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Improvement in the Production of Powder Coating Process of Fan Blades through PDCA

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Abstract: Plan-Do-Check-Act (PDCA) cycle is a spiral iterative scientific approach for achieving continuous improvement of quality whether in the process, product or service in any organization. This is paper review on the PDCA approach which throw some light on this topic which help us to understand how PDCA cycle can be implement and what kind of benefits can be achieved by adopting it. PDCA is problem solving technique which helps to improve the reliability and quality of the production. This method is followed by most of the Indian companies in order to maintain and improve their stake in the market and within the company processes for their success.
Keywords: - PDCA cycle, Continuous Quality improvement, lean.

I. INTRODUCTION

The success and the existence of companies in a market would be decided by the economic condition and stability of that company. This means company should generate sales market-oriented requirements in order to recognize in this drastically changing economic world as soon as possible. New technologies and materials enable new products which lead to open up new markets and trends, which creates demand for the product and lead to become economic stability. In order to this new production technologies should be implemented. These new production and information technologies transform significantly and help to sustain our industrial working world. Political and social changes signaling and accompany a shift in values, which leads to our industries significant precipitation takes place.

The pressure of competitive survival which is generated by advanced technology and globalization. For competition and survival, companies must consider various factors such as productivity, quality, cost, quality attributes, service and profit. In order to this company can only be survived, if the customer must be retained to them. For this good product with customer expectations and specification should be coincide with manufactured product. The quality cost, product cost and production processes are interrelated so as the customer retention and the economic condition is also depend on the customer retention and sale of the product.

The tasks of production management have become more diverse, difficult and demanding. The integration of the Indian market and the globalization of many industries, the increasing pace of innovation, the development of the leisure society and the overarching environmental and social problems, which must play a vital role in the economy, require the executives further perspectives and the traditional focus of production management significantly revoke out.

As to increase the production the customer must be retained and come back to ask the product. For this quality plays an undoubted important & incomparable role in the business. It can be said that if there is no quality control, there is no economic benefit, so which is our mere motto to be economic stable.

In this paper, intend of the research is to discover how the powder coating process is optimized. Various quality tool & techniques are implemented in this study in order to improve the process.

Powder coating is process in which powder, pigments & extenders and fillers & flow additive are coat are mixed together and then this mixed dry powder is sprayed on the surface for electrostatic coating for specific properties. This is advanced method of applying a protecting & attractive finish to a wide variety of materials and products. The charged powder particles of the powder adhere to grounded surfaces until heated and fused into a smooth coating in a curing oven. The result is a uniform, durable, high-quality, and attractive finish.

This paper is studied on the blade of the fan manufacturing process. The quality tools & techniques are brought into consideration in the powder coating process in order to make the production efficient. In this research quality cycle or PDCA is implemented to find root causes where there is chance of improvement in the process.

Competition is quite hard among the customer all the time and due to this, companies should continuously find new ways to differentiate from competitors. It is clearly indicated in this case that the ability to respond quickly to customers& gives the

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competitive advantage in a rapidly changing manufacturing environment. Due to this, the management of the company came to a decision that how systematically find the flaws and its counter measures in order to improve the quality and profit of the company, the delivery and cost benefit must be achieve.

II. LITERATURE SURVEY

A. *Powder coating literature review*

1) Leif Darner (1999) - His research in the field of testing the coated quality. 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. He stated that for any particular powder coating application there may be technical or quality standard to meet which refer to the specific test & testing equipment.

2) D.S. Richart (2000) - He investigates and performs an experiment to find out the viscosity difference between thermosetting & thermos setting powder. The melt viscosity of the thermoplastic powder resin is higher than thermosetting powder resin. The particle size of the thermoplastic resin powder is more difficult to grind than then thermosetting powder resin under cryogenic condition.

3) Y. Merck (2000) – he 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.

4) Petra Uhlmann and Karina Grundke, (2001), This research paper explain us that 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 wet-ling 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) Dastoori et al (2005), they work on measurement of electrostatic powder coating properties for corona & triboelectric powder coating guns to measure the deposited layer for both guns and long with the measurement of the powder thickness & adhesive properties of the powdered layer. There are many variables which affect the powdered coated layer thickness. The adhesion properties for both spraying system are almost equal at 6-7 s. Tribo-spray gun is independent of the angle and optimum angle is maximum 90 or normal to surface for corona spray gun with optimum voltage is 55 kv, where thickness & adhesion is maximum for both.

6) Lawrence R. Waelde (2005) – He explain the distribution and application of the thermosetting and thermoplastic powder on the basis of the particle size. He stated that thermosetting powder is used in electrostatic spraying system with maximum particle size about 75 µm and thermoplastic used in the fluidized-bed-coating process with heavier particle size of the powder which is below 44 µm.

7) Shah et al. (2006) 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.

8) Manabu Takeuchi (2008), he studied over corona & spray guns. He stated that for 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.

9) MitsurMatsuri (2009), this research paper explains about the improvement made by the researchers of powder coating by increasing the conveying air speed using the atomized coating system. The coating thickness in the recessed area was clearly increased with increase of the volume of conveying air from 80 to 120 L/min has yielded a 13% in the average coating thickness.

10) Barleta (2009), this paper states about the sliding spherical contact geometry to characterize of the scratch of the polyester powder coat electrostatically sprayed on the substrate and baked under different time-temperature in the oven. The coating thickness was evaluated by averaging five measurements equally spaced on the surface of the coated substrates.

11) VineetShibe and Vikas Chawla (2013) - This paper explains improve the life of the component and reduce downtime by

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improving the service life. This surface coating helps to make the surface of the product functionally effective. Corrosion, erosion mechanical and chemical properties can be improved with help of the wide range in the variety of the surface coating. Thermal spraying, chemical vapor and physical vapor distribution are the commercially techniques used for the process of the powder coating.

B. Literature review for PDCA

1) M. Sokovic el at. (2010) - this paper explain quality improvement methodologies like PDCA, Six Sigma, EDQM which can be used for continuous improvement of the product, processes and services in the organization. The PDCA cycle is a well-known fundamental concept of continuous improvement processes. This paper shows the limitation, characteristics and strength of the methodology. The result of the paper can be used as reference for taking the management decisions for various quality programs This explains that PDCA is more than just quality tool which is simple to understand and implanting is easy.

2) J.V.Kovach and E.A. Cudney (2011) - 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 method also 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.

3) EirinLodgaard and Knut EinarAasland (2011) - they stated that the PDCA is the basic technique for achieving highest level in the continuous improvement methodology. For product development PDCA methodology is also effective and efficient. This paper explains that how continuous improvement process is conducted compared to PDCA cycle and understands the improvement process in PD environment. This paper emphasis on the systematic way of using the PDCA cycle in an impressive and effective approach in the supplier industry and it can be one possible tool to achieve the desired improvements. Continuous improvements are an opportunity which can contribute and strengthen the product development phase. PDCA helps to find the success factor for PD in the organization and increase the efficiency and long term survival in demanding market.

4) Sergio Mergen el at. (2012) - this paper is on software engineering teaching in which PDCA approach is adopted and named as I-PDCA with teaching scenarios rather than management scenarios. This methodology helps to evaluate student learning and measure their strength and weakness. Further challenge to make student discipline and improving knowledge independent to their instructor. PDCA approach is adopted by including checklist as a tool for evaluation. This is act as efficient and promising from for evaluation.

5) Madan M. Jagtap and S.N. Teli (2015) - this paper explains that PDCA is a fundamental technique that helps to achieve quality product. PDCA is pioneered quality management approach for manufacturing by adopting the statistical process control as it is a clearly defined and repeatable process. On effective implementation of PDCA cycle increases duration of life for the breaks in the automobile manufacturing. After testing it was seen that the brakes withstood longer Reducing 75% of concerns regarding the braking reduced the warranty cost for the company customers are satisfied companies reputation is achieved warranty regarding concerns are reduced in brakes company is in no more high scale loss regarding the warranty issue in brakes

6) J. Ferrucci (2015) - is study carried out on evaluation teaching proficiency for mathematics teacher by introducing PDCA cycle for professional development approach which is a popular tool often use as teaching improvement process. The pre-service teachers involved with this project developed strong working relationships within their groups that allowed them the opportunity to collaborate and reflect on their mathematics lessons and teaching. The prospective teachers not only exhibited collegial qualities that supported learning, but they enhanced their teaching improvement skills by following a cohesive PDCA Cycle that included both mathematical and pedagogical knowledge.

7) Michael Glykasel at. (2015) - in this paper study carried out on the process and quality management to take initiative for enhancing the technical and vocational education &training (VET) which is a vital aspect. This paper emphasis on the quality, in general and main concept of the quality with its implementation and assurance and further it helps to regulate the quality management in VET and highlights the paths which are concerned with the VET.

8) BibiankaKayselyova and Michal tkac (2015) - DOE is very powerful tool in process improvement In PDCA cycle. The process improvement is applied in the truck company doe is applied in the PDCA process with detailed description and methodological framework applied. This study helpful to find the key factor which can help fir the improvement which enhance lifetime of the tyres of the truck. In this study improvement effort were made along with problem formulation, design analysis

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and result interpretation to improve the in the life of the tyres as consumption of fuel and tyre are the costly process. Improvement is made through PDCA cycle and Doe is conducted under the analysis both for the current and after improvement. Corrective action plan were propose and implement after find the key factor responsible for the tyre deterioration and breakdown.

9) GregoireNleme(2015) - In this paper study reveals the behave result of PDCA cycle which is applied in the automobile supply chain. This paper explains how manufacturers and suppliers plan and assure the quality in their supply chain. Result of this paper proves that the framework of PDCA is an effective tool for controlling and improving the quality in the automobile supply chains at the suppliers, in product development, at transportation and warehouse vendors, and in vehicle operations. Overview is given in the research paper that clarifies the wide scope of the determinants of the good quality in automobile supply chain. PDCA Cycle framework is helpful to sustain continuous improvement in the supply chain.

10) Mamtapatel and Dr. Raj kumar (2015) - this paper proposes that productivity can be improved by implementing the PDCA cycle as the production is improved in the milk industry by adopting it. In this paper improvement is done as the PDCA cycle is implementing to the process and finding the critical factor which affects the production rate. By improving those factors the production is also improved as well as the quality of the milk

C. 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

Powder coating is finely ground plastic particles of resin, pigment &extenders, and various flow additives and fillers in the thermoset or thermoplastic powder is added according to the specification, which is sprayed on the surface for coating. In this process dry powder is used as a coating agent and applied on the substrate which is grounded in which the powder is electrically charged. The charged particle is then sprayed on the sprayed on the substrate with the help of the gun. Then this powder coated material is then baked in the oven for a certain temperature at a temperature which is about 60° C to make the powder flow and form smooth coated skin over the material.

In this study the blade of the fans are used for powder coating which are of MS (mild steel) & aluminum. Brown color powder of the Nerolac is used to coat the fan the powder is electrostatically charged at the 60 kv and the sprayed at 4.5 to 5 kg of air at a distance of 12 inches with DFT ranges at 50 -65 micron of the powder coating. The gun used in this powder coating corona gun.

D. Types of Powder Coatings

Basically there are 2 type of powder coating which is termed as thermoset and thermoplastics. Thermosetting is form of joining of the cross-linking polymer in to defined shape. As once the powder is prepared and baked, it reacts with alternative chemical teams within the powder to polymerize, up the performance properties. This process of thermoplastic selection, it doesn't affect the baking method, however rather solely flows out into the ultimate coating.Thermoplastic powders do not chemically react in a cure phase. Thermoset powder coatings are applied and then cured in an oven at a specific time and temperature The cure process will cause a chemical crosslinking to take place, changing the powder into a continuous film that will not re-melt.

1) Basic process

a) The compound granules area unit mixed with hardener, pigments and alternative powder ingredients in an exceedingly mixer

b) The mixture is heated in associate extruder

c) The extruded mixture is rolled flat, cooled and broken into tiny chips

d) The chips area unit polished and sieved to form a fine powder

E. Powder types

The powder used in the powder coating is made up of mixture of resin and pigmentsin powdered form. Types of powder used as under:

1) Polyurethane

2) Polyester

3) Straight epoxy

4) Fusion-bonded epoxy

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5) Hybrid epoxy
6) Polyester epoxy

These ingredients are melted, cooled and grounded to a consistency similar to baking flour. In term of application powder classified into three steps

7) Pre-treatment or surface preparation
8) Application of powder coating
9) Curing process

III. METHODOLOGY

A. *Several basic objective of the PDCA cycle are as under*

1) For improving the progress of the industry both for contractors and associates.
2) PDCA cycle acts as a channel for communication between contractors, associates, and the traders.
3) It helps to deliver beneficial services to members that cannot be obtained in small groups or individually.
4) To be the authorized voice of the coating application industry.
5) To spread an approach of moral responsibility in business.

B. *Plan-Do-Act-Check Cycle*

This PDCA cycle refers to the four step iterative management approach that preaches continuous improvement. The Deming cycle or four step problem solving process which is used in this approach are as under:

1) Plan: Choose the process and identifying & analyzing the problem within the process and set the objectives.
2) Do: Developing and testing the potential solution by implementing the plan and collecting data on the basis of the result
3) Check: Measuring the performance, how effective was the solutionand analyze the results using the statistical methods
4) Act**:** Implementing the improved solution properly or fully and decide what are the changes required in order to improve the process further**.**

IV. CASE STUDY

A. *Processes of blade of the fan*

Raw Material used of the shank is chromium and iron based alloy and for the blades of the fan mild steel and aluminum are used.

B. *Different processes*

1) Blanking
2) Piercing
3) Die
4) Zinc plating

C. *Pre- treatment*

1) Firstly the inspection of the incoming material storage is performed when the material ids coming from the vendor and on the other hand the powder & storage of the chemical is also inspected at the storage end. Quality and quantity is checked.
2) Pre-degreasing of the metal is done initially before putting into the first tank under running water.
3) Degreasing - In this tank bundle of 400 pieces is dip. This process is carried up to 10 minutes. Degreasing is mainly used to remove oil and grease from the blades. Degreasing cleans almost all types' size and shape parts. Degreasing is also called defatting or fat trimming.
4) Water rinse& Activation - After the tank 1 process the pieces is dip into tank. This process is doing frequently and passing blower after taking out the material.
5) Phosphating & water rinsing – This is done for making the corrosion resistance and lubricity and can be done by dipping the material into the dilute solution of phosphoric acid in the tank.
6) Passivation - This process is also doing frequently. This process is used to remove the aluminum oxide layer are formed on the surface of aluminum. This layer is a few nanometers thick. So to clean the pieces of aluminum blades this process is used in this process.

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7) Water rinse - In the last tank the bundle of pieces is clean with water. This process is also doing frequently.
8) Dryer- In this process the fan dryer is used for 10 minutes for dry the bundle of pieces. It is placed at the top of the roof. And the bundles of pieces are hanged below the fan dryer.

D. Assembly

1) Assemble the blade and shank with the help of rivet and washer. 1hole = 5.4mm .In the riveting process three same size of rivet are used to assemble. Three different types of code are used on rivet to specify the blades.
2) After this clean these with cloth and forward to the next process

E. Inspection

After completing the process of the powder coating the blades are inspected before packing them. Visual checking and dry film thickness (DFT)

1) Visual checking of color - The checking of color firstly done through visually. This is macroscopic checking of color of the pieces.
2) DFT meter – Film thickness in coating large impact on cost and quality. DFT meter is used to check the 50 to 65 micron of powder coating thickness.
3) Piece Inspection - Fan blade piece is fixing in the fixture as the fixture is set vertical and then measure the angle which is vary from 8 - 9 degree with the help of the bevel protractor. As once the angle is measure set the fixture in the position then the length is measured which is vary from 38 – 39 with the help of the height gauge. The weight of piece is also varying from 233 to 300 gm. But the average weight is varies nearby 234 gm. The weight is checked on weighing machine.

F. Plan Phase

This is the first phase of the PDCA cycle, in this defining the problem, identifying the root causes and planning for the improvement of the process.

G. Analyze the current state of the process

Current process is to be checked and analyzed with the objective to identify the gaps within the current process performances. These gaps should be improved in order to improve the productivity of the process. Data is collected after powder coating on the surface of blade of the fan which is a sample of 1000 blades. Defect is observed after powder coating on the blades of the fan are as under are:-

1) Over Heating (blackness) – 4
2) Dust – 3
3) Pit marks or pin holes on coated surface – 2
4) Uncoated surface – 18
5) Variation in upper & lower side of blade DFT – 12
6) Color variations – 9
7) Poor adhesion of powder to substrate– 6

No. of defects found for the sample of the - 1000
Defect counted - 149
Defect percentage 149/1000*100 = 14.9 %

Defects	Count	Cumulative count	Cumulative %age	% age
Over Heating	46	46	30.88	30.88
Dust	33	79	53.03	22.15
Pit marks or pin holes	25	104	69.81	16.78

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Uncoated surface	18	122	81.89	12.08
Variation in upper & lower side of blade DFT	12	134	89.94	8.05
Color variations	9	143	95.98	6.04
Poor adhesion of powder to substrate	6	149	100	4.02000

Table: calculation of the defect before implementing

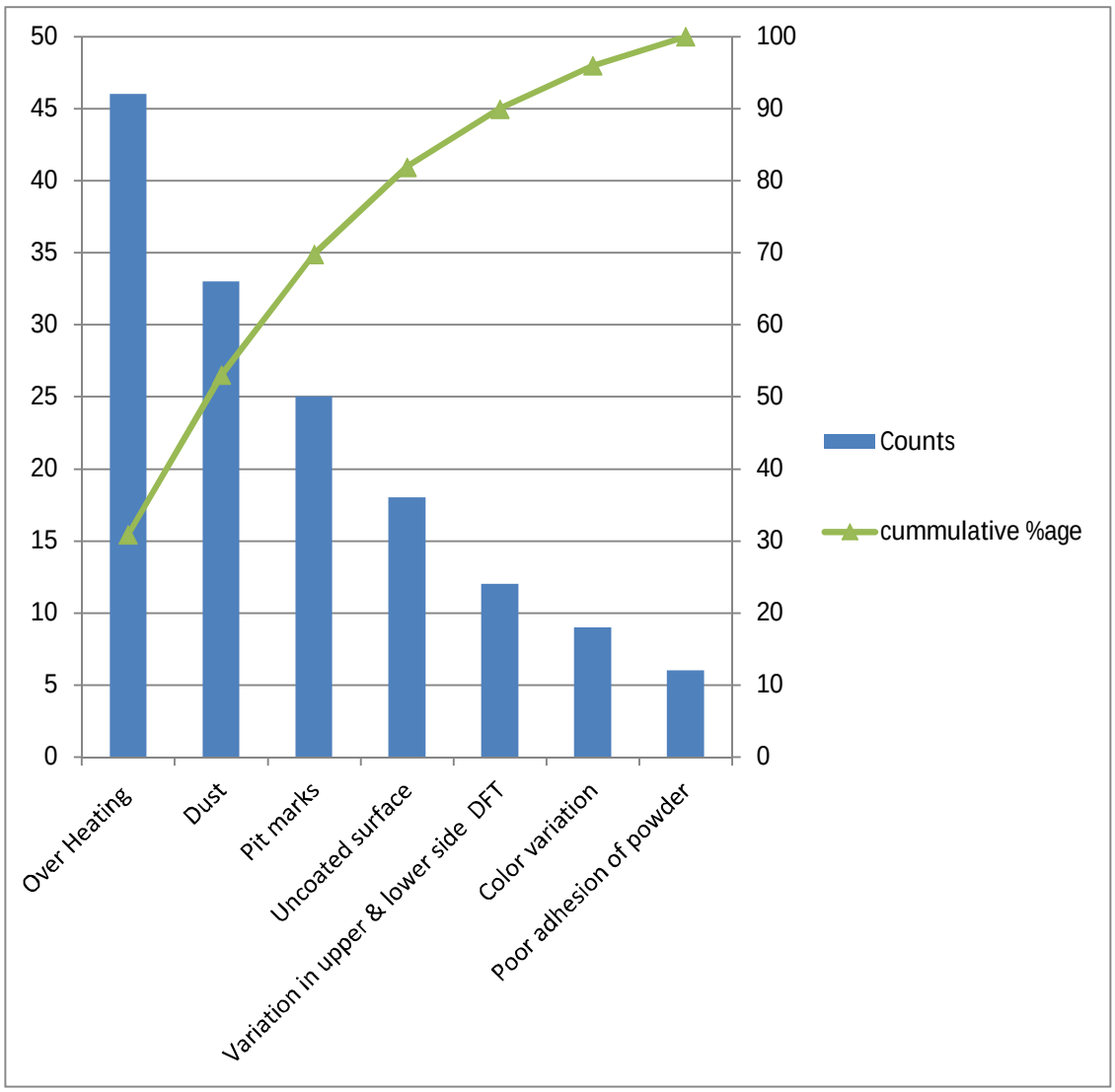

Fig. Pareto chart of the defects before implementing the remedies

H. Do Phase

This is the second phase of the PDCA cycle, as after knowing the problem and the analyzing the current process in the plan phase brain storming is required to find out the root causes of the problem in the process of the powder coating.

The cause and reason observed for the defect on the production line

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Sr. No.	Cause	Reason	Observations	Ok/Not ok	Cause Yes/No
1	Over Heating (blackness)	Heating sensor is not calibrated	Temperature sensor is not calibrated	not ok	Yes
2	Dust	From environment, from workers improper handling and storage of the powder	Poor housekeeping, worker without gloves, improper storage	Not ok	Yes
3	Pit marks or pit holes on coated surface	Moisture in powder, gas enclosure,	Improper storage of powder, poor house housekeeping, flow rate improper	Not ok	Yes
4	Uncoated surface	flow rate of powder, distance between gun & substrate, improper coating, charging or voltage problem	Clogged hoses, material is not cleaned before coating, gun problem,	Not ok	Yes
5	Variation in upper & lower side of blade DFT	Improper flow rate of the powder from spray gun, distance between material & gun, improper charging of the gun	Clogged hoses, less trained worker, worker skill not defined	Not ok	Yes
6	Color variations	improper mixing, uneven spray pattern, insufficient coating, variation in curing, residue of pretreatment	less trained worker, worker skill not defined	Not ok	Yes
7	Poor adhesion of powder to substrate	Uneven spray, insufficient coating.impurities on substrate, improper charging of the gun flowing of film from the edges of the metal	Parameters are not defined, no pneumatic system to clean the material before the coating, worker skill not defined	Not ok	Yes

Table observed defects on the production line

I. Defect occurs due to following factors

1) Heat sensor of the oven is not calibrated
2) Unclean working & storage area of the powder
3) Poor housekeeping.
4) Mishandling of the material while placing the blade fan on the conveyor chain.
5) Distance between the spraying gun and the material.
6) No cleaning system before the powder coating.
7) Clogged hoses of the gun and improper charging of the powder.
8) Sometime residue left after pretreatment

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9) Inspection of the material.

J. Result of trial after implementing the hypothesize remedies

Again the data is collected on the sample of the 1000 pieces of blades of the fan during the powder coating after changing as per the remedies suggested which is described as under are:-

1) Over Heating (blackness) – 17
2) Dust – 14
3) Pit marks or pin holes on coated surface –11
4) Uncoated surface- 9
5) Variation in upper & lower side of blade DFT -7
6) Color variations – 4
7) Poor adhesion of powder to substrate– 4

No. of defects found for the sample of the – 1000
Defect counted - 64
Defect percentage 64/1000*100 = 6.4. %

K. Check Phase

This is the third phase of the PDCA cycle in which data is gathered on the implementing the of the trail run. Measurement of the new processes and compared against the target set.

L. Remedies

1) Environment should be clean regularly
2) Improve house- keeping system
3) Cleaning of the spraying gun on regular interval of the time
4) Glove should be given to the workers
5) Oven heat sensor should be calibrated on prescribed time.
6) Distance of the gun and the material should be according to the manual.
7) Cleaning process is added before powder coating the material with a help of pneumatic system
8) Powder should be properly stored in the closed air tight container and the area should be cleaned regularly.
9) Check sheet and check list is implemented
10) Training is giving on the worker to do the powder coating as per manual

Defects	Count	Cumulative count	Cumulative %age	Percentage age
Over Heating (blackness)	17	17	26.56	26.56
Dust	14	31	48.43	21.87
Pit marks or pin holes	11	42	65.62	17.19
Cracking & splitting defect	9	51	79.69	14.07
Uncoated surface	7	58	90.63	10.94
Color variations	4	62	96.88	6.25
Water mark	2	64	100	3.12

TABLE CALCULATION OF THE DEFECT BEFORE IMPLEMENTING THE

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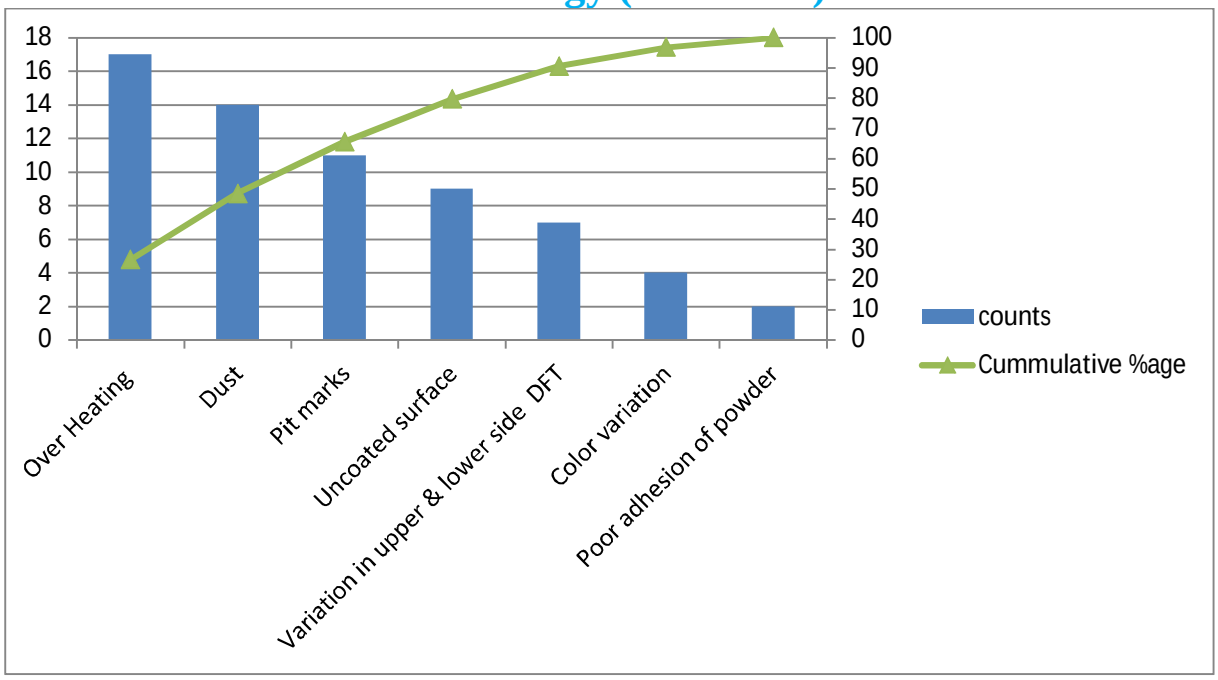

Fig. Pareto chart of the defects after implementing the remedies

M. Result

After calculating the above data the result is quite considerable which can be shown below in the form of the histogram below. The defect percentage is calculated on sample of 1000 before and after implementing the remedies which is as under

Defect percentage before implementing the remedies = 14.9 %

Defect percentage after implementing the remedies = 6.4 %

Difference of defect % before and after implementing remedies = 14.9 – 6.4 =8.5

So there is 8.5 % reduction in the defect % and the performance of the process is improved which is our prior necessity and goal of this study

N. Act Phase

This is the last phase of the PDCA cycle, as the improvement issues are applied and solved in the above phase. On the success of the study and experimental result of the applied remedies on the basis of the identified root causes of the problem, become the learning outcome and adopted method for powder coating. On behalf of this learning outcome, this method should be standardizing for the powder coating process. On standardization the process become improved on larger production.

Training should be provided to the worker in order to implement this process to the whole process for making the product better by reducing the defects and performance level is improved & maintained from learning of the each step of the PDCA cycle. This leads to the better productivity and increase the profit of the company.

V. CONCLUSION

This study is carried out to know how the production can be improved and help me to know how PDCA cycle can be implemented to the production line in order to reduce the defects in the process. In this case powder coating process is consider to implement the PDCA cycle in the process where it came to clarify that it is an iterative and systematic process which PDCA cycle can be implemented to the process in order to improve that process considerably. One can only get success if this process could be adopted in their process as a culture in the organization. By implementing this fact based result came into existence and can be accepted widely.This process should be monitored and seek further improvement of the process.

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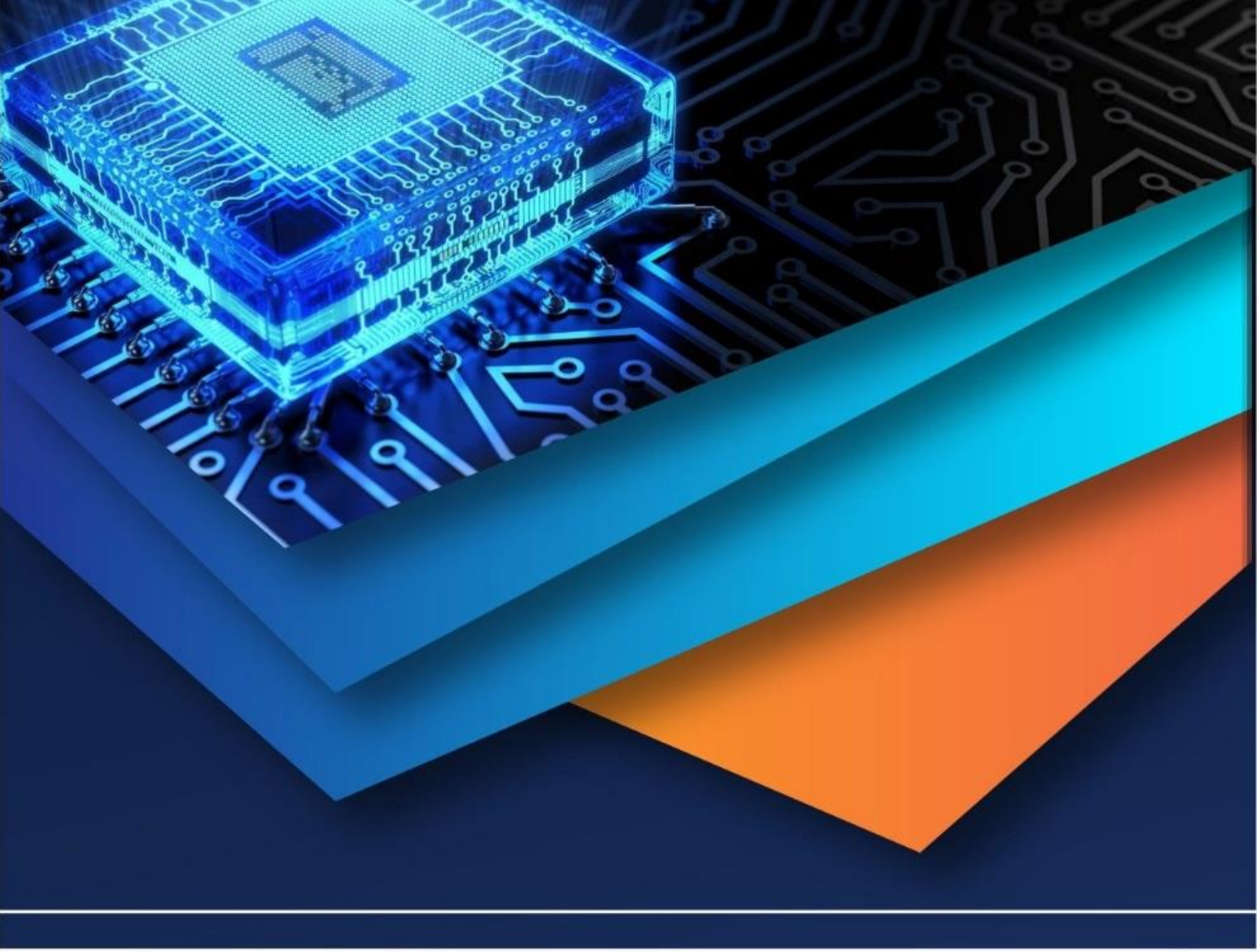

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