Surface Analysis And Mechanical Behaviour of Polysiloxane Coating on Alloy Steel Substrate

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Abstract- *This project deals about developing anti-scratch coating for automotive body. Automobiles undergo severe scratches on body and to some extend on the wind shields. An experimental investigation is carried out over automotive body to improve the scratch resistant using the newly developed polysiloxane coating. The coating process used is spray coating. Polysiloxane coatings are industrial protective and maintenance coating which is characterized by abrasion, chemical, extreme UV and high temperature. Scratch properties of polysiloxane coatings are critical in their application in many fields which require long-term protection and aesthetics. Critical input parameters of spray coating process such as nozzle distance, spraying time and pressure is optimized and corresponding output parameters are coating thickness, surface roughness, coating micro hardness, abrasion rate are studied. Taguchi`s L9 orthogonal array and Analysis of variance is used to conduct the experiment for finding the optimum process parameter. The coated samples will be examined using scanning electron microscopy (SEM) for micro structure analysis. Phase and chemical composition will be carried out using XRD and energy dispersive x-ray spectroscopy (EDAX).Optical microscopy is used to examine the microstructure of the coated samples. The Vickers Hardness Test will be taken to measure the micro hardness of the coating .In addition to it the adhesion, corrosive, wear test will be studied.*

Keywords- Substrate coating, Spray coating, Polysiloxane coating, Optical Microscope, SEM, Vickers's hardness test.

I. INTRODUCTION

The modern automobile is a grand assemblage of parts made from a variety of materials. Many of these parts have a protective coating applied to improve the appearance or provide additional durability to the substrate. In many coating systems the uppermost layer is a clear coating (ranging between 5–50 µm in thickness), which not only protects the underlying layers or substrate from chemical and UV degradation, but also provides protection from mechanical damage that can result in surface scratches.

SUBSTRATE FOR COATING:

A part of the car bonnet is used for this experiment to coat and analyze the scratch resistivity. The substrate is cut from the bonnet with respective dimensions 80x80 mm. The test samples has the dimension of 20x20 mm**.**

Fig 1.1-Substrate

MODERN AUTOMOTIVE COATING PROCESSES:

Modern automotive coating methods consist of five main steps. They include the following:

PRE-TREATMENT:

It removes and cleans excess metal and forms an appropriate surface structure enabling bonding of a corrosion protection layer.

ELECTRO DEPOSITION(ED):

The metal underbody and frames of automobiles are coated to prevent corrosion, whereas other areas like the roof are not rust proofed.

RUST-PROOF MATERIALS: SEALER / PVC

The third step is underbody coating and seam sealing using PVC (Polyvinyl Chloride) and urethane. Recently, PVC and acryl/urethane sealants have also been used in the underbody areas, a process called the Dampening Coat (DC), to impart noise-proofing and vibration-deadening. The noise and vibration are transferred from the engine, drive train, suspension system, road noise of the tires, and flowing air, and the underbody sealants reduce noise transfer into the passenger compartment of the automobile. A sealer like Poly Vinyl Chloride (PVC) is applied for anti-corrosion, elimination of water leaks, and minimization of chipping and vibrational noise.

PRIMER:

The fourth coating step is the application of a primer surface or simply primer. It can be water-borne, solvent-borne, or a powder. The main reason for primer application was to improve weather resistance, appearance, and chipping resistance

TOP COAT:

The final step in the body coating process is to apply the topcoat, which consists of two layers-the base coat and clear coat. The base coat contains the primary coloring pigment, and the clear coat provides a protective coating against environmental effects, corrosion, and UV light degradation.

SPRAY COATING:

It is a painting technique where a device sprays a coating (paint, ink, varnish, etc.) through the air onto a surface. The most common types employ compressed gas usually air to atomize and direct the paint particles.

AIR GUN SPRAYING:

This process occurs when paint is applied to an object through the use of an air-pressurized spray gun. The air gun has a nozzle, paint basin, and air compressor. When the trigger is pressed the paint mixes with the compressed air stream and is released in a fine spray. Due to a wide range of nozzle shapes and sizes, the consistency of the paint can be varied. The shape of the workpiece and the desired paint consistency and pattern are important factors when choosing a nozzle. The three most common nozzles are the full cone, hollow cone, and flat stream. There are two types of air-gun spraying processes. In a manual operation method the air-gun sprayer is held by a skilled operator, about 6 to 10 inches (15–25 cm) from the object, and moved back and forth over the surface, each stroke overlapping the previous to ensure a continuous coat. In an automatic process the gun head is attached to a mounting block and delivers the stream of paint from that position. The object being painted is usually placed on rollers or a turntable to ensure overall equal coverage of all sides.

II. OBJECTIVES

In this work, the automobile coatings are performed by the progress in controlling droplets and their deposition attributes, and by the development of new technologies and paint chemistries, a comprehensive and up-to-date review of automobile coatings and coating technologies was considered to be of value to industrial practitioners and researchers.

In this work the combination of Phenyl trimethoxysilane (PTMS), Dimethoxy dimethylsilane (DMDS), 3-Glycidoxypropyl methyl dimethoxysilane is used for coating over the substrate using the spray coating process.

III. EXPERIMENTAL SETUP FOR SPRAY COATING

The air inflator is connected to the input valve of the cylindrical tank and make tight, from the output valve the pipe is connected with the help of the pipe tightening clip. Pressure regulator is fixed at the end of the pipe by fixing the nipple in it. The nipple is connected to the inlet side of the regulator. The pressurized air is taken from the outlet of the regulator. Another piece of pipe is connected to the airbrush (spray gun) and made tight with the clip. The air inflator is given power supply with Switched-Mode Power Supply (SMPS) and switched on. The air flows from the inflator to the tank and get compressed. The required pressure is set with the help of the knob in the regulator and by pressing the trigger in the spray gun the compressed air is released for setting the pressure. The polysiloxane chemical is poured into the storage cup in the spray gun so that atomized air mixes with the polysiloxane.

COATED SUBSTRATE:

According to the parameters included the substrate are coated with different pressure, substrate distance and spraying time. There are totally nine substrate with different composition parameters used for optimizing it.

TAGUCHI METHOD TREATS OPTIMIZATION PROBLEMS IN TWO CATEGORIES:

(i) STATIC PROBLEMS:

Generally, a process to be optimized has several control factors which directly decide the target or desired value of the output. The optimization then involves determining the best control factor levels so that the output is at the the target value. Such a problem is called as a "STATIC PROBLEM".

This is best explained using a P-Diagram which is shown below ("P" stands for Process or Product). Noise is shown to be present in the process but should have no effect on the output! This is the primary aim of the Taguchi experiments - to minimize variations in output even though noise is present in the process. The process is then said to have become ROBUST.

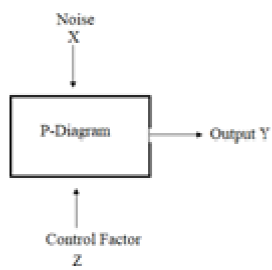

Fig 3.15 P-Diagram for Static Problems

ii) DYNAMIC PROBLEMS:

If the product to be optimized has a signal input that directly decides the output, the optimization involves determining the best control factor levels so that the "input signal / output" ratio is closest to the desired relationship. Such a problem is called as a "DYNAMIC PROBLEM".

This is best explained by a P-Diagram which is shown below. Again, the primary aim of the Taguchi experiments - to minimize variations in output even though noise is present in the process- is achieved by getting improved linearity in the input/output relationship.

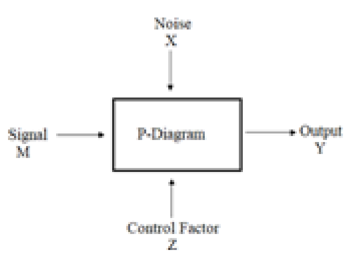

Fig 3.16 P-Diagram for Dynamic Problems

SPRAY COATING PROCESS PARAMETERES AND THEIR LEVELS:

Table 3.2

Parameters	Level 1	Level 2	Level 3
Pressure (kg/cm^2)	1.05	1.40	1.75
Substrate distance (cm)	10	15	20
Spraying time (sec)	5	10	15

EXPERIMENTAL PLAN FOR SPRAY COATING AS PER L9 ORTHOGONAL ARRAY:

Table 3.3

Specimen	Pressure (kg/cm^2)	Substrate distance(cm)	Spraying time (sec)
1	1.05	10	5
2	1.05	15	10
3	1.05	20	15
4	1.40	10	10
5	1.40	15	15
6	1.40	20	5
7	1.75	10	15
8	1.75	15	5
9	1.75	20	10

The column of orthogonal array represents experimental parameters are to be optimized. Row of orthogonal array represents the level of each parameter. S/N ratio will be calculated in the MINITAB software using Taguchi method. After experimentation and testing the response value such as coating thickness, surface roughness coating micro hardness to determine the optimal process parameters. ANOVA will be performed to estimate the magnitude of factors effects on the response characteristics.

IV. RESULT AND DISCUSSION

Table 4.1- Measurement of Surface Roughness and Coating Thickness

SAMPLE	SURFACE ROUGHNESS(μm)	COATING THICKNESS(μm)
1	0.503	44
2	0.543	51.3
3	0.56	77
4	0.601	101
5	0.633	129
6	0.619	104
7	0.556	144
8	0.508	173
9	0.476	221

The coating thickness of the coated samples is measured by using the samples which is masked on one side, the stylus profilometer probe slides over the sample which shows the difference in the thickness. Surface Roughness is measured by rolling the probe over the coated surface of the sample over three different place, the average is taken to know the overall roughness of the particular sample.

MAIN EFFECT PLOT FOR COATING THICKNESS:

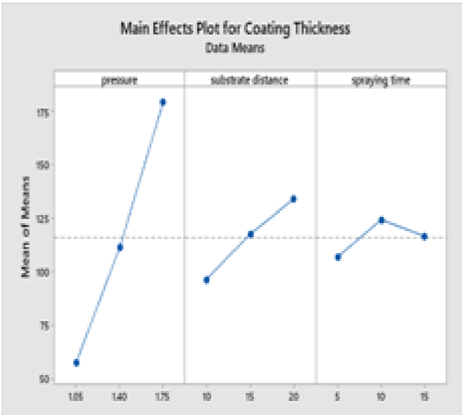

Fig 4.1 Mean Effect Plot for Coating Thickness

As the pressure increases the flow velocity of the polysiloxane fluid increases and condenses on the substrate, so the pressure is directly proportional to the coating thickness. The coating thickness is decreased when the substrate distance is low, it increases when the distance is increased. The spraying time increases with respect to the pressure the amount of fluid will be ejected from the nozzle and thus the coating thickness varies accordingly.

MAIN EFFECT PLOT FOR SURFACE ROUGHNESS:

Fig 4.2 Mean Effect Plot For Surface Roughness

As the pressure increases the surface roughness is decreased. In the substrate distance initially the surface roughness remains constant. As the spraying time is increased the surface roughness is also increases but initially the roughness is low due the decrease in the spraying time.

MEASUREMENT OF MICRO-HARDNESS:

Table 4.2- Measurement of Vickers Hardness

SAMPLE	VICKERS HARDNESS
1	18.85
2	19.63
3	21.36
4	22.4
5	63.03
6	70.86
7	71.54
8	73.06
9	74.73

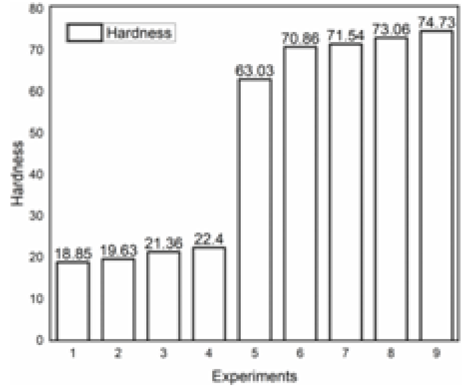

Fig 4.6 Hardness Graph

Initially the Micro-hardness value for the uncoated steel substrate is 9.8HV. The micro- hardness value for the polysiloxane coated substrate increases gradually from18.85HV based on the influence of the parameters, as the thickness of the film increases the hardness value increased drastically to 74.73HV.

V. CONCLUSION

The conclusion drawn from the present investigation are as follows:

The polysiloxane coating was successfully coated over the substrate by spray coating technique. The input parameters such as pressure, substrate distance and spraying time of coating process was optimized using Taguchi`s L9 orthogonal array method. The coating properties such as coating thickness and surface roughness were measured by Stylus Profilometer, the coating thickness was increased from 44µm to 221µm and surface roughness was decreased to 0.476 µm from0.503µm.The physical and surface characteristics were measured successfully.

The Morphological analysis was carried out by FE-SEM the good dispersion of the polysiloxane on the substrate with a distance of 20cm and the elemental composition was confirmed by the EDS. The physical characteristics was carried out by XRD, it shows that the coating to be in crystalline nature having silicon, carbon and oxygen as the component. The Mechanical properties were studied using Vickers Hardness Test. We observed that the hardness was increased from 18.85HV to 74.73HV and 296.552% was the increase in micro hardness. Due to the features of facile and eco friendly preparation, the coatings are potential in the application of automobiles

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