Study of Coating on Ceramic Metal Substrate

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Abstract: Corrosion is one of the most difficult problems to overcome for any engineer and when special dealing with moist surface and moist environment. Project was to create a plate for air pre heater and boiler, both having moist environment, which would stand high impact force, high heat absorption and would not corrode. Multiple ceramic coating on multiple plates preceding with proper cleaning of low carbon mild steel plate and succeeding with multiple tests to see if it fits perfectly to use in pre heaters

Keywords: Ceramic metal substrate, Principle Stress, Enamel, Vitreous Coating & Corrosion.

I. INTRODUCTION

Corrosion in metals may be defined as the deterioration of a metal by chemical or electrochemical interaction with its environment. It can also be defined generally as the deterioration of a material or its properties because of reaction with its environment. For metallic materials, corrosion is normally electrochemical, that is a chemical reaction in which there is transfer of electrons from one chemical species to another. In an aqueous environment, some metals characteristically give up electrons and dissolve in a reaction called dissolution or corrosion. Corrosion in aqueous environment accounts for the greatest amount of corrosion. Corrosive aqueous media include the atmosphere, fresh water and the soil. Others are alkalis, acids and salt solutions.

Among all durability problems, the Corrosion of steel is a major problem. Although several corrosion preventive methods are available, coating to steel is an effective tool to prevent corrosion. To overcome the problem of corrosion, materials with good mechanical resistance together with corrosion protection is required. Performance of coatings under combined wear and corrosion conditions. The coatings perform under these tribo-corrosion conditions is essential, Enamel presents optimum corrosion protection and high hardness values but the low fracture toughness reduces its resistance to abrasive wear related to brittle fracture. At the same time this kind of layer shows very good functional and aesthetical properties. It can not only be finished with a smooth and aesthetical surface, but also provide good chemical stability and corrosion resistance, as well as excellent resistance to abrasion and thermal shocks in extreme erosion environment. The microstructure of enamel, the chemical composition of the frit, and the deposition parameters are crucial for the final properties. A disadvantage of enamel is a tendency to crack or shatter when the substrate is stressed or bent, but modern enamels are relatively chip- and impact-resistant because of good thickness control and coefficients of thermal expansion well-matched to the metal. “The coefficients of thermal expansion of enamel should be well-matched to the metal used for the coating”.

The corrosion of metals and alloys can be reduced or prevented in various ways. These include the formation of a protective oxide or insoluble film on the surface of the metal, sacrificial anodic protection with a less noble metal connected to the metal in a galvanic circuit and the use of organic, inorganic and metallic coatings. All the various options have their advantages and disadvantages. Inorganic or oxide coatings provide additional advantage of chemical inertness, high temperature stability and superior mechanical properties as compared to other coatings. The choice of option depends on the particular situation. Apart from economic and other technical considerations, three very important factors for good protection in terms of coatings include good adhesion, similar thermal coefficient of expansion of the coatings and the metal and low conductivity and diffusion coefficient across the coating.

Enamel refers to a glassy, vitreous and usually opaque substance that is used in protective or decorative coating on metal, glass or ceramic ware. Enamel could be used in varnishes, paints and coatings. Enamel is made of melted glass; it is made by fusing powdered glass to a base by firing, usually between 750 ℃ and 850°C. After drying, it produces a hard and glossy finish—an enamel-like surface that has a bright luster. Enamel protects materials from corrosion. Coatings made from enamel have a great potential to protect steel from corrosion. Enamel paint should not be confused with "painted enamel" that is used for decorative purposes. In painted enamel, vitreous enamel is applied with brushes and fired in a kiln, mainly on porcelain objects. After drying, it produces a hard and glossy finish—an enamel-like surface that has a bright luster. Enamel protects materials from corrosion. Coatings made from enamel have a great potential to protect steel from corrosion. Colour in enamel is obtained by the addition of various minerals, often metal oxides cobalt, iron, or neodymium. The latter creates delicate shades ranging from pure violet through wine-red and warm grey. Enamel can be transparent, opaque or opalescent (translucent). Different enamel colours can be mixed to make a new colour, in the manner of paint.

The degradation of metal plates used for the heat recovery in the air pre-heaters under combined wear and corrosion is studied, almost all industries in the world uses heat recovery systems like Air pre heaters to economise the process by the utilization of waste heat from the outgoing flue gases, In thermal power plants the air pre heaters are installed after steam producing boilers, in

present date the metal plates used for the heat recovery are suffering from the corrosion, even the metal used is made up of stainless steel it is becoming difficult to prevent the degradation of metal plates due to corrosion. By knowing all these present problems a positive effort is made to solve them through this project.

II. APPLICATION

The conventional firefighting techniques have many drawbacks, such as toxic to humans and leaves residue (for dry chemical-based fire extinguisher). For water-based fire extinguishing techniques also have drawbacks, as they freeze in cold climate and conducts electricity, using sound waves with certain frequency as a fire extinguisher will have advantages as they are not leaving any residue and toxic material behind as by products.

2.1 **Air Pre-Heater:**

It is a device designed to absorb heat from waste flue gases of combustion process and it is Re-used for pre heating heating the cold air which is used for combustion process, to make the process economical.

2.2 Economizer:

The function of the economizer is to extract some heat which is carried away by the flue gases up in the chimney or stack and utilize it for pre-heating the feed water supplied to the boiler. It is placed in the path of the flue gases in between the exit from the boiler and entry into air pre heater/chimney.

2.3 Steam super heater:

In super heaters, the wet or saturated dry steam is superheated by increasing steam temperature above its saturation temperature. The super heater is installed in the path of flue gases after the furnace .

2.4 Uses of Air Pre-heaters:

1. Air heater is an important Boiler auxiliary which primarily preheats the combustion air and utilized for efficient combustion in the furnace.

2. The air heater recovers the waste heat from the outgoing flue gas of a Boiler and transfers the same to the combustion air.

3. Drop in flue gas temperature improves the Boiler efficiency by about2.5%,

4. Having an air heater in the downstream of economizer the Boiler efficiency is considerably improved.

Further the air heater may also be used for heating the air to dry the coal in the pulverizing plant

III. METHODOLOGY

The project aims for reducing the corrosion by applying ceramic coating on metal substrate, this is achieved by creating compositions of three different grades of ceramics i.e301,290,206. 4 different composition of the above mentioned grades is created with the help of ball milling. alumina balls are used to remove the impurities, act as a catalyst for drying and assist in ball milling.

The composition includes 40% of grade 301, 20% of grade 290, 20% of grade 206 and 20% water. This composition with alumina balls are left for ball milling for around 4 to 5hrs before coating them on the metal substrate.

Once the mixture is prepared, the mixture is taken to filtration process where the mixture is filtered properly and poured into the spraying gun. Mixture is then fed into the spraying gun and the spraying process gets started, spraying has to done carefully. This is carried out with another process called heat treatment i.e the metal substrate is placed inside a furnace for 10 to 15min and fired at a temperature 850 ℃

IV. TESTING

In order to widen the range of the service temperature of the enamel-ling equipment, it is necessary to study the thermal shock resistance of the enamel coatings. For this purpose, one must use a sensitive method of defect detection that would make it possible to obtain quantitative information regarding the degree of destruction of the coating. It is highly effective for revealing minute (fine) defects in the coating. In view of this, there is a basis for expecting that this method would make it possible to study the process of destruction of enamel coatings due to the thermal effects.

There were different corrugated plates enamel coated at 5 different temperature .All the five plates were given thermal shock one by one.

Process:

All the coated plates are first fired in low temperature furnace at 5 different temperature i.e 800℃,850℃,830℃,820℃,840℃.All the coated plates are left for cooling and get the well polished coat. Initially the plates are kept in the furnace at 200 ℃ after preheating the furnace for 30 minutes. Meanwhile water is kept in a container at normal room temperature.

Once heating the plate is done at 200 ℃ the plates are then taken out of LTF and submerged into water which is at room temperature immediately for a minute and observation is made for any kind of breaking or chipping. If there is no chipping 20 ℃ temperature is raised and again same test is carried out until we find chipping or breaking. On finding chipping or breaking at a certain temperature, take the Thermal Shock Temperature a value above that.

Ex :On getting chipping at 300 ℃ then we take TST at 280 ℃

1. Thermal Shock Resistance is the subtraction of water temperature from TST.

Ex. TST= 280 ℃

Water temp = 30 ℃

TSR= 280-30= 250 ℃

The test results are compiled below.

Material : Low carbon mild steel

TABLE 4.1{CLASS : AA (FIRED AT 840 ℃)}

CYCLE	NAME OF MATERIAL	HEATING TEMP. ℃	COOLING TEMP. ℃	REMARK	RESULT
1.	CORRUGATED METAL PLATE	200	30	NO CHIPPING	
2.		220	30	NO CHIPPING	
3.		240	30	NO CHIPPING	
4.		260	30	NO CHIPPING	
5.		280	30	NO CHIPPING	
6.		300	30	NO CHIPPING	
7.		320	30	NO CHIPPING	
8.		340	30	NO CHIPPING	THERMAL SHOCK TEMP.
9.		360	30	CHIPPING OBSERVED	

TSR = 340-30 =310 ℃

TABLE 4.2{CLASS:AAA (FIRED AT 830 ℃)}

CYCLE	NAME OF MATERIAL	HEATING TEMP ℃	COOLING TEMP. ℃	REMARK	RESULT
1.	CORRUGATED METAL PLATE	200	30	NO CHIPPING	
2.		220	30	NO CHIPPING	
4.		260	30	NO CHIPPING	
5.		280	30	NO CHIPPING	
6.		300	30	NO CHIPPING	
7.		320	30	NO CHIPPING	TST
8.		340	30	CHIPPING OBSERVED	

TSR = 320-30=290℃

TABLE 4.3{CLASS:B (FIRED AT 820℃)}

CYCLE	NAME OF MATERIAL	HEATING TEMP. ℃	COOLING TEMP. ℃	REMARK	RESULT
1.	CORRUGATED METAL PLATE	200	30	NO CHIPPING	
2.		220	30	NO CHIPPING	
3.		240	30	NO CHIPPING	
4.		260	30	NO CHIPPING	TST
5.		280	30	CHIPPING	

				OBSERVED	

TSR= 280-30 =250 ℃

TABLE 4.4{CLASS: C (FIRED AT 800 ℃)}

CYCLE	NAME OF MATERIAL	HEATING TEMP. ℃	COOLING TEMP. ℃	REMARK	RESULT
1.	CORRUGATED METAL PLATE	220	32	NO CHIPPING	
2.		240	32	NO CHIPPING	TST
3.		260	32	CHIPPING OBSERVED	

TSR= 240-32 =208 ℃

TABLE 4.5{CLASS: A (FIRED AT 850 ℃)}

CYCLE	NAME OF MATERIAL	HEATING TEMP. ℃	COOLING TEMP. ℃	REMARK	RESULT
1.	CORRUGATED METAL PLATE	300	30	NO CHIPPING	
2.		320	30	NO CHIPPING	
3.		340	30	NO CHIPPING	
4.		360	30	NO CHIPPING	TST
5.		380	30	CHIPPING OBSERVED	

TSR= 360-32= 328 ℃

4.2 IMPACT RESISTANCE TEST:

As the name suggests we put the plates under a sudden impact force.

The enamel coated corrugated plates are placed under a 19.62 N force i.e 2kg metal ball.5 different sample plates are tested one by one by the following process to determine if the coating comes off the plate or not.

Enamel coated corrugated plate is placed on the podium.. 2kg ball is suspended above the plate at 750mm height. First the plate of 800℃ is kept on the podium and 19.62N forced is applied. If there is no breakage or chipping in the plate then that plate is selected.

The test result for the IRT is mentioned below.

TABLE 4.6

Name of the material	Class	Force applied	Remarks
CORRUGATED METAL PLATE	A	19.62N	No chipping observed
CORRUGATED METAL PLATE	AA	19.62N	Minute chipping observed
CORRUGATED METAL PLATE	AAA	19.62N	Chipping observed
CORRUGATED METAL PLATE	B	19.62N	Huge amount of chipping observed
CORRUGATED METAL PLATE	C	19.62N	Huge amount of chipping observed.

4.3 SPECIFIC GRAVITY TEST:

This test is conducted to get a composition best for coating on the corrugated low carbon mild steel plate. In this process different composition are prepared and 20 ml of the created composition is taken in a conical beaker. Initially the weight of the beaker without mixture is taken and weight of the beaker with the mixture is taken.

Following formula is used to find out the specific gravity

(Density of the ceramic)/ (Density of water)_____eqn (1)

Weight of the ceramic = Weight of the beaker with composition - weight of the beaker without composition .

*Empty wt: 84.752g

*final wt: 117.890g
*volume:20ml
eqn(1)=117.890-84.752

20

=33.129/ 20

=1.61

The specific gravity ranges from 1.0 to 1.6

4.4 CFD ANALYSIS:

Computational fluid dynamics (CFD) is the use of applied mathematics, physics and computational software to visualize how a gas or liquid flows -- as well as how the gas or liquid affects objects as it flows past. Computational fluid dynamics is based on the Navier-Stokes equations.This test was done in order to get various thermal and physical properties of the plate after coating is done.

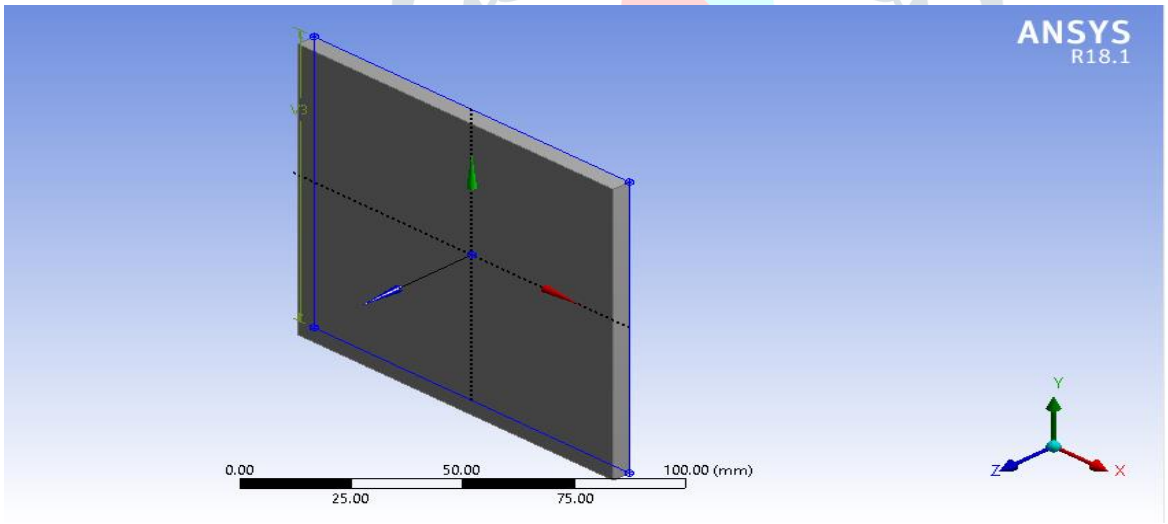

Fig 4.1: CAD model of the given low carbon mild steel corrugated plate.

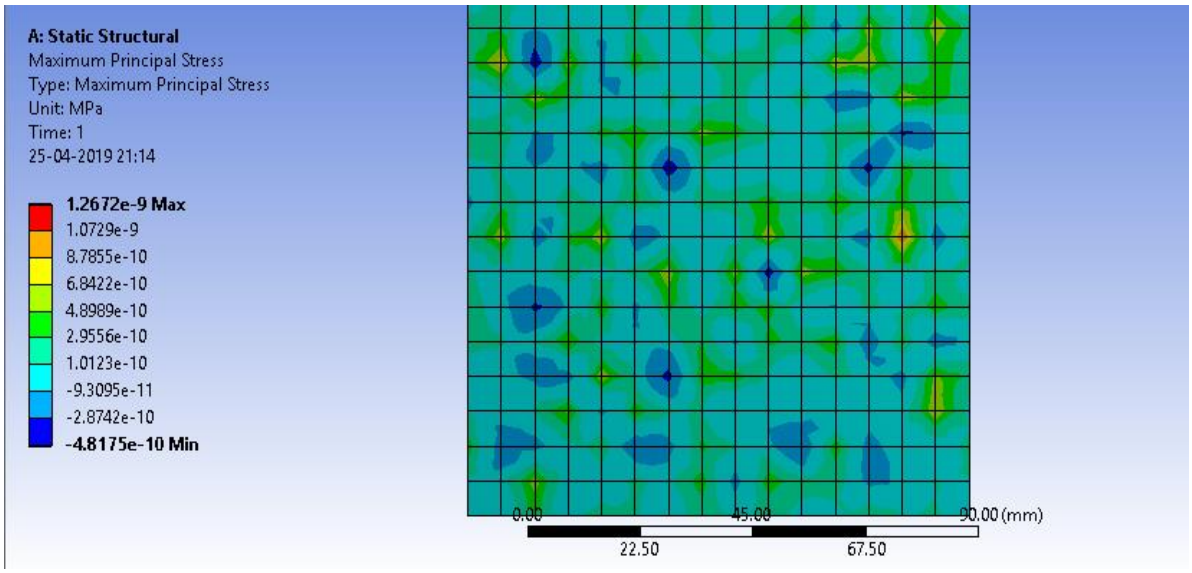

Fig 4.2: Static Structural Analysis. For Maximum Principal Stress.

Minimum principal stress is -4.8175e-10 and Maximum Principal stress is 1.2672e-9. The different colour patches shown in the analysis are different values at plate at 850℃

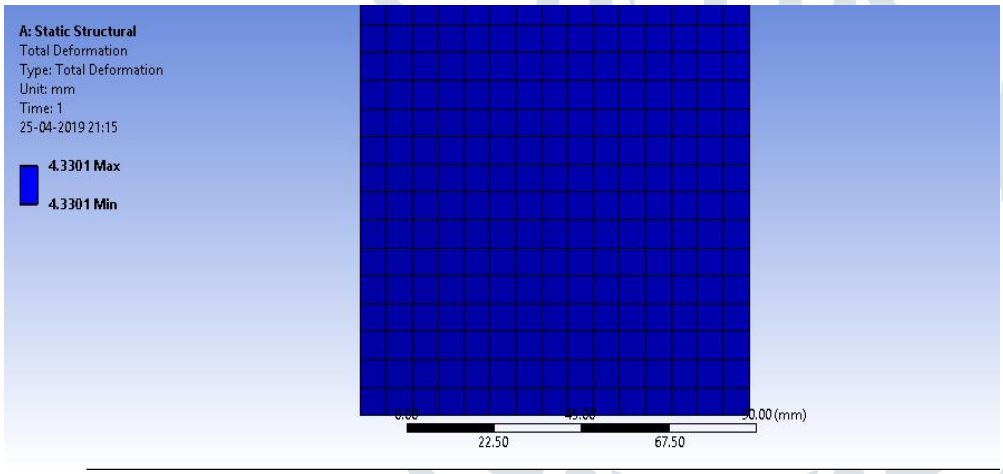

Fig 4.3: Static Structural Analysis or Total Deformation

Static Structural analysis of Total deformation at 850℃ is 4.3301 mm

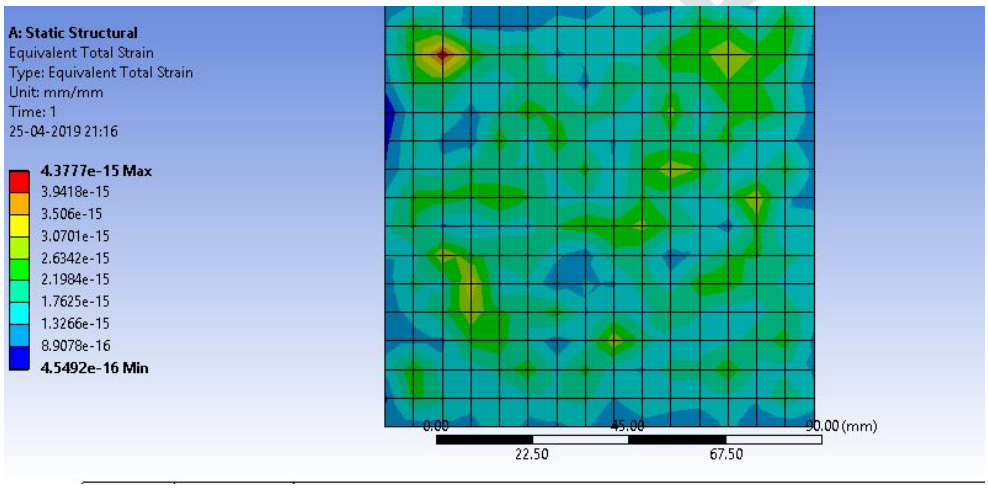

Fig 4.4: Static Structural Analysis for Equivalent total Strain.

Equivalent total strain gives a total value of strain in any engineering body, the total strain components are calculated by addition of components of elastic, plastic, thermal and creep strain.

The above fig represent the Equivalent strain acting on the plate when the plate is subjected to a temperature of 800℃, as mentioned the maximum strain is 4.3777e-15Mpa, Static Structural analysis of Total deformation at 850 ℃ is 4.3301 mm.

V. CONCLUSION

From experimental analysis the maximum stress the coated plate can withstand 360 ℃ when coated at 850℃.The impact resistance test proves that when coating fired at 850 ℃ the impact gives a minute or no chipping.After mixing different compositions the perfect composition that gives 1.6 specific gravity is mixed and created. A low carbon corrugated metal plate can be used in boiler or air pre heater if it is ceramic coated in order to prevent corrosion and increase the life expectancy of the plate.

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