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Design, Development of Plasma Coating Machine for Textile Roller Drum

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Abstract

In industries corrosion problem is increased in day by day. Now days the corrosion protect in substrate us very important and it is possible to avoided corrosion in metal by using different technics and methods like thermal spray, powder spray, detonation spray, plasma spray, etc. corrosion is natural process that converts a refined metal to a more chemically stable from such as a it is oxide, hydro-oxide or sulfide. it is the gradual destruction of materials by chemical and electrochemical applying coating in substrate using thermal spray processes is an established in industry method. A metal plate with having high strength is much needed for the industrial purpose. The life durability to withstand for the longer time so that it would be economical for the industries and needs less maintenance required. This paper explains in to avoid corrosion by using coating method. The coting material is aluminum. Many industrial coating processes involve the application of a thin film of functional material to a substrate, such as paper, fabric, film, foil, or sheet stock.

Keyword: coating, thermal spray, coating material, design, testing.

INTRODUCTION

Coating is the extra layer applied on a surface for a primary reason. It is also a process to apply a layer to the surface. Functional coatings may be applied to change the surface properties of the substrate, such as adhesion, wettability, corrosion resistance, or wear resistance. In other cases, e.g. semiconductor device fabrication (where the substrate is a wafer), the coating adds a completely new property, such as a magnetic response or electrical conductivity, and forms an essential part of the finished product.

A major consideration for most coating processes is that the coating is to be applied at a controlled thickness, and a number of different processes are in use to achieve this control, ranging from a simple brush for painting a wall, to some very expensive machinery applying coatings in the electronics industry. A further consideration for 'non-all-over' coatings is that control is needed as to where the coating is to be applied. A number of these non-all-over coating processes are printing processes.

Numerous methods exist for evaluating coatings, including both destructive and non-destructive methods. The most common destructive method is microscopy of a mounted cross-section of the coating and substrate. The most common non-destructive techniques include ultrasonic thickness measurement, XRF coatings thickness measurement, and ultra-micro hardness testing.

THERMAL SPRAY:

The most basic principle of the thermal spray coating is that the thermal energy that is generated is used for the heating and melting of the metal powder in the combustion chamber through feedstock. After that the spray gun is used for the flow or spray of the molten metal particle with very high speed. The molten metal gets kinetic energy from the combustion of the gases such as acetylene and oxygen or LPG gas to accelerate the powder particles. Thermal spray coating has different types of layers such as lamellar structure. Lamellar structure is a layer like a sandwich structure. The porosity is very low in the thermal spray coating process as compared to other deposition process.

Thermal spraying encompasses a family of processes including Wire Flame, Powder Flame, Electric Arc, High Velocity Oxy-fuel (HVOF), Air Plasma Spraying (APS), Low Pressure Plasma Spraying (LPS) and so on. Plasma spraying is the most flexible or versatile of all the thermal spray process. The high temperatures of the process permit the coatings deposition for applying any ceramic coating such as chromium, zirconia and alumina. In general, this paper will present the development of ceramic coating for wear and corrosion resistant for industrial application.

It is important to understand the relationship between the properties of the coating and its performance and how it can be controlled during the coating process. Then, to validate the relationship of the parameters specimen was prepared to examine the final quality of the actual processes. Alumina (Al_2O_3) was used as main coating material

Alumina

It is very good conductor of heat and electricity.

It is highly resistance to corrosion.

It is light weight material.

Very low melting point it's about 669.7 ^{0}C.

Aluminum is nonmagnetic material.

It is nontoxic material.

Alumina strength is very high.

It is high ductile material.

The aim of this study is to develop ceramic coating to the metal substrate applied for industrial such as stand for wear, chemical resistant and restoration for worn out surface. In order to get this objective, alumina material was used as a feedstock. Observing the cross section and surface of the coating such as entrapped gasses, voids, adherent and un-melted particles will present the coating properties; because they create points of stress concentration during coating process. The major limitation of the plasma spraying process are machine parameters and metal substrate preparation to obtain the desired coating and well coating properties with high bonding.

LEAD SCREW DESIGN

As per ASME code

The permissible shear stress τ_{max} without keyways is taken as 30% of yield strength in tension or 18% of the ultimate tensile strength of the material whichever is minimum.

Therefore,

$$\tau_{max} = 0.18 \times S_{ut}$$

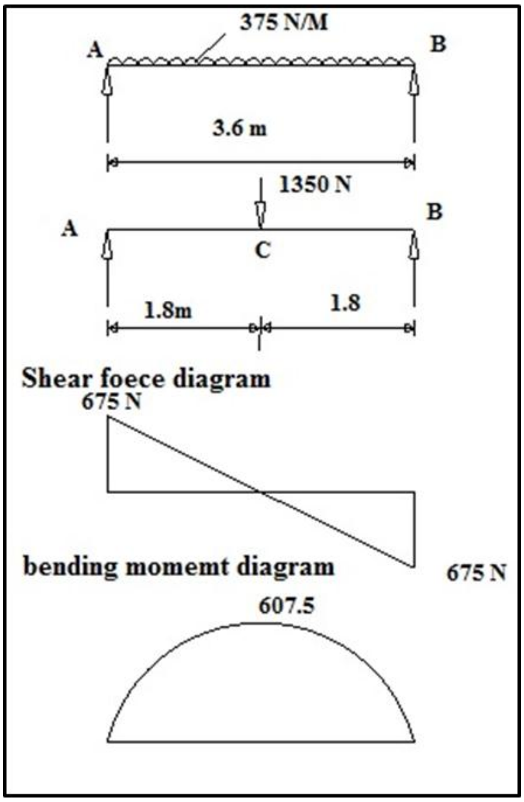
$$\tau_{max} = 0.30 \times S_{yt}$$

$$\tau_{max} = 0.18 \times 630 = 113.4\ N/mm^2$$

$$\tau_{max} = 0.30 \times 350 = 105\ N/mm^2$$

As the keyways are present, the above values are to be reduced by 25%.

$$\tau_{max} = 0.75 \times 105 = 78.75\ N/mm^2$$



Calculations for support reactions

$R_A + R_B = 375 X 3.6$

$$R_A + R_B = 1350\ N \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Taking moment @ point A

Ma = 0

$$R_B \times 3.6 = 375 \times 3.6 \times 1.8$$

$$R_B = 375 \times 1.8$$

$$R_B = 675\ N$$

From equation 1,

$$R_A = 675\ N$$

Shear force calculation,

S_{AL}=0

S_{AR}=675 N

S_{BL} = 675 – (375 X 3.6) = - 675 N

S_{BR} = 0

Bending moment calculations

For point for maximum bending moment,

$$\frac{675}{x} = \frac{675}{3.6 - x}$$

$$675 \times 3.6 = (675 + 675)x$$

$$2430 = (1350)x$$

$$x = \frac{2430}{1350}$$

$$x = 1.8\ m$$

$M_A = M_B$ =0

Raking moment @ point C,

$$M_C = R_B \times 1.8 - 375 \times 1.8 \times \frac{1.8}{2}$$

$$M_C = 675 \times 1.8 - 375 \times 1.8 \times \frac{1.8}{2}$$

$$M_C = 607.5\ NM$$

Now,

$$M_{max} = M_C = 607.5\ NM$$

$$M_{max} = M_C = 0.6075 \times 10^6\ Nmm^2$$

Design of shaft based on torsional rigidity: -

$$T_e = \frac{\pi}{16} \times d^3 \times \tau_{all}$$

$$\tau_{max} = \tau_{all} = 78.75\ Nmm^2$$

$$18750 = \frac{\pi}{16} \times d^3 \times 78.75$$

d = 10.66 mm

Design of shaft based on bending

$$M_e = \frac{\pi}{32} \times d^3 \times \sigma_b$$

$$\sigma_b = \text{ bending stress} = \frac{S_{ut}}{3}$$

Factor of safety = 3

$$\sigma_b = \frac{630}{3} = 210 \text{ N/mm}^2$$

$$607.5 \times 10^3 = \frac{\pi}{32} \times d^3 \times 210$$

d = 30.88 mm

Against both combining torsional and bending moment :-

The equivalent torsional moment is given as

$T_e = \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$

From design book service factor

$K_b = K_t = 1$

Where, K_b= Combined shock and fatigue factor applied to bending moment

K_t= Combined shock and fatigue factor applied to torsional moment

$T_e = \sqrt{(1 \times 607.5^2 + (18.750)^2}$

T_e = 607.789283 N-m

T_e = 0.607789283 X 10^6 N-mm^2

Equivalent bending moment

$$M_e = \frac{1}{2}(K_b M_b + \sqrt{(K_b M_b)^2 + (K_t M_t)^2})$$

$$M_e = \frac{1}{2} \times 607.5 + \sqrt{(1 \times 607.5)^2 + (18.750)^2}$$

$$M_e = 607.644615 \text{ Nm}$$

$$M_e = 0.607644615 \times 10^6 \text{ Nmm}^2$$

But,

$$\tau_{max} = \frac{16}{\pi d^3} \times \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

$$d^3 = \frac{16}{\pi \tau_{max}} \times \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

$$d^3 = \frac{16 \times T_e \times 10^6}{\pi \times 78.75}$$

$$d^3 = \frac{16 \times 0.607789283 \times 10^6}{\pi \times 78.75}$$

$$d^3 = 39307.24317$$

d = 34.00 mm

d = 40 or 44 mm (from design data book.)

we have selected the diameter of shaft = 44 mm at middle. Hence nominal diameter of screw is selected 44 mm.

we know,

$$T_e = \frac{\pi}{16} d^3 \tau$$

$\tau = 44.70$ N/mm^2

$$M_e = \frac{\pi}{16} d^3 \sigma$$

$$\sigma = 89.38 \text{ N/mm}^2$$

$$\tau = 44.70 \text{ N/mm}^2 < 78.75 \text{ N/mm}^2$$

$$\sigma = 89.38 \text{ N/mm}^2 < 210 \text{N/mm}^2$$

By using above equation we have checked the allowable shear stress and allowable bending stress and it is seen that the both values are within limit hence design is safe.

There are two types of threads for lead screw square threads and trapezoidal threads. For our application we will select trapezoidal threads. Nominal diameter is the largest diameter of the screw. It is also called as major diameter. Here, leads screw is manufactured from the shaft so that nominal diameter of the lead screw is 44mm.

As per discussion with technical team of manufacturers and referring the machine design book the nominal diameter considered 44mm

$$\text{NominalDiameter} = d = 44\text{mm}$$

Pitch of the lead screw is calculated from the nominal diameter from table. [Machine design Data Book by V. b. Bhandari, Mc Grew Hill Education (India) Private Limited, pp. 5.68]. For diameter of the 40mm or 44 mm pitch is taken as 7mm and lead of screw is same as pitch.

$$\text{Pitch} = p = l = 7\text{mm}$$

Core diameter of the screw is given by

$$d_c = d - p = 44 - 7 = 37 \, mm$$

Mean diameter of the screw is given by

$$d_m = (d - 0.5p) = (44 - 0.5 \times 7) = 40.5\text{mm}$$

Compressive stress

$$= \frac{W}{\frac{\pi}{4} \times {d_c}^2}$$

$$= 0.34877 \text{ N/mm}^2$$

For trapezoidal screw, thread angle is given by [Design of Machine Elements by V. B. Bhandari McGraw Hill, pp. 192]

$$2\theta = 30°$$

Therefore,

$$\theta = 15°$$

$$\tan\alpha = \frac{l}{\pi d_m} = \frac{8}{\pi \times 40.5} = 0.0628$$

Considering friction between lead screw and plasma coating gun's nut arrangement is 0.15

$$\mu = 0.15$$

$$\mu \sec\theta = \frac{\mu}{\cos\theta} = \frac{0.15}{\cos 15} = 0.1553$$

Torque required to overcome friction at the thread surface is given by,

$$M_t = \frac{Wd_m}{2} \cdot \frac{(\mu\sec\theta + \tan\alpha)}{(1 - \mu\sec\theta\tan\alpha)}$$

$$M_t = \frac{375 \times 40.5}{2} \cdot \frac{(0.1553 + 0.0628)}{(1 - 0.1553 \times 0.0628)}$$

$$M_t = 1672.05\text{N} - \text{mm}$$

Where W = total load = 375N

As both the ends are fixed inside the bearing, so that there will be no friction at the both ends. Therefore, total torque $(M_t)_t$required to drive the lead screw is same as the M_t.

Now, Power required to drive the lead screw is given by at 30rpm

$$\text{kW} = \frac{2\pi n (M_t)_t}{60 \times 10^6} = \frac{2\pi \times 40 \times 1672.05}{60 \times 10^6} = 0.0070.$$

Lead screw summary

Sr. No.	Description	Value
1	No. of Starts	Single Start
2	Type of Thread	ISO metric trapezoidal
3	Nominal Diameter (d)	44mm
4	Mean Diameter (d_m)	40.5mm
5	Pitch *(p)*	7mm
6	Lead *(l)*	7mm
7	Material of screw	40C8
8	Length of lead screw	3600mm
9	Power required *(kW)*	0.0070

Above mentions specifications of lead screw and solid shaft of the diameter 44mm and length 3600mm and pitch 7 mm is supplied to the lead screw manufacture to manufacture the lead screw with specified specifications.

Testing-

Coating object Preparation:

In this study metal substrate, commercial mild steel material was used and this shape is circular that is shaft are used in this experiment. The surface roughness of metal substrate was prepared by shot blasting process using carbon steel material. The test specimen diameter is 42mm and length is 1m are considered.

Experimental procedures:

In this study, ceramic coating was produced using proposed of Plasma Coating Equipment Alumina material is used for coating purpose. The customer requirement is coating thickness is about 150to 250 micron. Alumina material in the form of wire with size 3.15 mm used to develop the coating. The feedstock the alumina fed and injected into the flame where it was melted and accelerated towards the substrate. The molten feedstock hitting the substrate will be cooled and bound together to form an adherent coating.

Measurement of coating thickness:

The important parameters are:

1. Visual Inspection.
2. Spraying thickness

Coating Thickness Gauge:

A coating thickness gauge is aa device used to measure the thickness of dry film paint, rust or any other material being applied as a secondary layer to a metal surface. A coating thickness gauge (also referred to as a paint meter) is used to measure dry film thickness. Dry film thickness is probably the most critical measurement in the coatings industry because of its impact on the coating process, quality and cost. Dry film thickness measurements can be used to evaluate a coating's expected life, the product's appearance and performance, and ensure compliance with a host of International Standards.

Dry film thickness (DFT) can be measured using two methods: destructive thickness measurement, where the coating is cut to the substrate using a cutter; and non-destructive coating thickness measurement, using techniques which do not damage the coating or the substrate such as magnetic, magnetic induction and eddy current thickness measurement methods.

The non-destructive coating thickness measurements can be taken on either magnetic steel surfaces or non-magnetic metal surfaces such as stainless steel or aluminium. Digital coating thickness gauges are ideal to measure coating thickness on metallic substrates. Electromagnetic induction is used for nonmagnetic coatings on ferrous substrates such as steel, whilst the eddy current principle is used for non-conductive coatings on non-ferrous metal substrates.

Elcometer offers a wide range of coating thickness gauges to measure dry film thickness. The Elcometer range of non-destructive coating thickness gauges includes mechanical and digital coating thickness gauges, suitable for dry film testing, complete with a wide range of probes and calibration foils to suit your application. Coating thickness gauge is shown in Fig No.24.

Thickness measurement:

Thickness of coating depends on the application and type of coating employed. Coating is the most critical component in an anticorrosion coating system. The main function of coating is to providing corrosion protection by adhesion to the substrate.

Various method is used to measure the coating thickness. In this experiment DFT device is used to measure a coating thickness. following steps are involved to measure coating thickness.

1. First step is on the DFT. Device.
2. Set DFT in master piece at zero.
3. Set DFT IN 250-micron master.

DFT. Probe is placed in sample object and get in result in DFT. monitor.

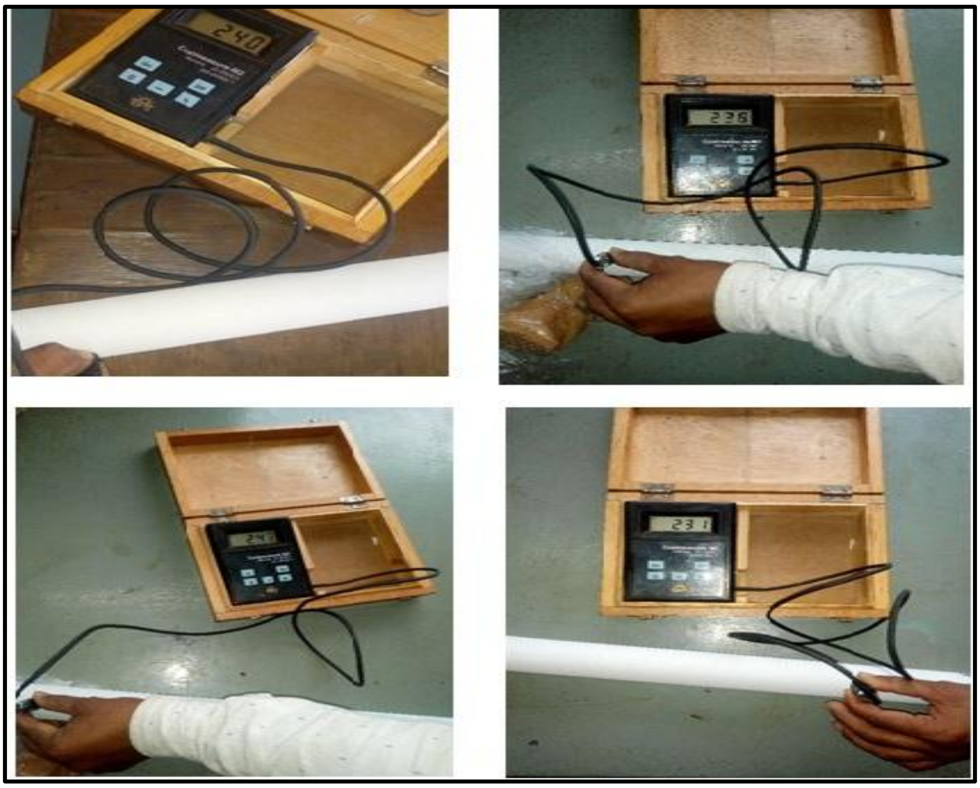


Fig No.1. Coting thickness measurement.

Observation of test samples

SR.NO.	Area considered	Time required Min.	Coating thickness value				Remark
			1	2	3	4	
1	1m	1.44	239	240	241	240	OK it is within limit
2	1m	1.52	238	240	236	238	OK it is within limit
3	1m	1.5	243	244	243	242	OK it is within limit
4	1m	1.48	232	230	231	231	OK it is within limit

RESULT

In this project we have designed the standard test set up for thermal spraying application as per given specifications by manufacturer. The developed mechanism is working as per owner's requirement. The following points are conclusions for project work: -

The coating thickness up to 200 to 250 micron is achieved and it is acceptable for customer as per their quality standard.

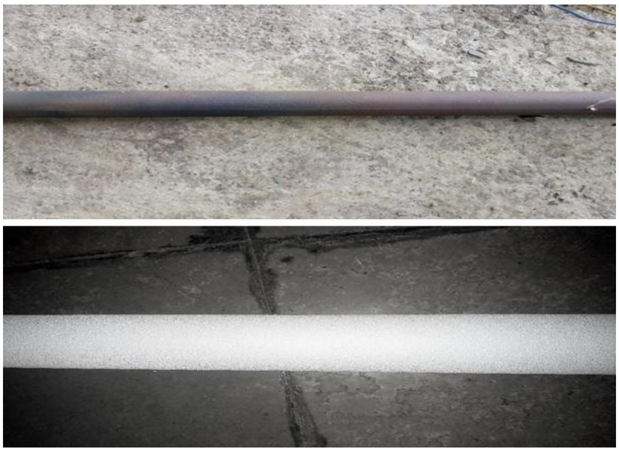


Fig. No.2. Shaft for before and after coating.

CONCLUSION

- Plasma spray ceramic coating are used to extend the product life, increase performance and reduce production and maintenance costs which is suitable for industries needed. Alumina is the best material in terms of quality which is suitable used for the above application. In order to produce the quality coating, machine parameters play the important role in getting the optimum coating.
- The coating thickness up to 200 to 250 micron is achieved and it is acceptable for customer as per their quality standard.

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