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DEFECT ANALYSIS AND THEIR PREVENTION OF POWDER COATING PRODUCTS

Ms.Pooja Prakash Thorat, Student, Dept. Of Mechanical Engineering, Deogiri Institute of Engineering and Management Studies, BATU University.
Mr. Shrikisan Julalsing Parihar, Associate Professor, Dept. Mechanical Engineering, Deogiri Institute of Engineering and Management Studies, BATU University.

Abstract
This paper presents a study of defects analysis and prevention of Powder coating products. Powder coating is widely used in industry to give a product protection from the atmosphere, improve the aesthetics and the surface finish. Electrostatic powder coating process (EPCP) using Corona gun is extensively studied in this work with the perspective of determining operating variables which govern the quality of coat. The parts which were studied were found prone to orange peel defect, cracks , uncover peel off and were having high dry film thickness (DFT). It was revealed that three controllable process variables namely the applied voltage, powder flow rate and blow air flow rate were responsible for quality of the film coated. Further the Taguchi method(Tm) was used to investigate the effects of process parameters on the response characteristics. The effect of each parameter on both response characteristics namely the orange peel defect and DFT was studied using PDCA cycle. Different combination pf parameters are verified experimentally and the quality of powder products is confirmed.

Keywords: Electrostatic powder coating process (EPCP), dry film thickness (DFT), PDCA (plan–do–check–act , Taguchi method (Tm), Water Drying Oven(WDO), Powder curing oven(PCO).

I. Introduction

A tremendous amount of financial loss is incurred every year as a result of premature failures of coatings. Coating failures can occur for many of reasons, although they are typically a result of poor application, a defective coating, or an inadequate specification. A determination of the fundamental causes behind coating failures is critical. Not only this help in assigning financial responsibility, but knowing how a coating has failed is often the first step in planning how to fix it. To investigate a failure, and analyze the conditions that promoted the failure, important information must be collected on the failed coating. Background information on the coating type and application procedure, the service history and environment, and physical evidence of the failed coating are necessary to determine why, how, when, and where a failure may have occurred. If these answers are provided during the course of the investigation, future failures may be better understood or possibly prevented. The conditions that promoted the failure are essential identifying the underlying factors that may have initiated the failure. Provided in this survey is a step by step approach to paint and coating failure analysis investigation. The accepted theories and mechanisms, which cause coatings to fail, will be explored in this report. In powder the beginning of the cycle and are removed through the rest of the development process. Defects occur all the way through the development process. Hence, defect prevention becomes an essential part of powder coating process for quality improvement. Defect prevention is a process of improving quality whose purpose is to identify the common causes of defects, and change the relevant processes to prevent that type of defect from recurring. The purpose of defect prevention is to identify those defects in the process. In this study, in order to improve powder coating process quality, defects are first identified from a daily rejection data, classified and then eliminated by finding the root causes, for which preventive mechanisms are established for reducing re-occurrences of similar defects , thus improving Quality[1].

Taguchi method has established itself as an important tool for the robust design in obtaining the high quality process and product which are least sensitive to noise with minimal manufacturing costs. It involves various steps of planning, conducting and evaluating the results of specially designed tables called 'orthogonal array' experiments to study entire parameter space with minimum number of trials to determine the optimum levels of control parameters [6].

II. Literature

Leif Darner He explains that the cured powder coating film can be checked on the basis of their characteristics considering their specifications, many test can be conducted. Positive and negative tolerance value exists for these tests and performed on the basis international standard procedure criteria.Any particular powder coating application there may be technical or quality standard to meet which refer to the specific test & testing equipment [7].

Y. Merck stated that thermosetting powder coating on the basis of epoxy resin is used longer that other resin powder it has vital amalgamation of low molecular mass and melt viscosity [3].

Petra Uhlmann and Karina Grundke, in his research paper explain us that the quality of the powder coating is depend on the film forming which depend on the coalescence of the individual powder particles , wetting of substrate and flow of irregular film into flat surface. The wilhelmy balance method successfully applied by them and their investigation of the temperature dependence of the wetling tension and the influence of several concentration. Leveling additive helps in decreasing the wetling tension of the epoxy resin. No additives affect the viscosity of the epoxy resin [5].

Shah et al. this paper carried out on the study of the coarse powder and air flow. It about the particle flow behavior in the powder coating booth & its coating quality under certain conditions. The parameters powder charging, powder flowing space are main variable in which the charged powder accelerated from gun to the substrate under the effect of aerodynamic, electrostatic and gravity forces and powder deposition to the work pieces. The important parameters that affect the powder travelling are air flow rate, powder spray rate and applied voltage [4].

Manabu Takeuchi he studied over corona spray gun, the charge to mass ratio deposit on substrate is more than un-deposited while powder coating. This ratio was increased by placing a pair of external assisting electrode for corona spray gun. In this corona gun free ions accelerated towards the substrate can be decreased by creating magnetic field in the powder coatings space [2].

J.V.Kovach and E.A. Cudney this paper explain about PDCA is quite important tool for the continuous improvement which can be implemented successfully and perceived effectively than other tools. Further this continuous improvement methodalso helps to improve the performance and the culture of the working environment. this study have also found evidence that suggests the use and effectiveness of different tools varies between applications in different environments, as well as how various organizational factors, which are often hard to control, have a direct effect on the success of these initiatives. These tools are helpful in problem investigation and able to resolve the problem [8].

III. Powder coating

Powder coating is a technique in which dry powder is used for coating the surface in the finishing process. There is a lot of variety in the powder coating where the dry powder is used as free-flowing agent. In this methodology the powder is used as applying agent used to protect the surface this powder coating also helps to make the product decorative. Powder coating process can be used for huge range of the materials which can be used for commercial as well as domestic products.

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3.1 Powder coating defects

1) Orange Peel -The surface of a coated product doesn't have an even smooth appearance to it after the coating is applied as shown in Fig1. Whether your powder coating or liquid coating, orange peel is usually not desirable because it creates a poor overall finish appearance when your all don coating your product.

Fig.1 Orange peel

2) Pinhole - Pinholes, often also referred to as surface blowholes, occur sporadically and over large areas and can affect all cast piece areas. In many cases, they only become visible after mechanical processing, but they are always visible to the naked eye as shown in Fig 2. Pinholes can appear in various forms, from spherical blisters with a bare**,** metal surface or covered with small graphite skins to larger, irregularly shaped cavities accompanied by slags or occurrences of oxidation.

Fig.2 Pin Hole

3) Bubbles – A bubbles in a coating applied over a casting are caused by trapped porosity. Heat causes air or moisture trapped in porous pockets in the substrate to rupture through the coating as the air escapes. Bubbles in coating over a steel part also are most likely caused trapped air or moisture as shown in Fig 3.

Fig.3 Bubbles

4) Cracks – It is similar to alligatoring but here cracks are limited to a small area, unlike alligatoring cracks. It is caused when the paint is applied during very cold weather or due to the application of paints prior to drying of undercoat a shown in Fig.4

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5) Chipping off (Peel Off) - Peeling of paint is mainly caused by moisture on the surface, poor surface preparation, using an incorrect painting system as shown in Fig 5. It is the swelling of a paint film caused due to loss of adhesion between one or more coatings or between primer and parent surface and moisture on the surface.

Fig.5 Chipping off (peel off)

6) Overcoat - Overcoat in a coating is generally happen due to excess of powder flow through gun. If the nozzle diameter is not proper component get overcoat as shown in Fig 6.

Fig.6 Overcoat

IV. Experimental set up

The setup used for doing experimentation is consist of Raskog trolley(component), corona gun, WDO&PCO temperature panel & black powder. The Raskog trolley component is made of hot rolled steel sheet and pipe, it is fabricated in a shape as shown in Fig7, dimensions of raskog trolley are 780x444x306 mm^3 as shown in Fig 8.

Fig.7 Raskog Trolley

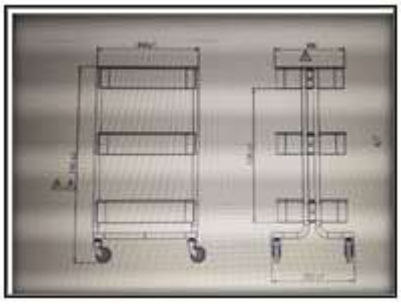

Fig.8 Sketch of Raskog Trolley

4.1 Experimental Procedure

4.1.1Process Analysis

The substrate is first passes through pre-treatment stage prior being powder coated which is then cured in oven. Data is collected after powder coating on the surface of different component which is a sample

of 100 Pieces . The defects were measured at the five different location., current process parameters as shown in Table 1

Table1: Current process parameters and their ranges

Sr. No	Process Parameters	Ranges
1	AutoGun flow (gm/min)	30-50
2	Manual flow(gm/min)	40-50
3	Voltage (v)	60-80
4	Current (A)	40-60
5	Conveyor speed(mtr/m)	2.6
6	Pitch (mtr)	0.9
7	Air pressure(bar)	4-5

Following defects were observed after powder coating on component surface as below
1) Over Heating (blackness) – 4
2) Dust – 3
3) Pit marks or pin holes on coated surface – 10
4) Uncoated surface – 18
5) Variation in upper & lower side of component DFT – 5
6) orange peel – 4
7) Poor adhesion of powder to substrate(Peel off) –3

The part's inspection reports prior conducting the experiments showed that orange peel and other defects has the maximum contribution in rejection. To add the solidity to the experiment coating powders from two different supplier's viz. Asian Paints and Jotun Pvt Ltd were used.

4.2 Powder coating trials with different parameters

Two parameters namely gun parameters and temperature parameters were used for the study of powder coating quality and then occurrence of defects were observed by means of visual inspection. The results were plotted in terms of graph proportion of defects with respect to temperature.

4.2.1 Results and Discussion

1) Effect of varying gun parameters on powder coating process:-

The most common way of applying the powder coating to metal objects is to spray the powder using an electrostatic gun, or corona gun. The gun imparts a negative charge to the powder, which is then sprayed towards the grounded object by mechanical or compressed air spraying and then accelerated toward the workpiece by the powerful electrostatic charge. There is a wide variety of spray nozzles available for use in electrostatic coating. The type of nozzle used will depend on the shape of the workpiece to be painted and the consistency of the paint. The object is then heated, and the powder melts into a uniform film, and is then cooled to form a hard coating. It is also common to heat the metal first and then spray the powder onto the hot substrate. Preheating can help to achieve a more uniform finish but can also create other problems, such as runs caused by excess powder. The corresponding analysis is as stated in the Table2

Table2: Analysis of process parameters and their ranges

Sr. No	Component name	Auto Gun flow (gram/ min)	Manual flow (gram/ min)	Voltage (v)	Current (A)	Conveyor speed (mtr/min)	Pitch (mtr)	Air pressure(bar)
1	Upper leg	50-60	80-90	85-90	75-80	2.9	0.8	4 -5

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2	Middle leg	50-60	80-91	85-90	75-80	2.9		
3	Bottom leg	50-60	80-92	85-90	75-80	2.9		
4	Bracket	60-70	80-93	85-90	75-80	3.2		
5	Basket	50-60	80-94	85-90	75-80	2.6		

The corresponding analysis is as stated in the Table 2 , It is observed that process parameters mostly depends auto gun flow, voltage ,current and conveyor speed. After parameters setting no of defects is reduced as compare to previous process parameters, as shown in Table 3, Comparison of process parameter before and after parameters setting as shown in Fig.9

Table3: Observed defects before and after parameters setting

Sr. No	**Defect Name**	**Top Leg**		**Basket**		**Middle Leg**		**Bottom legs**		**Brackets**	
		Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
1	**orange peel**	2	1	3	1	4	1	4	1	3	1
2	**over coat**	3	1	3	1	3	1	3	1	2	0
3	**uncover**	3	1	7	3	3	1	3	2	8	3
4	**pin holes**	4	2	1	2	5	3	5	3	2	1
5	**bubbles**	5	2	3	1	1	0	1	0	1	0

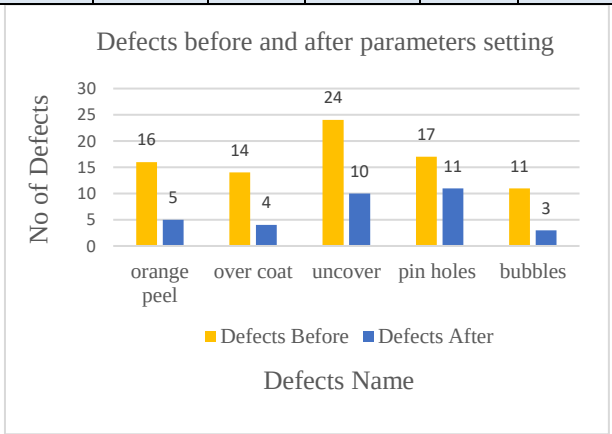

Fig.9 Comparison of defects before and after parameters setting

2) Temperature parameter analysis:-

The temperature and time of exposure required for a coating is known as the cure schedule. In this process ,powder coatings product normally cure at PCO at temperatures of around 235°C (455°F) maintained for 10 to 15 minutes, before being set aside and given time to cool as shown in Table 4. The exact temperature and the length of time required to cure can vary depending on the component length. WDO &PCO temperature panal as shown in Fig.10

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Fig.10 Photograph of WDO and PCO temperature panal

The high temperatures are required to melt the powder particles and achieve 'flow out', where the melted plastic flows and meets to form a consistent liquid layer. As the curing process continues, the layer dries and hardens. Once cooled, thermoset powders will form a hard and permanent layer that can't be heated back into a liquid.

Table4: Temperature parameters setting

Component Name	PCO Temp °C	Time (min)	1	2	3	4	5	6	7	8	9	10	No of rejection
Raskog Trolley	220	4	x	x	x	x	x	✓	x	x	✓	x	80%
	225	4	x	x	x	✓	x	✓	✓	x	X	x	70%
	230	4	✓	✓	✓	x	✓	✓	x	✓	X	✓	30%
	235	4	✓	✓	X	✓	X	✓	✓	✓	✓	✓	20%

Data in Table 4 is analysed and it is observed that no of rejection at 220°C is more as compare to 235°C, from this data below graph is plot as shown in Fig11.

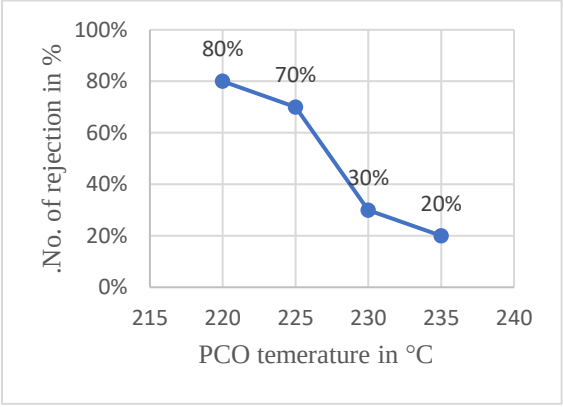

Fig.11 Plot of rejection vs PCO temperature

V. Conclusion

It is clear that Taguchi methods and PDCA cycle can effectively be used for control of variables that affect the quality of powder coated parts. The effects of the process parameters viz. applied voltage, powder flow rate, blow air flow rate and powder, on response characteristics viz. uncover ,overcoat, pinholes and orange peel, were studied.

The effect of temperature parameters process reduces the rejection of component. All the process parameters considered for analysis has significant impact on the response characteristics

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