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INVESTIGATION ON CORROSION BEHAVIOUR OF FUNCTIONALLY GRADED CHROMIUM COATED MILD STEEL IN BOILER TUBES

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Abstract -

Mild steel is one of the commonly used materials in all industries. But its limited corrosion resistance property makes its applications lesser .To expand its applications, its mechanical properties needs to be enhanced. One of the important ways to protect from corrosion problems is to coat with noble metals like chromium and its alloys. In this study, chromium was successfully coated on the mild steel substrate using DC magnetron sputtering technique. Experiments were carried out by varying DC power supply and all other parameters were kept constant. The corrosion properties of the chromium coated mild steel specimens were studied by conducting neutral salt spray test as per ASTM B117-19 standard. compared the results with substrate material.

Key Words: *Mild steel, Chromium, DC magnetron sputtering, Corrosion properties.*

1.INTRODUCTION

Boiler tube materials require good heat transfer rate, mechanical strength and corrosion resistance to resist against the working fluids. Mild steel is a type of carbon steel which is one of the most commonly used material in manufacturing of boiler tube due its high thermal conductivity, affordability, strength and versatility. However, the major problem of mild steel is their lack of corrosion resistance. By improving the surface conditions the corrosion resistance, hardness of a material can be enhanced. Thus, to enhance the properties of the mild steel it needs to be covered with a protective layer or surface coating.

Surface coating technique is generally used in most of the protective applications. Surface coating acts as a protective barrier for the material in its working environment. Physical vapour deposition is an important technique to improve the mechanical properties and corrosion resistance of a material. Various methods such as Sputtering, elctro deposition, Electro plating, pulsed ,laser deposition are most commonly used to produce thin films. Among these techniques, magnetron sputtering provides high adhesion, high absorption and more homogenous films. In this paper, corrosion behaviour of chromium sputtered mild steel with varied DC power supply are reported. Proper selection of parameters such as DC power supply, temperature, sputtering gas flow rate is important to achieve desired corrosion property.

2. MATERIALS AND METHODS:

In this study, mild steel, a most common material for Boiler tube has been selected as the base metal. The base metal was processed into a square shape having a 50mm*50mm*5mm size. To investigate Corrosion properties, a totalof 2 samples were prepared according to DC sputtering power. Chemical composition of mild steel is shown in the table 1.

Element	Amount wt %
Fe	98.81 – 99.26
Mn	0.30 – 0.65
Si	0.10 – 0.35
C	0.25 – 0.29
P	0.16
Ni	0.0071
Co	0.0013
Cu	0.0029
Sn	0.005

Table-1 Chemical Composition of Mild Steel

MATERIAL PROPERTIES OF CHROMIUM

Chromium is highly esteemed for its exceptional resistance to corrosion and its remarkable hardness. A significant breakthrough in the remarkable of steel manufacturing occurred when it was found that the addition of metallic chromium could render steel highly impervious to both corrosion and discoloration, resulting in the creation of stainless steel.

SURFACE PRE-TREATMENT OF MILD STEEL

Before initiating the sputtering process, Pre-treatment of mild steel is necessary to remove rust formation because would cause uneven thin film deposition. To remove the contaminants and toprovide rough surface for better coating between the surface and substrate, mild steel samples were mechanically polished with sand papers of 120 to 600 grid papers, cleanedwith acetone and dried using hair dryer.

DC SPUTTERING METHOD

The equipment used for sputtering of chromium is a DC magnetron sputtering machine. Before initiating the deposition process, the mild steel samples were kept in the vacuum chamber. Samples were pre-sputtered for about 10 to 15 minutes to remove contaminants in the vacuum chamber. For pre-sputtering process oxygen, a inert gas is used. Chromium target were fixed in the target holders. Then suitable process parameters have been applied as per requirement. In the DC sputtering process toobtain optimal conditions, sputtering power has been varied for sample 2 and 3 and all the other parameters have been kept constant. Process parameters for sputtering is shown inthe table 2. Fig 1 describes about the experimental setup ofDC sputtering.

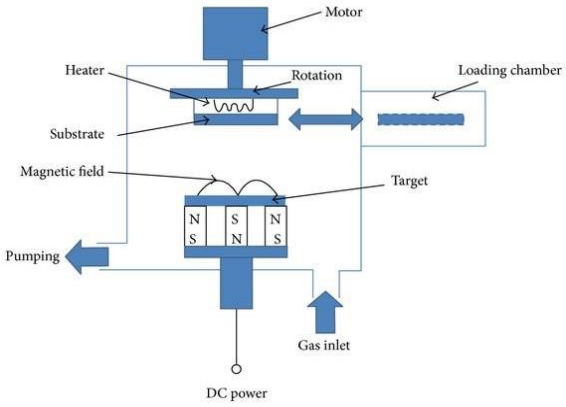

Fig -1 describes the experimental setup of DC sputtering

PARAMETERS	
Deposition power	400W,600W
Deposition time	60min
Oxygen gas flow	10ml/min
Distance between target and substrate	10cm
Substrate temperature	35^0C
Substrate rotationspeed	5 rpm

Table-2 Process Parameters for DC Sputtering

FILM CHARACTERIZATION

Corrosion Analysis

The corrosion analysis of the mild steel and chromium sputtered samples were analyzed using neutral salt spray test. Samples were kept in salt spray test chamber for about 48 hours with the proper parameters. Table 3 describes about the salt spray corrosion test chamber parameters.

Sl.No	Test conditions	Requirements	Actual
1	Chamber temperature	35°C	34.2° to 35.9°C
2	pH of solution	6.5 to 7.2	6.9
3	Air pressure	12 to 18 psi	15psi
4	Concentration of sodium chloride	5%	5.0-5.2%
5	Collection of solution per hour	1 to 2ml	1.1 ml
6	Test hours	96hrs	48hrs

Table -3: Corrosion chamber parameters

3.Results and Discussion

Salt spray test is standardized method for testing corrosionresistance property of a material. Mild steel and chromium sputtered samples have kept in salt spray chamber for 48 hours. All the three samples showed red rust in about 24 hours. Fig 2 shows the photographs of samples after salt spray test.

(a)

(b)

(c)

Fig 2: Photographs of material after salt spray testing (a)Sample-1(Mild steel) (b) Sample-2 (c) Sample-3

From the Fig 2(a) shows that the sample has more pits and damaged layer on the surface. For the sample 3, there is nodamaged layer and less pits were observed. But for the sample 2, the coated layer was peeled and more pits were seen when compared to sample 2. From the results, it is observed that sample 3 shows more corrosion resistance than sample 2 and sample-1(mild steel) substrate.

CONCLUSION:

In this study, chromium was sputtered successfully with variations in deposition power to investigate the corrosionbehavior of mild steel substrate. As a result of Salt spray corrosion test, both substrates and samples were kept in salt spray chamber for 48 hours with same parameters. All the three-sample showed red rust in 24 hours. The coated layer was peeled more in sample 2 than thesample 3.

Sample 3 which was coated at the sputtering power of 600W showed more corrosion resistance as per the results of salt spray test. For the sample 2, which was coated at the sputtering power of 400W showed less corrosion resistance .So, the optimized deposition power was 600W for the Sample 3 better than two samples.

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