsible for reinforce the matrix. Only by optimizing the Cr/C ratio will Ni-Cr-C alloys through great corrosion and wear resistance be produced.

The SHS717 alloy is a patented 8-element glass-forming alloy that includes chromium (20-25), tungsten, molybdenum, and boron (all three less than 10), carbon, silicon, manganese (all 3 less than 5) and the balance iron. It was precoured from nano Steels Company and was designed afterwards considerable research over a long period of time. It has certain atomic ratios of elements to optimise hardness, erosion resistance, glass forming ability, and corrosion resistance.

Spraying of HVAF was done with an arc gun equipped with Arc Jet attachments and a variety of spray settings. The following optimized parameters were used to deposit the 0.020" coatings for the elevated temperature erosion studies: current 200A, overlapping spray pattern of 0.35", spray distance 5", traverse velocity 24"/s, voltage 33V, primary air pressure 65 psi, green air cap and spray head pressure between 19to 20 psi.The treating temperature was set between 540°C and 670°C, which is the temperature at which practically all boiler tubes work. TEM (Transmission Electron Microscopy) was used. The coatings were subjected to TEM analysis in order to determine the crystal structure and detect nano-sized phases. The nano-structured material's thermal stability and corrosion resistance are examined.

3. Coating Methods

3.1 Thermal spraying

Materials with an extraordinary "strength-to-weight ratio" are in high demand. Metal Matrix Composites can be produced in a variety of ways to get suitable qualities as demanded in their application. When compared to unreinforced monolithic metal, metal matrix composites are widely recognized to offer more mechanical qualities, like higher elastic modulus, improved wear resistance, and yield strength. Particulate reinforced metal matrix composites are gaining acceptance in comparison to fibre reinforced MMCs because of their high throughput, comfort in their fabrication, and cheaper manufacturing costs. Nano composites are created when one of the phases in a mixture is nanoscale.

"Melted (or heated) materials are sprayed onto a surface in this coating technique. Electrical techniques (plasma or arc) and/or chemical techniques (combustion flame) are used to heat the 'feedstock' (coating precursor). Thermal spraying can provide thick coatings (approx. thickness range is 20 micrometers to several mm, depending on the process and feedstock), over a large area at high deposition rate as compared to other coating processes such as electroplating, physical and chemical vapor deposition" [25]. Metals, alloys, ceramics, polymers, and composites are among the coating materials accessible for thermal spraying. They are fed as powder or wire, heated to a molten or semi-molten state, and accelerated as micrometer-sized particles towards substrates. Thermal spraying often uses combustion or electrical arc discharge as a source of energy. Coatings are formed as a result of the aggregation of multiple sprayed particles. The surface may not heat up significantly, allowing the coating of flammable substances. Coating quality is usually assessed by measuring its porosity, oxide content, macro and micro-hardness, bond strength and surface roughness. Generally, the coating quality increases with increasing particle velocities. Lech Pawlowski has summarized the following thermal spray processes that have been considered for the deposition of coatings: Flame spraying, Plasma spraying, High Velocity Oxy-fuel (HVOF), Arc Spraying [25].

3.3 Flame Spray

Depending on kind of feedstock material used flame spray is classified into three types: wire, powder, or rod-flame spray. Flammable gases are used in flame spray to generate the energy required to melt the coating material. There is no extension nozzle in which acceleration can occur, hence combustion is effectively unconfined. Hydrogen, acetylene, propane, natural gas, and other fuel gases are common. Traditional flame spraying produces more oxides, porosity, and inclusions in coatings due to the lower temperatures and velocities used. Cross section of flame Gun is shown in Figure 1.

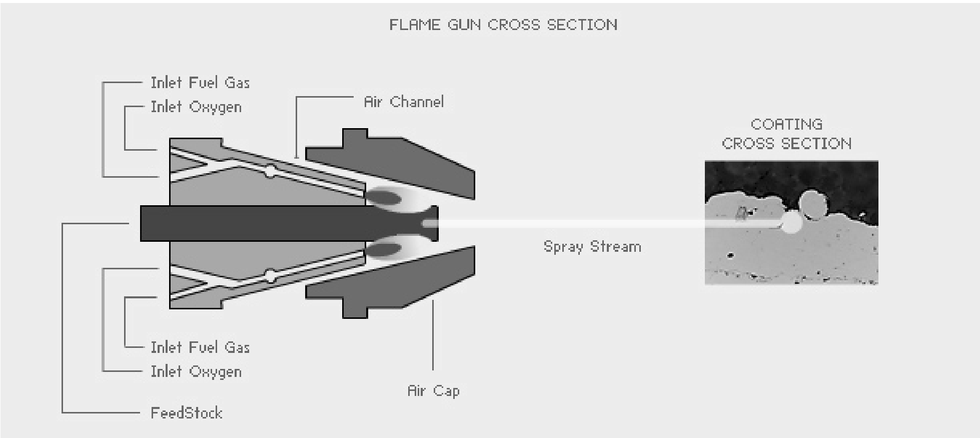

Figure 1: Cross section of flame gun

3.3 Plasma Spray

The most flexible of the thermal spray methods is plasma spray (Figure 2). Plasma has the ability to spray any material that can be sprayed.

An arc is formed between 2 electrodes in systems. The plasma gas expands and accelerates via a curved nozzle as it is heated by plasma generating gas, which is commonly argon/helium or argon/hydrogen in plasma spray the arc, reaching speeds of up to MACH 2.The arc zone reaches temperatures of 36,000°F (20,000°K). Several millimeters from the nozzle's exit, temperatures in the plasma jet are still 18,000°F (10,000°K).

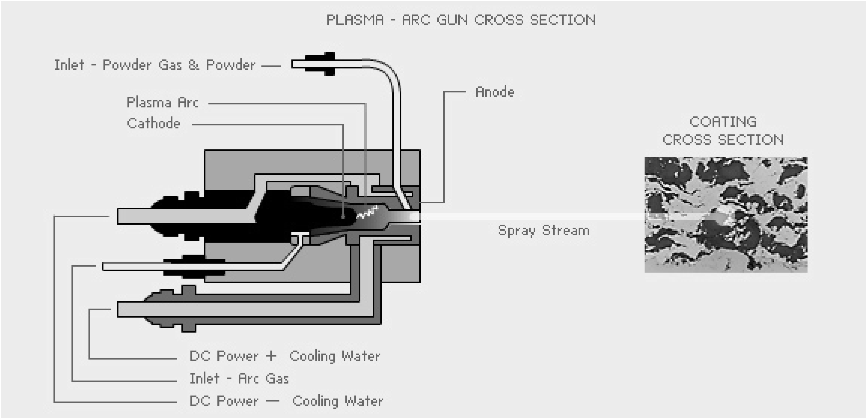

Figure 2: Cross section of plasma arc gun

3.4 High Velocity Oxy-fuel (HVOF) Spray

HVOF devices (High-velocity, oxy-fuel devices) are a subset of flame spray, as seen in figure 3. Between ordinary flame spray and HVOF, there are two main differences. To heat and speed up powdered coating material, HVOF uses restricted combustion and an enlarged nozzle. HVOF devices typically function at hypersonic gas velocities, which are higher than MACH 5. Extreme velocities generate kinetic energy that aids by creation of dense, adherent coatings in their as-sprayed condition.

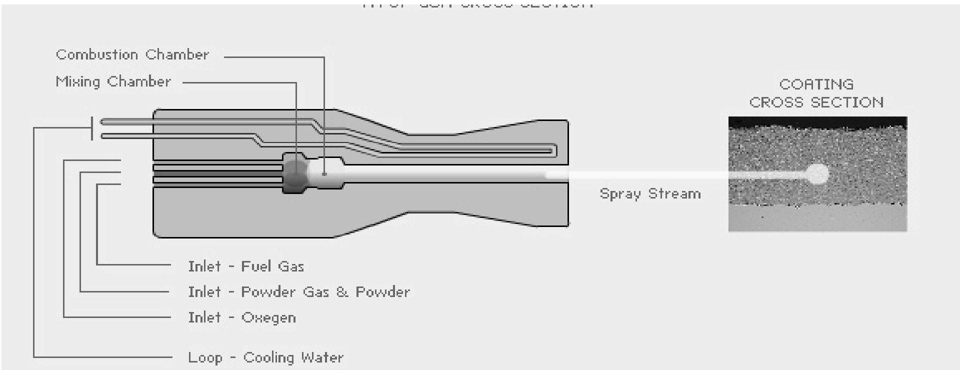

Figure 3: High Velocity Oxy-fuel (HVOF) Spray

3.5. Arc Spray

Electric-arc spray (shown in Fig. 4), like flame spray, was discovered in the early twentieth century. Although the technique has been invented since quite long, it is still a highly effective thermal spray technique. A modest, low-power arc is drawn amid of 2 electrically charged wires in electric-arc spray. In terms of the power supply and wire feeding devices, arc spray equipment is similar to GMAW (MIG) welding equipment. With only 12 kW (42 MJ) of electricity, common arc spray machines can spray iron and copper alloys at rates up to 40 lbs/hr (18 kg/hr). Of all the technologies, electric-arc spraying offers fastest coating rate. Because there is no flame or plasma, electric-arc spray devices are thermally efficient, and minimal heat is conveyed to the component being coated.

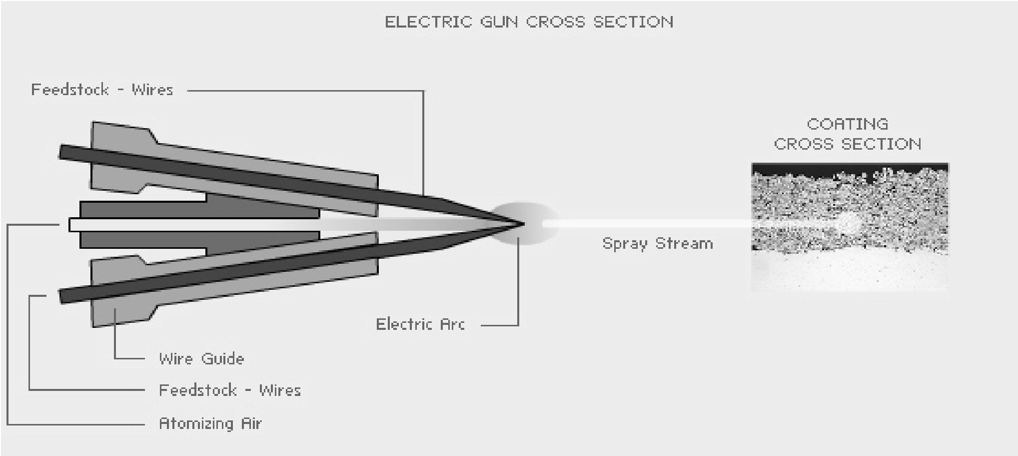

Figure 4: Cross section of Electric gun

4. Conclusion

A nano-structured NiCrC alloy coating have been successfully prepared by HVAF technique with cry milled powder as the feedstock. The nano-structured NiCrC coating exhibited a very compact and homogeneous microstructure and possessed increased hardness, improved fracture toughness, and enhanced high temperature corrosion resistance compared with its conventional coarse-grained counterpart. In high temperature environment, the coating showed a good thermal stability, keeping grain size in the nano-scale and remaining a high hardness after long time heat treatment. These results suggest the HVAF sprayed nano-structured NiCrC coating as a hopeful candidate for improving boiler tubes protection. It is clearly evident the nano structured composite coating have many advantages over the coarse grain structure so there is lot of space and scope for future.

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