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Bits Reduction in the Electrodeposition Process of a Pickup Truck: a Case Study

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Abstract

Painting process is critical in the manufacturing process of commercial vehicle to provide both protection and decorative elements. Good quality coating is important to reduce cost and concurrently achieve customer satisfaction. A systematic approach and applications of the basics and advanced management tools and techniques are used to improve the quality of the coated body. One of the proposed approach is to utilise the PDCA-cycle to reduce the defects on the electrodeposited body. In the present study, the bits defect on the electrodeposited automobile bodies is investigated. Within the multilayer coating on bodies, the iron filing leads to the bits defect that appears on the electrodeposited coating surface. The iron filings arised from the metal assembly process carried out in the bodyshop, remained on the body during the painting process in paint shop.The defected surface can be removed through the process of sanding which is high in cost and requires extensive production time. Therefore, the best method to prevent the bits defects is by removing or reducing the iron filing through filtration, magnetic separation and surface adjustment process. The implementation of filtration system, magnetic separation and surface adjustment process improved 36% of bits and reduced 42% of sanding man hour with a total saving of RM40.00 per unit.

Keywords: *electrodeposition, defect, quality improvement, PDCA.*

1. Introduction

The goal of the painting process in the commercial vehicle assembly is to provide a uniform coating for protection and decorative purposes. Therefore, to successfully achieve the goal of painting, the process is segmented into a number of parts. These parts, or ‘layers’, are applied in a specific order and although the function of each ‘layers’ are unique, somehow there is interaction between the parts to achieve the desired balance of properties [1]. The multilayer coatings in the current technology include pre-treatment, electrodeposition (ED) primer, primer surfacer and wet on wet technology of top coat that consists of both base coat and clear coat. The functions of multi layers coatings are corrosion protection for primers, smoothness and chip resistances for primer surfacers, and colour and weather resistances for the final top coat.

The processes that carried out in the paint shop are pre-treatment and ED, sealing, ED sanding, primer coating, primer sanding and top coating. The pre-treatment of car bodies manufactured using differen metals critically require the state of the art corrosion protection and also provides the best adhesion for electrodeposition coating.

The ED process is a special coating method where the ED paint that is dispersed in water is electrically deposited on the surface of substrate to form a uniform and water-insoluble film. The primary process for ED is electrolysis [2], [3]. The fundamental aspect of ED is reported by Beck [4], whereby the ED process forms a uniform coating on the bodies for protection of corrosion. There are two types of electrodeposition processes, namely anodic and cathodic electrodeposition. The anodic ED relies on carboxyl groups, while the cathodic relies on amine groups. The disadvantages of anodic system is that it induces some dissolution to the metal ions of the parts that being coated. As a result, the resistance towards corrosion obtained coatings is limited and discoloration can occur due to the presence of the iron in the anodic films. On the other hand, cathodic ED was developed back in 1970s with several advantages, including high throwing power, superior corrosion protection, and virtually no absence of dissolution of metal occurring on the coated articles [5].

The ED process started with pre-treatment stage, namely are pre-cleaning, pre-degreasing, degreasing, water rinsing, surface conditioning, phosphating, final water rinsing and deionized water rinsing. After the pre-treatment stage, the ED process takes place; it includes ED, ultrafiltration and final deionized water rinsing. After

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the ED process, the coated unit is dried through oven baking process.

1.1. Quality improvement

A poorly cleaned body contributes negatively to the quality of the electrodeposited body. It is commonly known in the automobile industry that, many surface defects arise from the poorly cleaned surface after the ED process. As a solution, the defected surface on the body is required to be removed by sanding process before proceeding to next coating process which is the primer coating. Since the process of sanding is costly, it is very important to provide a good quality surface of the electrodeposited body. The good quality surface can be achieved by reducing the defects during the ED process. The common defects of the electrodeposited surface are bits, pinhole, cissing, sludge, grind mark and line mark. Due to the criticalness of having the defects, many studies have been conducted on the applications of reducing defects in automotive painting process.

One of the major defect from ED process is the bits. Accumulation of remaining particles within dipping tank is the root cause for producing the bits. Removal of these particles is possible by utilizing a set of a micro hydro cyclons combined with pressurised paper band filters and magnetic separation [6]. The commonly used method in the industry for the filtration system of pre-treatment and ED is by inserting the filter bag inserted into the filter housing for the particle removal. Standard filter types is the bag filters with particle retention ability of up to 25 or 50 µm. The polypropylene material in a needle is the common filter material. The filter bags are normally placed in a stainless steel basket, followed by placing this basket in a stainless steel filter vessels where the numbers of baskets could be between two and eight within a vessel. Thereafter the paint flows from top to bottom under pressure, however maintained as low as possible for best filtering effect. For best results, the filters are flushed and cleaned every week. Any damage filter can be identified by monitoring the pressure differences between the input and the output of the filter cartridges. The operation of the filter bag must stopped in the case of the presence of heavy particles and consequently the filter bags have to be replaced. The filter bags should be replaced to the coarser mesh-size that is > 100µm. The performance of the bag filter can be enhanced significantly by innovatively applying magnetism concept through the magnetic pre-filters [7]. An innovative novel filter is introduced due the inefficiency of the filter bag [8]. In the case of improving the defect that is occurring from the characteristic of the structure, the optimal location of supporting bonnet structure of automobile bodies was studied [9]. The quality problems frequently occurred due to accumulated dirt that supposed to be cleaned with cleaning agents. As a solution, the implementation of ON/OFF confirmation logic control based spray was carried out to ensure that the body passes through proper cleaning process [10].

The PDCA-cycle is a dynamic model and an intergral part of the process management which is designed to be used as a dynamic model because one cycle represents one complete step of improvement [11]. In order to coordinate the contionuous improvement effort, the PDCA-cycle is utilized. In the plan-stage the problem is identified using Pareto-chart and subsequently the root cause is analysed through cause and effect diagram. The Pareto-chart a special type of bar charts in which the categories of responses are listed on the X- axis, the frequencies of responses (listed from largest to smallest frequency) are shown on the left side Y-axis, and the cumulative percentages of responses are shown on the right side of Y-axis. The cause and effect diagram is is a tool used to organize the possible factors that could be negatively impact the stability, centre, spread, and shape of a critical to quality (CTQ) characteristics measure [14]. A brainstorming session is conducter to identify the main rootcause item [13]. Following to that, in the do-stage the implementation of the filtration and magnetic separation, there will be measurement on the effect of the implementation in the check-stage. Finally in the act-stage, the results of the implementation is interpreted and the PDCA-cycle is restarted again to sustain and improve process further.

2. Problem Analysis

In the plan-stage the major problems are analysed based on the collected data on defects occurred after the ED process, where these defects are detected on the coated surface after the baking process through visual inspection. In more details, the bright lights and the associate reflections measured through visual inspection are used for locating and evaluating any defects. Some of the defects found are bits, grind mark, rough surface, line mark, sludge, pinhole, mapping mark and sanding mark. As a method to identify the main problem, the defects are plotted in a chart as depicted in Figure 1. Based on the chart, it can be observed that the main problem is the bits that accounts for 93 % of the overall defects.

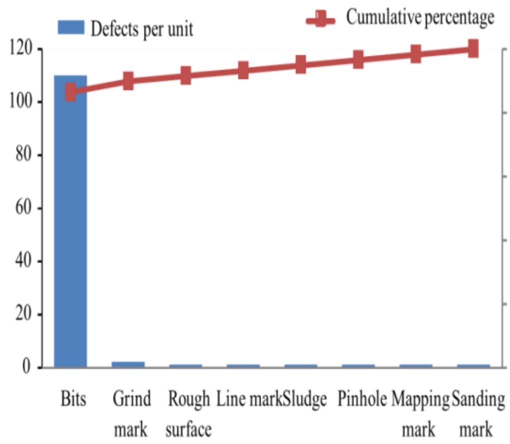


Figure 1. The electrodeposition defects

Therefore, bits are selected as the main defects that critically requires a solution. Bits are basically foreign materials that are found to be sticking on the coated surface. By using microscope, the bits can be observed to be iron filing, phosphate bits and electrodeposition paint bits. In terms of characteristics, the shining and rusty particles are the iron filings and the whitish and powdery particles are both the phosphate bits and ED bits as depicted in Figure 2.

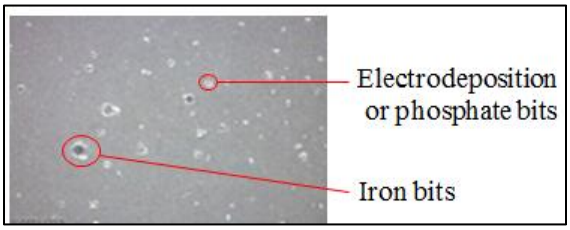


Figure 2. Depiction of bits

Defects categorizations based on percentile are shown in Figure 3 where the highly occurring bit defect is iron filing with up to 55% of occurance bit.

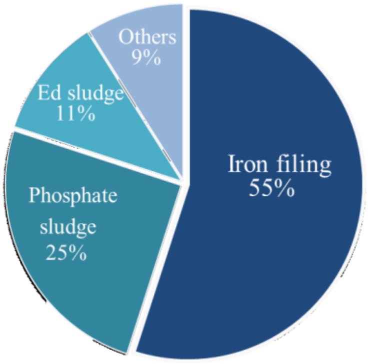


Figure 3. Bits categorization chart

The iron filings originate from the body assembly process at the Body shop, where the process consists of spot welding, welding, grinding, and sanding process of the assembly of the metal part. The actual iron filings found on the body in white is shown in Figure 4.

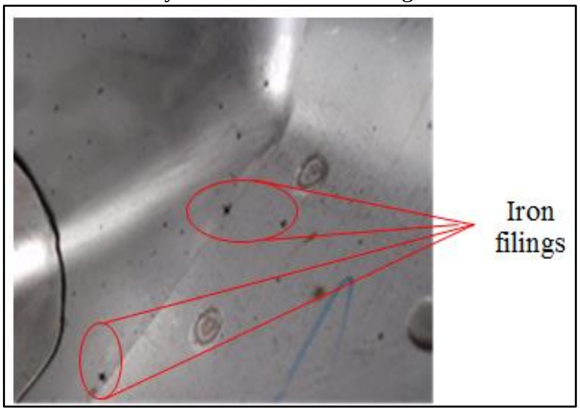


Figure 4. Iron filings on body in white

The root cause of bits is analysed by using Ishikawa diagram as shown in Figure 5. The analysis is divided into four main factors, namely man, method, machine and material.

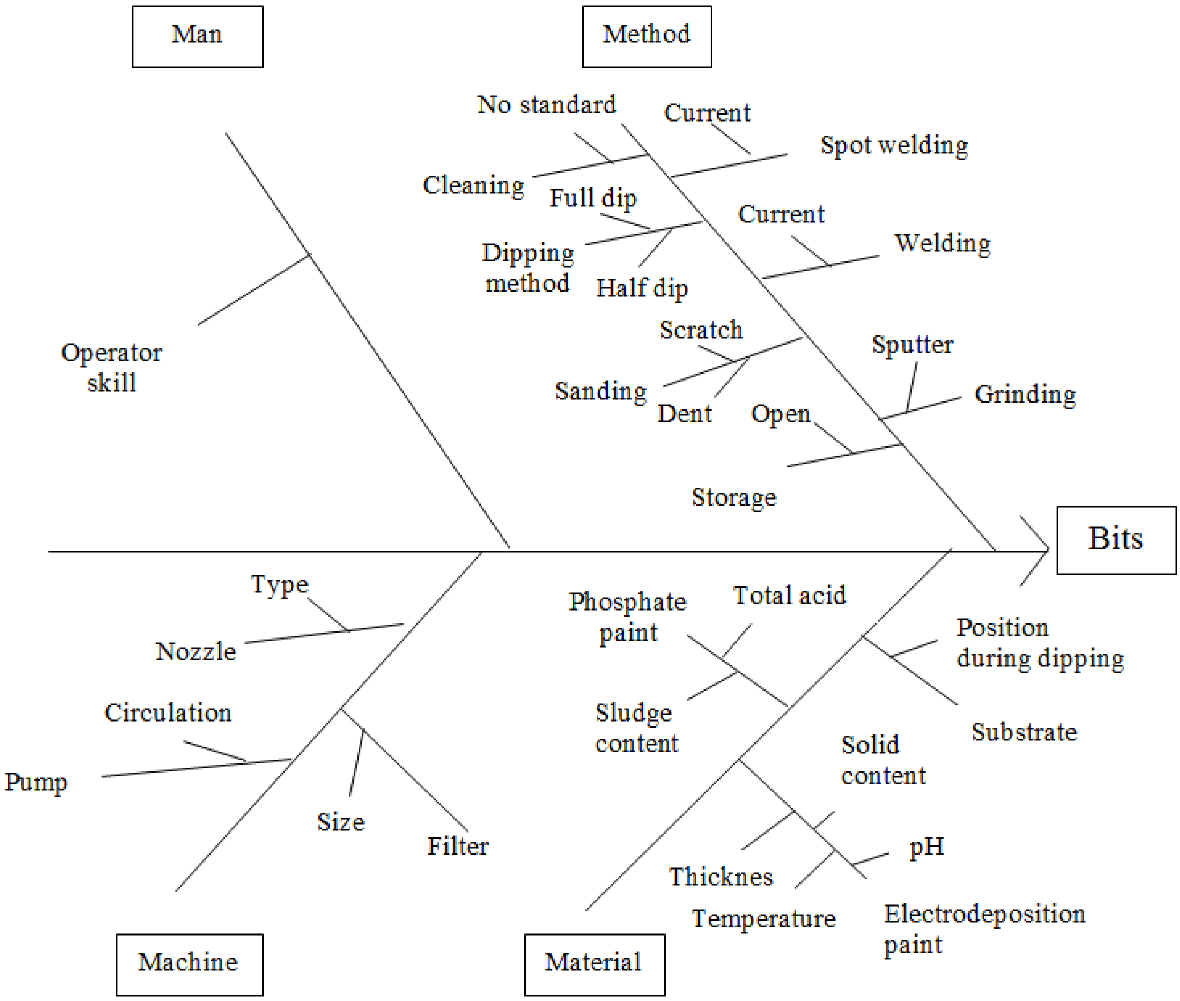


Figure 5. Bits rootcause analysis

2.1. Rootcause through Man

In terms of the man factor, an operator's skill towards spot welding, welding, grinding, and sanding process directly influence the defect volume of the iron filing. The operator's skill is controlled by a skill chart and is evaluated each month. However, specially for the welding operation, only a certified skilled operator is allowed to perform the welding process.

2.2. Rootcause through Method

The processing methods in a Body shop that produces the iron filings are spot welding, welding, sanding and grinding. The spot welding and welding processes are the steps taken to assemble the metal parts to build a complete body. Additionally, during the assembly process both spot welding gun and welding machine are used and followed by grinding process through portable hand grinder to grind the sputter that are produced during the spot welding process. Finally, in order to

produce a smooth and good surface for the subsequent painting process, defects including dent and scratches on unit are smoothened by using the sanding machine. The methodologies for removing iron filings in every processes are discussed. In the case of iron filing reduction in spot welding process and welding process is conducted by periodical checking of the current parameter once in every three months. For the sanding and grinding processes, the defects including sputter, dent, and scratch are controlled. Furthermore, a cleaning method is established to clean the body to clear off the iron filings before delivery to paint shop. The body is then vacuumed with high pressure vacuum and cleaned with sew rag and subsequently stored at the White Body Storage (WBS) area. In order to prevent the accumulation of iron filing inside body during storage in WBS, the buffer quantity at WBS is controlled. However, there are still iron filings remaining on the body which are carried over to the paint shop. Some of the remaining iron filings on the body may settle inside the dipping tanks during the pre-treatment and ED processes. The dipping methods are half dip or full dip. Therefore, it is very important to note that minimising the iron filings at the body shop stage itself is critical to reduce any accumulated defetcs that are carried over to the paint shop.

2.3. Rootcause through Machine

Some of the the machine used in the processes are inclusive of filter, pump and nozzle. The iron filings removal inside a tank depended on the filter size and number. The left over foreign materials must be reduced through this filtration system. In the case of the pump, the workabilities of spraying pump and circulation pump are involved. The spraying nozzle type determined the spraying efficiency on the body whereas the spraying angle ensured the nozzle is sprayed at the correct angle to remove the iron filings on the body.

2.4. Rootcause through Material

The substrate, ED paint and phosphate paint are material factors that contribute to the bits. The paint formula, bath paint and pigment particle size within ED paint that leads to the generation of bits. The paint formula is the paint formulation that include resin composition, ash content and additive. For bath paint, the contents that contribute to defect are solid content, pH and bath temperature. These parameters are unequivocally controlled according to the standard specifications provided by the paint supplier. Furthermore, the paint supplier would provide weekly reports of the parameters control. The grinding condition affect the pigment particle size where the phosphate paint factors are in the form of sludge and crystal sized. The phosphate sludge is generated after the chemical reaction with body and is filtered through filtration system. Besides, the substrate position during the dipping also influenced the bits count on units.

For initial countermeasure, it is proposed to remove the iron filings inside the dipping tank by filtration system and magnetic separation. In filtration system, smaller sized filter is used to trap the iron filing, while magnet bar utilized in magnetic separation to attract the iron filings. By applying these two countermeasures, the amount of iron filings inside the dipping tank is expected to be reduced.

3. Experimental condition

In the first cycle of do-stage cycle, a filtration system is installed in the dipping tank to trap the iron filings within the dipping tank itself. There are ten dipping tanks for the Pre-treatment and ED processes. The filters are installed in the Pre-treatment tanks that consist of both circulation and spraying systems. The circulation system is used for the liquid circulation inside tank where the body is dipped into,where else, the spraying system is located in upper portion of the spraying tank to rinse the body after the dipping process. The size and quantity of the filters installed in the tanks are described in Table 1. The filter bags are placed in the stainless steel basket and together positioned inside the stainless steel filter vessel. In the filter bag, there are magnets with 9000 gausses strength to capture the iron filing through magnetic separation method.

Table 1. Filter quantity and size for according to tank functional areas

Tank No and Name	Spraying filter		Circulation filter	
	Quantity (unit)	Filter size (micron	Quantity (unit)	Filter size (micron)
1- Pre degreasing	2	25	8	50
2- Degreasing	2	25	8	50
3- Water Rinse 1	2	25	3	50
4- Surface Conditioning	2	25	3	50
6- Water Rinsing 2	2	25	3	50

The material of the filter is based on the nylon, which can be washed and re-used for repeatable filtrations. The complete filtration system is shown in Figure 6.

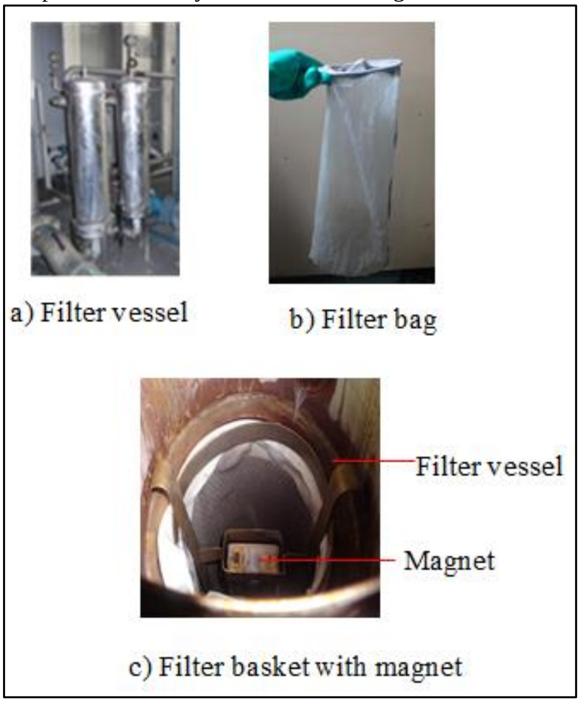
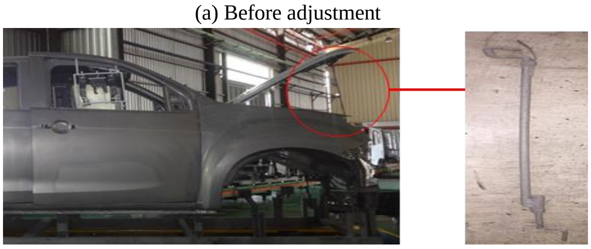


Figure 6. Filtration system with filter bag and magnet

In the second cycle of do-stage, the position of the bonnet is changed by modifying the bonnet stand, where the bonnet stand is designed to hold the bonnet during the ED process. The specification of the bonnet stand is modified from 315 mm to 730 mm in length, while its position is adjusted from 25° to the highest, 70°. Figure 7 (a) shows the position prior to the bonnet adjustment and Figure 7 (b) shows the bonnet position after the adjustment. Finally, the bits count on the bonnet area is measured after the oven baking process.

(a) Before adjustment



(b) After adjustment

Figure 7. Repositioning of the bonnet

4. Results and Discussion

The iron filings are trapped inside the filter after the installation of the filtration system. The trapped iron filing inside filter bag is shown in Figure 8.

Figure 8. Iron collection inside the filter bag

The quantity of the bits on the coated surface is shown in Figure 9. The amount of bits that can be seen and felt by hand are counted in a 100 millimetres square outside of the coated body. The measurement is taken at the three surface areas, namely roof surface, bonnet surface and door surface. The bits count before the experiment are recorded and presented as depicted in Figure 10. The bits counts on the roof surface, bonnet surface and door surface are 58, 45, and 7, respectively. Most of the bits are accumulated on the roof area as compared to door and bonnet due to the difference in the surface orientation. The roof is in horizontal orientation, while the bonnet is 25° and the door is in vertical orientations.

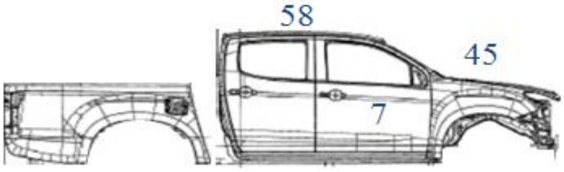


Figure 9. Bits counts on the unit before the experiment

The bits counts are improved 25%, 27%, and 29% at the roof, bonnet and door surfaces, respectively, after the filtration system and magnetic separation. Details of bits counts comparison before and after the installation of filtration and magnetic separation methods are illustrated in Figure 10.

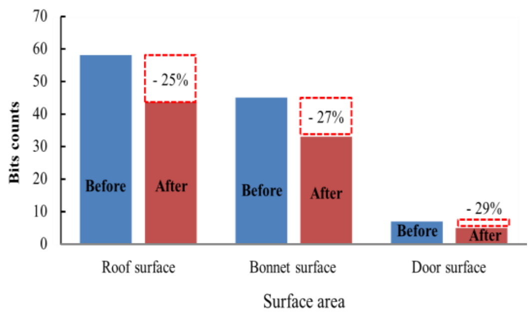


Figure 10. Comparison of bits counts before and after filtration and magnetic separation

Before the application of the filter, iron filing size in the range of more than 125 µm was found on the coated surface. However, with the filter application, the size of iron filing detected on the surface area became much smaller to only 56 µm. The filter is effective in trapping the iron filing that is size bigger than 56 µm. The iron filings that sized more than 125 µm escaped and less than 56 µm remained and sticked onto the unit. The size of the bits is identified by microscope as shown in Figure 11.

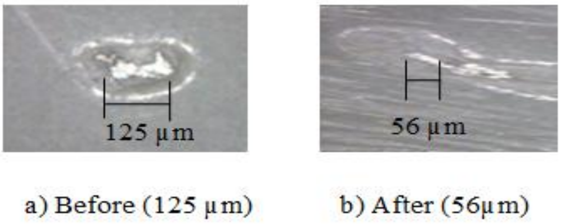


Figure 11. Bits size on the unit

Since the bits count on the vertical area is very low, the PDCA cycle two is conducted and implemented by slanting the vertically positioned bonnet. To reduce the bits on the bonnet surface, the bonnet position was shifted from 25° to 70°. The adjustment of the bonnet position improved the bits counts on the bonnet surface by 34% as illustrated in Figure 12.

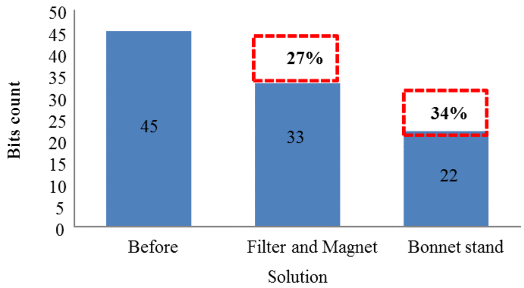


Figure 12. Bits count on unit after bonnet adjustment

By the implementation of the new bonnet stand, another quality problem related to the ED process was improved, which is the air pocket issue. The air pocket is formed due to the air trapped at the inner part during the coating process. The surface area with air pocket exposes the surface area to corrosion due to not having ED paint on that surface area. There is no formation of air pocket found after changing the bonnet position. The bonnet's inner surface area with the air pocket formation is shown in Figure 13 (a) and the bonnet inner surface area without the air pocket formation is shown in Figure 13 (b)

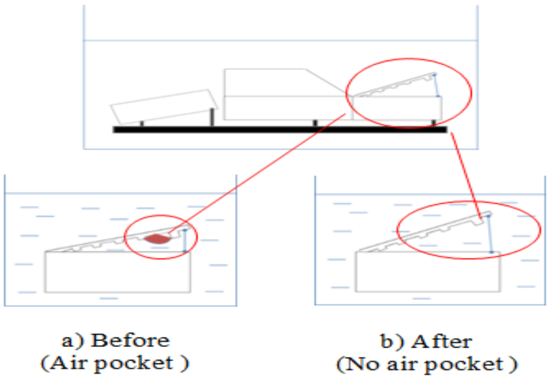


Figure 13. Bonnet's inner surface comparisons after bonnet adjustment

By applying the filtration and magnetic separation methods into the dipping tank, the rework activity of sanding on the surface area was reduced. Therefore, the man hour, manpower and sanding disc consumption are reduced. The reduced items are illustrated in Table 2. The man hour is reduced from 0.45 to 0.26, while the manpower is reduced from 8 persons to 6 persons. The sanding disc consumption for sanding activity is also reduced from 8 to 5 pieces per unit. By translating these figures into cost, this activity contributes to the saving of RM 3.00 on sanding disc consumption and RM 37.00 on man hour cost.

Table 2. The reduced items before and after the countermeasures

Item	Before	After
Manpower	8 persons	6 persons
Man hour	0.45	0.26
Sanding disc consumption	8 pieces	5 pieces

5. Conclusion

The main defect of the electrodeposited surface was the generation of bits. The major contribution of the bits was iron filing that was generated from welding, sanding, grinding, and spot welding processes at body shop during the metal assembly process. The iron filings were carried over to paint shop and accumulated inside the dipping tank. By introducing the filtration and magnetic separation methods into the pre-treatment system resulted in being successfully reducing the iron filing inside the tank. Through the proposed method, the number of bits improved by reducing up to 25%, 27%, and 25% on roof surface, bonnet surface and door surface, respectively. The number of bits is further reduces by 34% after the adjustment of the bonnet stand. The average number of bits reduced was by 36%. In the perspective of the operational expenditure, the sanding man hour used to improve the electrodeposited surface is reduced by 42% with a total saving of RM40.00 per unit.

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