ENHANCEMENT IN CORROSION RESISTANCE BY NANO-STRUCTURE Ni-Cr COATING FOR BOILERS APPLICATION

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ABSTRACT: *The consequences of corrosion are many and effect of these on the safe, reliable and efficient operation of equipment or structure are often more serious. To avoid corrosion the current investigation is made and corrosion behavior of Nano Ni-Cr coating on (Fe-Mn0.48∓0.05) was evaluated in tap water. A Nano structured Ni-Cr coating was prepared by Ball Milling Technique. The specimen with and without Nano Coating was exposed to Linear Polarization Resistance Test (LPR). The coating was found to reduce the corrosion rate of 15x* 10^{-3}*(mpy) of bare sample to 0.05439x*10^{-3} *(mpy) of Nano Ni-Cr coated sample. Corrosion Resistance shown by the investigated coating is due to* Cr_2O_3 *phase formed on coating thus the results are favorable for boiler applications.*

Keywords: Nano Technology, Ni-Cr Coating, Ball Milling, Linear Polarization Resistance Test

1. INTRODUCTION

Fire tube boilers have serious concern over degradation on high temperature due to hot corrosion, about 50% of total arrest time is due to boiler's downtime. So the power generation industry is more focused in research on corrosion resistance in boiler tubes and it must be addressed [1–4].

Development of high corrosion resistant coating from thermal spraying is more popular for boiler tube. To synthesize coatings for corrosion resistance of boiler tubes thermal spraying has attained more popularity, due to its flexibility and feasibility for on-site applications, in contrast with other options of surface improvement [5–10].

Deposition of feedstock powder has been done by various forms of thermal spraying which usually includes the fully/partially melting of feedstock powder [11]. The cold spray process is the most useful and effective. Phase transformation will not occur during the deposition process because coating powder does not oxidize in flight.

According to the literature Synthesis of Nano-Structured coatings are usually done by Mechanical milling of powders [12–16]. It is accepted that the nickel based alloys has various applicable properties, such as high thermal conductivity, high corrosion resistance and wear. Furthermore, nickel based alloy having high percentage of chromium is popular coating materials for corrosion resistance because they show high resistance to oxidation. NiCr is remarkable against corrosion, a character stick that makes it function in boiler industries is it apply to coat boiler tubes that confront collision of flue gas particles having a high velocity that corrode boiler tubes.

Nano-structure NiCr powder was successfully synthesized and coated on our samples of boiler tubes.

2. EXPERIMENTAL DETAILS

The substrate material in the current study was boiler tube steel; most commonly used boiler tube steels in Pakistan. The nominal chemical composition of this boiler tube steel and Ni-Cr coating using XRF has shown in Table 1.

Table: 1 Nominal composition of Boiler tube and Ni-Cr coating

XRF details of Ni-Cr coating and Boiler Tube				
	Fe	Cr	Ni	Mn
Boiler Tube	92.52±0.05	---	---	0.48±0.05
Ni-Cr Coating	72.42±0.05	18.67±0.24	7.88±0.26	1.03±0.12

The test specimens of dimensions 1x1 cm^2 were cut prepared from the boiler tubes. The specimens were ground and polished using emery papers of 80,160,220,400,600 grit sizes. Subsequently, the specimens were polished down to mirror finish on cloth wheel polishing machine using Alumina powder suspension.

The requirements of linear polarization resistance test (LPR) were that the samples are soldered to a copper wire of length 10 inches and molded into epoxy. The Ni-Cr Nano structured powder was synthesized with following composition.(Ni~ 7.88±0.26%, Cr~18.67±0.24 %) in a planetary ball milling machine, the parameters used in ball milling were ball to powder weight ratio 10:1, running time to pause time(min) ratio is 8:20 at 250 rpm.

To compare results with the Ni-Cr Nano coated sample, we have selected commercially available paint, commercially available primer and paint-primer coating as shown in figure 1, for each coating LPR was conducted in tap water.

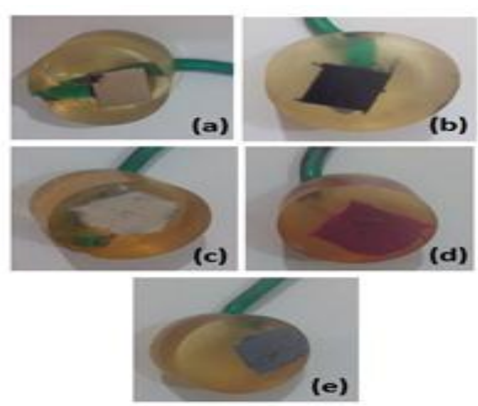

Fig. 1 Snapshot of (a)Bare sample (boiler tube), (b) Paint-primer sample, (c) Painted Sample, (d) Primer sample, (e) Ni-Cr coated

Linear polarization initial perimeters are shown in figure 2.

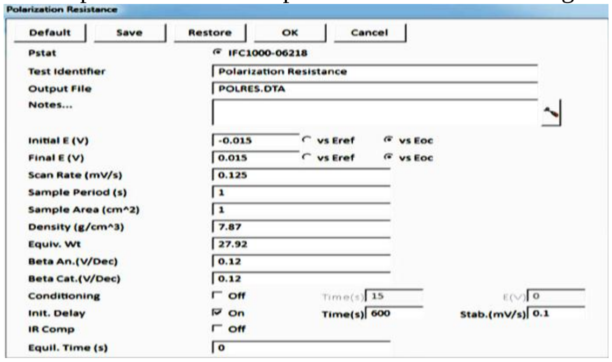

Fig. 2 Snapshot of parameters used in LPR test

3. RESULTS AND DISCUSSION

In order to evaluate the corrosion resistance of each of the samples, linear polarization resistance (LPR) tests are conventional tools. In an electrolytically conducting solution when a metal electrode is immersed, electrochemical mechanism of corrosion starts. Two simultaneous reactions are involve in this process.

Metal will pass from a solid surface into an adjacent solution at anode sites, and by doing so leave a surplus of electrons at the metal surface. The excess electron will flow to nearby sites, designated cathodic sites at which they will be consumed by oxidizing species from the corrosive solution. The corrosion current (I_{corr}), generated by the flow of electron from anodic to cathodic sites, could be used to compute the corrosion rate by the application of modified versions of Faraday's Law in eq (1):

$$C= \frac{Icorr \times E}{A \times D} \times 128.67 \qquad (1)$$

Where;

C= Corrosion Rate (mpy)

E= Equivalent weight of corroding metal (gm)

A= Area of corroding metal (cm^2)

D= Density of corroding metal (gm/cm^3)

Table: 2 Corrosion Rates(mpy) obtained by LPR test

Samples	Corrosion Rate(mpy)
Bare (Boiler Tube)	$15x10^{-3}$
Paint Primer coated	$9.605x10^{-3}$
Paint Coated	$3.659x10^{-3}$
Primer Coated	$1.591x10^{-3}$
Ni-Cr coated	$0.05439x10^{-3}$

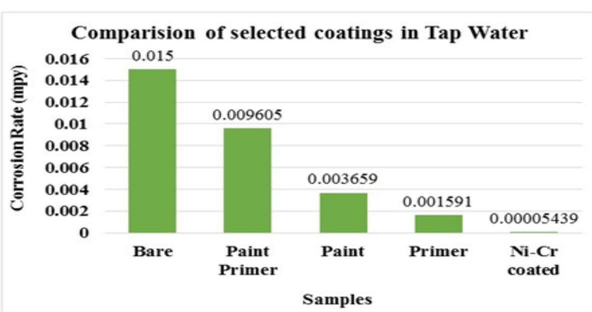

Fig. 3 Comparison between coated Samples

From the LPR test, the corrosion resistance evaluated are shown in table 2 and figure 3. The bare sample which is the boiler tube shows the highest corrosion rate of 0.015 mpy. As shown by the XRF data in table 1, this sample contains 99.52% of Fe it is likely that iron oxide phases like Fe_2O_3 and FeO are produced on the surface when the sample is exposed to tap water. The samples coated either by the paint or primer shows reduced corrosion rate of 0.003659 and 0.001591 mpy, respectively. The basic difference between primer and paint is of a resin and pigment respectively. Porous surface is sealed by the risen contained in the primer. Our study shows that paint-primer coating shows low corrosion resistance then primer coating. It might be due to the formation of porous coating on the surface of steel. However, the primer coating was non-porous and adherent. The highest corrosion resistance was observed in the case when the sample was coated by nanostructured Ni-Cr. The corrosion rate as measured by the LPR test for Ni-Cr coated sample was 0.00005439 mpy which is almost 100% improvement in corrosion resistance as compared to the bare sample. This notable resistance in corrosion in Ni-Cr sample is believed to be the impact of Cr which is almost 18.67 ± 0.24% present in the sample as shown by the XRF data (table 1) whereas the bare samples are free from Cr; thus immune to corrosion.

The Chromium (Cr) forms Cr_2O_3 protective scales at higher temperatures when exposed to the actual boiler applications. The Cr_2O_3 has a very high melting temperature (2435°C), therefore, it is thermodynamically stable at elevated temperatures for boiler applications. Therefore, in our samples Cr_2O_3 forms a dense, continuous and adherent layer hindering the oxygen-substrate interaction reducing the corrosion effect. Another aspect of improved corrosion resistance in Ni-Cr sample is the nanocrystalline form of Nichrome powder used in the coating preparations. Y. Wang et al have shown that the nanostructured Al2O3/TiO2 coatings provide improved corrosion resistance as compared to the bulk Al2O3/TiO2 coatings. It is reported that the coating formed by the bulk powder are immune to grain dislodgment due to grain boundary cracking [17]. T. Ishizaki and Y. Masuda relates the improvement in corrosion resistance of nanostructured Cerium Oxide coated on Magnesium alloys with the superhydrophobicity achieved by the nano surface textured [18]. Their potentiodynamic polarization resistance tests reveal that the corrosion resistance increases as the surface hydrophobicity is increased. Similar results have been discussed by A.D. Pogrebnjak et al where they have formed nanodimensioned grains (2.8 - 4 nm) formation in Ti-N-Cr/Ni-Cr-B-Si-Fe alloy. The nanograins have resulted in high corrosion resistance and the hardness of the samples has also been increased [19].

Therefore, the overall understanding of nanostructured materials in Coating science is that the nano-sized powder agglomerate with each other cohesively forming nanosized grain boundaries. These nanosized grain boundaries improve the surface hardness and the surface hydrophobicity. Thus, the hard and hydrophobic surface of the coatings block the anodic and cathodic reactions between the substrate and the oxygen or corrosive media diminishing the corrosion effect during high temperature boiler applications. Therefore, this approach of nanostructuring the Ni-Cr alloys can provide a long lifetime of the boiler tubes making them highly corrosion resistive surfaces.

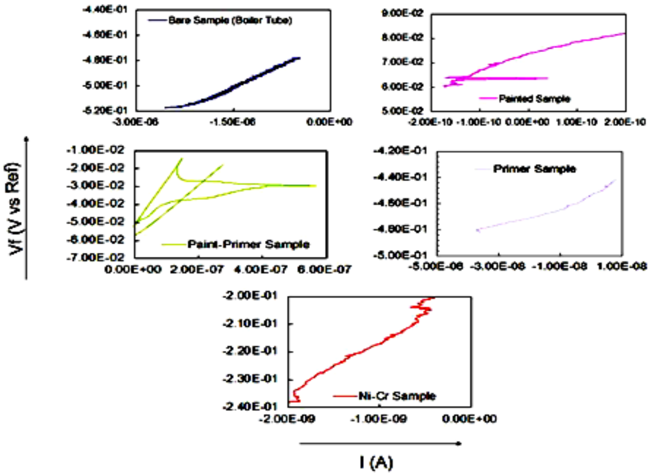

Fig. 4 Current Vs Voltage graph of Samples

4. CONCLUSION

Ni-Cr Nano-structured powder was successfully formulated and deposited on our samples of boiler tubes.

- Coatings were found to be uniform Nano-structured.
- In all the four coatings (i.e. Paint, Paint-Primer, Primer, Ni-Cr) Ni-Cr coating was found to have high corrosion resistance in comparison with their conventional counter-coatings.

5. REFERENCES

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