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Improvement of Automotive Paint Blistering in Production Line

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ABSTRACT

Painting the body and other elements, such as the wing or bonnet, is one of the costliest aspects of vehicle manufacturing. Surprisingly, the painting could cost even more than the body itself. The high expenses are due to the processes involved in the painting process rather than the machines used in the paint shop. From this perspective, it is evident that automobile makers constantly monitor the painting process to avoid any deviations from the desired outcome. Therefore, this paper aims to investigate the impact of blisters, one of the most common painting faults, and offer suggestions for improvement. The Ishikawa diagram was referred to measure the blister root cause. A few possible root causes were derived and later studied to create a trial. The trial showed the actual result needed for the production team to tackle blistering issue. The setup for the painting process required the optimal adjustment of different parameters such as humidity, temperature and the consistency of the lacquer itself. To eliminate the blister and other paint shop defect, a proper guideline and proper maintenance of the paint shop itself are needed. For long term solution, it needs to have a new build up paint shop equipped with all the current technology such as robot spray to eliminate too much rework on the unit before conducting top coat spray. From the present analysis, it can be summarized that the major root causes of blister are the trapped air and sweat of the operator during the preparation process.

Keywords: blister, automotive paint, paint shop, automotive production, paint defect

Abbreviations

ED	electrode deposition
FQG	Final Quality Gate

1.0 INTRODUCTION

According to psychology of seeing, colour is described as "the eye as a ball with two holes; light enters at one of them, the pupil and the nervous message leaves at the other, the optic disc, where the fibers of the optic nerve lead to the brain" [1]. Besides that, colour is also described as a quality to the surface of physical objects. Perceiving the true nature of colour consists of the simple opening of one's eyes and letting the right type of stream enters. Physical colour is a characteristic of a visual radiation, whereas perceived colour is an aspect of visual perception. It is like saying that the colour is defined as the way of our eyes seeing the physical of thing, which is then later defined as the colour characteristics of red, blue and green.

The history of automotive paints started in early 1900. It started in 1910 which is roughly 6 years after Henry Ford founded Ford Motor Company. These coatings were products from the "varnish" category. The process of painting a car in those days took a long time to finish. It can take as long as 40 days to finish painting for one vehicle [2]. The painting process was much like old wood coatings. The technology was based on the same air-dry varnish systems and used for carriages equipped to a horse and also the wooden furniture [3]. They were brushed on the surface of the car which was then allowed to dry. The coating was then smoothly sanded and refinished in the same manner. After it had achieved the desired thickness, the surface was polished and cleaned. This system was used until the mid-1920's. However, the drawback of the system is that only black colour can be used for painting the automobile [4].

In 1923, a nitrocellulose lacquer system was developed which offered many colour choices and easier application [5]. The lacquer systems required a spray gun that was invented by a dentist and to achieve the desired properties, the vehicle required spray application of 3 to 4 coats of paint [6]. The spray gun application is much

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faster than the brush method. It minimizes the sanding between coatings and applied product evenly. But the lacquer also has a drawback as it has poor resistance to certain chemical solvents like gasoline. Continued exposure of gasoline spills could stain and damage the lacquer finishes.

Later, a major development in paint technology using "stoving enamels" based on alkyd resins was developed. The product was selected because it has a higher gloss yield than varnish [7]. Enamels form a durable film through chemical reaction after they are sprayed on the vehicle and baked in an oven. It is resistant to chemical and solvents, and can be applied much faster [8]. It can add many different choices of colour for the consumer. However, the paint oxidizes in sunlight fairly quickly. The colour begins to fade and dulling when exposed to sunlight in several weeks. This system was used by most vehicle manufacture until 1957, when solution acrylic lacquers were introduced to improve the durability of enamel finishes. It offered much improved durability and wider range of bright and pleasing colours especially metallic [9].

The new acrylics was used in the process called "reflow". Based on the same process as alkyd resins, the vehicle was baked in the oven after it has been coated on the surface with the product using spray gun [10]. Baking the vehicle in the large oven caused the solvents to evaporate and the product to flow to form a smooth finish on the vehicle surface. Although the gloss was not quite up to the level of stoving enamels, it was quicker and efficient. It can help the manufacturer to save more time and money as well as build the product much faster. The "reflow acrylics" was a popular system until 1960 [11]. In 1960, the Ford Motor Company realized that most of the consumers purchase a vehicle based on the colour of the car that is shiny and glossy. So they went to work with another new group of suppliers to create "acrylics stoving enamels". Ford Motor Company at that time had the best method to offer the consumer to purchase their vehicle. It was not long before the competition kept pace. This product was also applied using a spray gun [12]. It had high gloss, durable and oven cured to produce a hard and colourful surface. The "acrylics stoving enamels" was popular and used by the manufacturer until the early 70's.

In 1970, the application of two-coat acrylics painting systems was used by the Japanese and the Europeans. They provided the consumer with metallic or metal flake paints on their vehicle [4]. The Americans loved it because of the unique and different colour provided. Later in the decade, manufacturers were looking for harder paint and more resilient elements that could dry faster [13]. They found a way to achieve that by including a "cross linking" free radical additive in the formula. A catalyst was added to the paint. The product was sprayed on and the process of curing began. This process became more popular for larger vehicles like airplanes [4]. It is still in use today in both acrylics' enamels and newer polyurethane products. But it costs too high for vehicle applications.

Blistering and bubbling are frequent coating issues that can be caused by a variety of factors. The presence of bubbles or blisters in wood, plastic, metal, or other materials can result in severe production losses [14]. Since the external surface of a vehicle is very noticeable, the automotive coating requires critical surface appearance and corrosive protective properties [2]. Surface defect such as blister is highly essential to prevent or treat because it affects both the look and the effectiveness of a coating to offer protection and corrosion. Some faults might be avoided by controlling rheology and surface tension during application, drying, or baking, as detailed by Schoff [15], while others could be corrected by maintaining a high degree of cleanliness in the paint plant or improving the substrate surface quality [16]. The blister problem is one of the highly problems which always occur even after the unit has been out of paint shop, without the proper explanation.

During the application of the paint layers, a variety of faults might develop. One or two spray painting is perhaps the worst feasible approach for painting vehicle bodywork in terms of faults, but it is the only one that delivers the desired aesthetic so far [17]. Foreign substance is the most typical defect (dirt). Every auto factory has to fight dirt and application defect on a daily basis. Although application errors resemble dirt, they are caused by spray process flaws such as spits, drips, and overspray [18]. Blisters in Figure 1 are dome-shaped flaws that most commonly form when a coated item is immersed in water, although they can also form when water falls on a horizontal coated surface when the coating is subjected to excessive humidity. Corrosion can cause blisters as well. If non-corrosion blisters do appear on an auto finish, they do so early in the coating's life [15]. Thus, this paper aims to solve the problem of blistering defect during production process in the automotive paint shop. In addition, the paper investigates the impact of blisters, one of the most common painting faults, and offer suggestions for improvement.

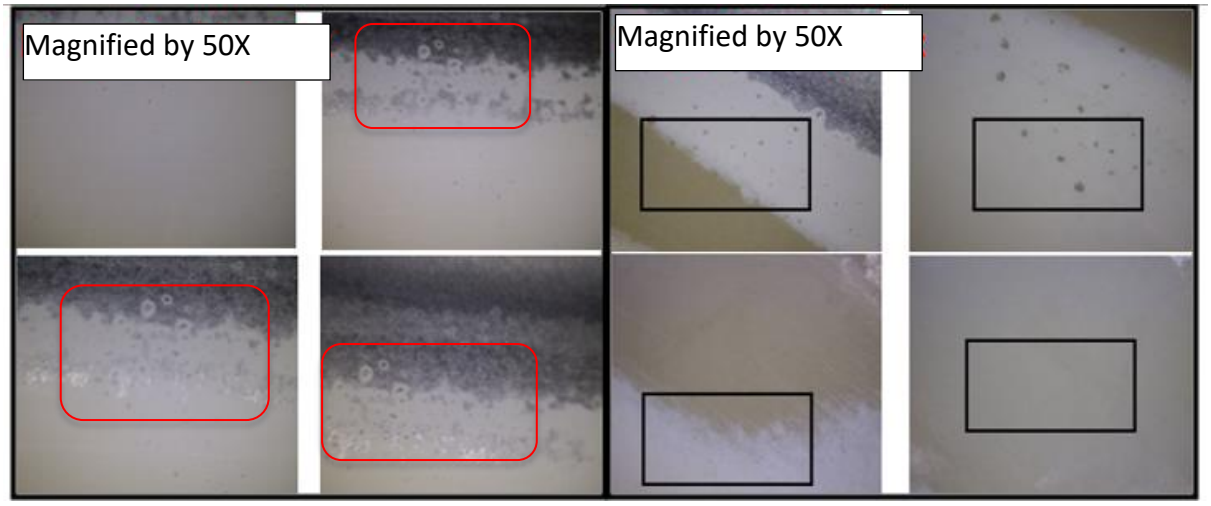

Figure 1. Blister Trend on Ed Surface

2.0 METHODOLOGY

In this research, Kaizen methodology was followed where the plant floor was visited directly and the problem was identified. Problem identification and analysis were made with the help of microscope to recognize the blister. Regarding the root cause analysis of the problem, the Ishikawa fish diagram was used to find the possible root cause of the blister. The possible root cause was then applied to create the line production trial with steel plate to create blister defect. In the end, the graph before and after the implementation of countermeasure and the graph of quality in the line were plotted to see the reduction in blister. Thus, this was used to validate the observed results. The methodology used for this research is shown in the following Table 1. From the possible root, the actual root cause can be defined accordingly.

This case study can be categorized as applied development research since the result gathered from the action is taken to eliminate the defect in the paint shop for automotive painting process [19]. In detail, this project is carried out to find the possible root cause of blister.

Table 1: Kaizen methodology description

Item	Description
Problem Identification	Description of what is blister and when it occurs in the production line
Data Collection	Data of blister defect on the production line is collected at each station.
Root Cause Analysis	The root cause analysis is done based on the data collected and based on the trial done with the steel panel to produce blister.
Develop Countermeasure	Ishikawa fish diagram is used to determine the countermeasure to be implemented.
Implemented the Countermeasure	These improvements are then implemented in the production line.
Evaluate the Countermeasure	The countermeasure is then evaluated by counting the blister occurrence in the production line at the final quality gate.

2.1 Problem identification and analysis

Blister is one of the major defect contributors in painting shop problem besides dirt and fibre. Blister problem occurs upon completion of the painting process and mostly detected after the buy-off process of the unit. The production body with blister is then studied to found out if the defect is actually blister of another defect. It is because the dirt and bubble defect look similar as the blister. A visual observation was carried out on the painted panel and blister defects were marked and recorded by a digital camera. The macroscopic view of blister defects on the painted panel is shown in Figure 1. The defects were less than 0.5 mm and they appeared as tiny dark spots from a side view. The surface topography of the defect was recorded by an DYNOLITE camera measuring laser microscope.

The defect was then studied to identify the type of blister. Specifically, it identified the actual problem of blister which affected the company. The blister affects the company by increasing the take time and cost of production if they occur. The defect takes a long time to be repaired and has to be repaired down to the electrode deposition layer. The monitoring graph is collected to define how serious the blister problem is in the painting process [20]. The present work answered the problem that the paint shop is facing and how to handle the problem by finding the suitable solution for the defect problem.

The possible root cause for the blister defect was measured. The possible root cause was listed using the fish bones method. This helps to see the whole picture of painting process connected with the defect that occurs during the process. Trial was conducted to see if the defect could turn up in certain conditions. If that is the issue, some of the possible root causes can be eliminated and be focused on the actual connected cause that is close to blister [21].

2.2 Data collection

The data of blister occurrence were collected before and after the process improvement at the respected quality gate. The effectiveness of the solution was then measured by collecting the data from the quality side. There were 3 places where the data for solution countermeasure were collected. The first place was after the electrodeposition process before the car body entered the primer spray booth. The second place was to collect the quality data after primer coat process of coating process. This was the finish product of the car body. The last quality gate for blister checking was the FQG (final quality gate) situated after the top coat and polishing process. The reason for taking three time measurements was because blister took time to develop and occur on the car body. Later, the data were analyzed to see if the countermeasure brings any change to the quality of the product. The comparison data of before and after blister occurrence were then plotted in a graph as presented in the result and discussion. This graph focused on the final quality gate.

Blister defects are count on the occurrence of each blister in the production body. This can be evaluated by the quality person. The quality person writes down the blister defect if found on the production body when he/she checks it at the final quality gate.

2.3 Root cause trial

The action plan was created based on the analyzed data from the possible root cause method [22]. Each possible root cause was analyzed to construct the most appropriate recommended solution [23]. The solution or countermeasure brings new breath to the painting process in the automotive paint shop. Some of the countermeasures can be applied even in other company which practices manual painting process. Trials were run using a test panel provided to make sure that the blister came from sweat of the operator. Two ED panels were prepared. The first ED was with the alloy Zink and the other ED was without alloy Zink. The trial run through the normal process in the paint shop. The only difference was when the test panel reached the operator at the moist sand area before the top coat, the operator purposely touched the panel without using glove. Then, these test panels continued to the next process. After finishing drying for base coat, polishing panel was kept inside the box in the humidity condition and monitored for 2 days. The result for this panel trial was then reported in the root cause trial.

3.0 RESULTS AND DISCUSSION

3.1 Blister analysis

Special work team was formed and called as Quality Improvement team. Analysis of the blister was done by the help of this team. The number unit being analyzed was 18 cases. From these cases, 2 blisters were found between electrode deposition (ED) process and primer, the other 6 cases were found between primer and base coat colour. The first unit to be analyzed was a unit with blister at the right hand side of the front door. This unit was found with blister on November 2020. The blistering (from contamination) appeared on the paint surface with irregular blister pattern. During the observation using DYNOLITE, the blister looked like a pimple-like bumps or some kind of water in between the ED and primer surface. After layer sanding, it was confirmed that the blister appeared on the ED surface. The suspected root cause from this analysis was that the operator at the ED sanding conducted the sanding with contamination from outside; hence, leading to blister.

The second analyzed unit was the unit with blister which appeared on right hand side of C-pillar or in other words the fender. The blister appeared on dried paint surface and looked like a pimple and bumps or water mark. After layer sanding process by using the DYNOLITE, the blister was believed to be on the top coat layer as shown in Figure 2. This might be due to touching the unit with bare hands during the touch up paint process.

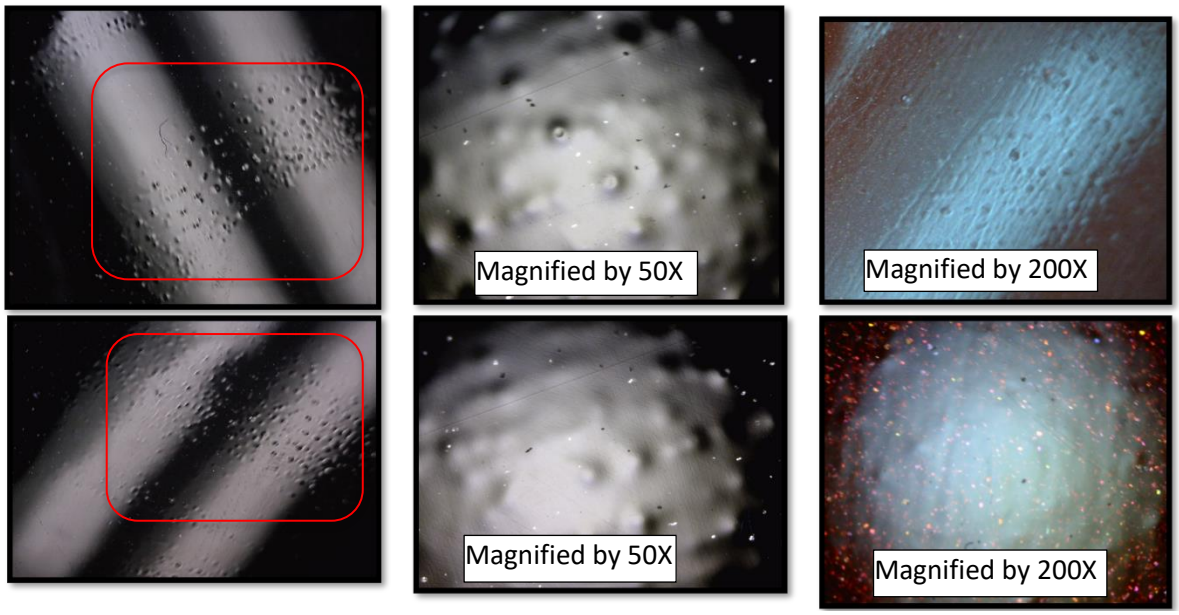

Figure 2. Blister trend on Top Coat Surface

3.2 Containment action

Root cause for the blister was list downed in terms of Ishikawa diagram or fish bone diagram as shown in Figure 3. All the possible root causes from Ishikawa diagram were done. This was then converted into the cause and effect analysis diagram in Table 2. These trials were run with the main objective to create blister from the brainstormed cause of blister. Only one of the trials managed to create blister which was the sweat from the operator hand while doing the moist sanding on the unit.

Table 2: Cause and effect diagram

No	Item	Activity	Result	Status
1	Mist and wind from sea	Panel test with various parameters and in various conditions - Mar 2011	No blister detected on all panels	x
2	Sweat from painter			
3	Oil on hands			
4	Bacteria in DI water	Continuous monitoring for bacteria level in DI water and ED tank	On-going	r
5	Rust on bare metal surface	Trial on lot C-Class PM 08 Lot 13 to create blister at LH Frt Fender and trunk lid through different method of sanding	UMP unable to check sample. DAG result not blister	x
		Checking presence of blister on 4 Lot, 2 lot C-Class and 2 Lot E-Class with no metal rework carried at B21 (except rework at metal finish)	Blister detected but not on marked surface	
6	Long period BIW storage	Checking the duration of BIW from Body Shop off until ED ON	Data Show no relation to blister	x
7	Water contain in wiping thinner	Checking the presence of water in wiping thinner in each line - Oct 11	No water detected	x

8	Process parameter control	Conduct PTED chemical analysis for PTED to 3rd party lab	On-going	r
9	Reactive liquid that can cause blister	Conduct paint durability test against any liquid material available	On-going	r
10	Wet sanding process	Conduct dry sanding trial at primer sanding	Same result with wet sanding. Still has blister	x
11	Sweat from operators	Conduct test for blister on various touching and sweat to layer and time	On-going. Got panel on 6/4/2012	r
12	Evaluation of tag rag effect	Conduct test on tag rag effect based on used/new tag rag and heat and pressure effects	No blister detected on all panels	x

Legend: x - not relevant; r - under study

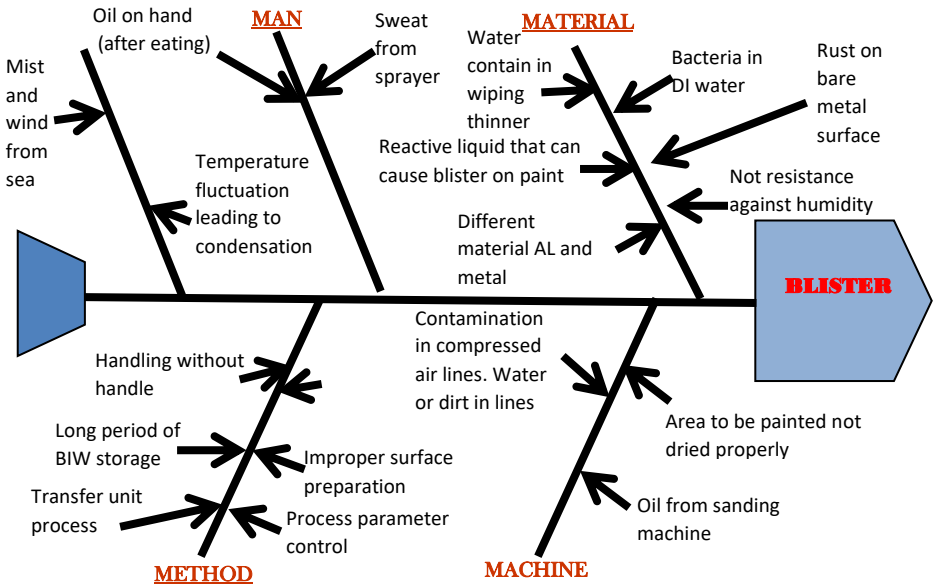

Figure 3. Ishikawa diagram for Blister contamination

Figure 4 shows the trial method done to create and test the subjected root cause of blister in the production line. After two days, the panel started to produce blister on the paint surface. This trial used black colour paint. The second trial was conducted on the two units itself with the same method, but the only difference is that the unit was allowed to go through wiping process. The result for this second trial showed that the blister occurred on the first unit only after 1 day the unit was sprayed by the paint shop. The second unit for the second trial did not develop any blister**.** The target for this research was to tackle the blister on the current situation and for the year 2020.

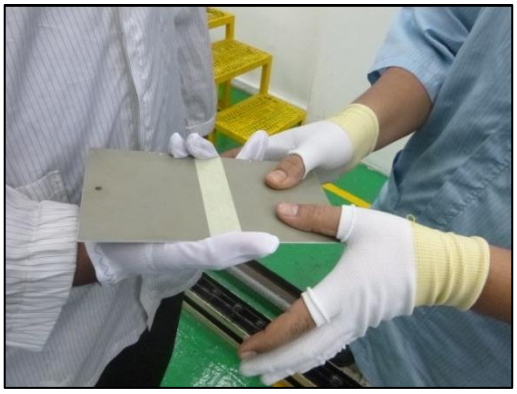

Figure 4. Trial for blister method

Data of blister were collected from Final Quality Gate (FQG) at the paint shop; FQG is the quality booth for defect checking of unit after Top Coat process as shown in Figure 4. The distribution of these blisters showed that they were more pronounced in parts where the coating system has been repaired. Blistering was at its most prevalent during the months of August to December, when large amounts of rain, coupled with high humidity and short spells of sunshine, prevented moisture from completely drying out on vehicles.

3.3 Improvement Implementation

The implementation of the improvement began with the priority set (using the 5W 1H method) which was the improvement that came from machines, methods and humans. Of the 6 priority improvement plans, the most dominant improvement came from the man as much as 4 items, followed by the method as much as 2 items and then material as much as 1 item as in the explanation.

The first improvement done was the replacement of sew rag that was normally worn for better adhesion and water absorbend such as the microfibre as shown in Figure 5. The microfibre was used for automotive surface body and approved by the production quality team. After replacing the wiping item material, there was a decrease in the paint defect and not just for blister.

(a) (b)

Figure 5. Replacement of Wiping clothes from sew rag (a) to microfibre (b)

To tackle the human sweat from the operator and the oil from the body and human hand, the spray booth was secured with updated air ventilation process since this air ventilation helps the human to work in a normal condition and balance the humidifier situation. Figure 6 shows that the downdraft of air ventilation is checked every day before spraying process starts. The operator was enforced to wear glove at all times including when handling the car body or even pushing it on the trolley. The fewer operators who touch the vehicle, the less risk for the vehicle to have defect like blistering. Since the problem can be tackled during the preparation process, the paint shop can be in a better quality condition and it helps to improve the quality of vehicle painted at the paint shop.

Figure 6. Air flow checking

3.4 Evaluation after Improvement

Based on the results of implementation to reduce the number of blistering in the automotive paint production, we can see that the effect of the improvements made was enough to provide significant results on the decrease in defect as shown in Figures 7 and 8.

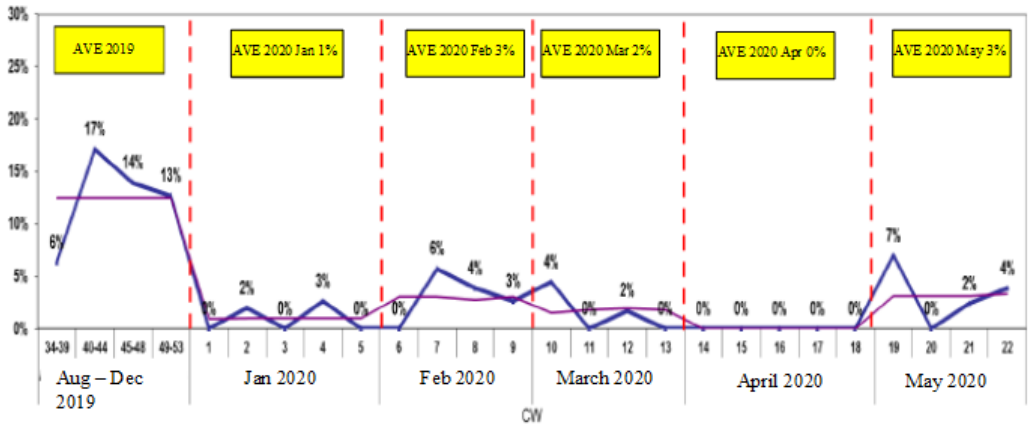

Figure 7. Graph of blister at the first quality Inspection (FQG 1)

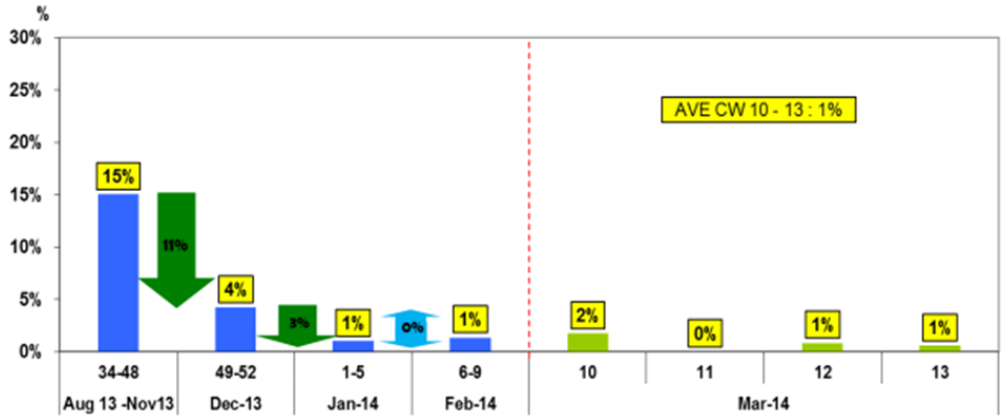

Figure 8. Graph of Final check for blister

One of the main causes of this phenomenon was osmotic pressure developed by the meeting under and in between the different layers of the coaling of water-soluble salts of all sorts. In fact, the blisters which occurred in sizes varying from pin-points 10 to 35 mm in diameter were found to contain acid and salty water mixture as

shown in Figure 9. They were situated between the primer and tile metal or between the primer and the top coat. Thus, any paint film will blister if weather conditions are bad enough, regardless of when the vehicle is painted. Cars painted in the summer months will often not show blistering until the monsoon and some may have been painted even years ago and can have blister during the months [24]. Figure 10 shows the improvement of blister after some actions were taken to tackle the blistering problem at the paint shop production line. This confirmed that the action taken was the most important in order to eliminate the blister effect during production process.

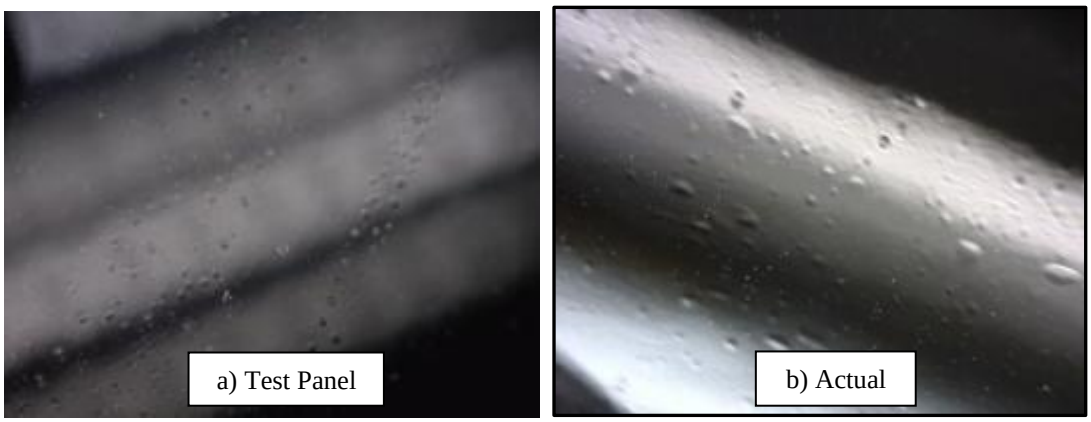

Figure 9. Result for Blister

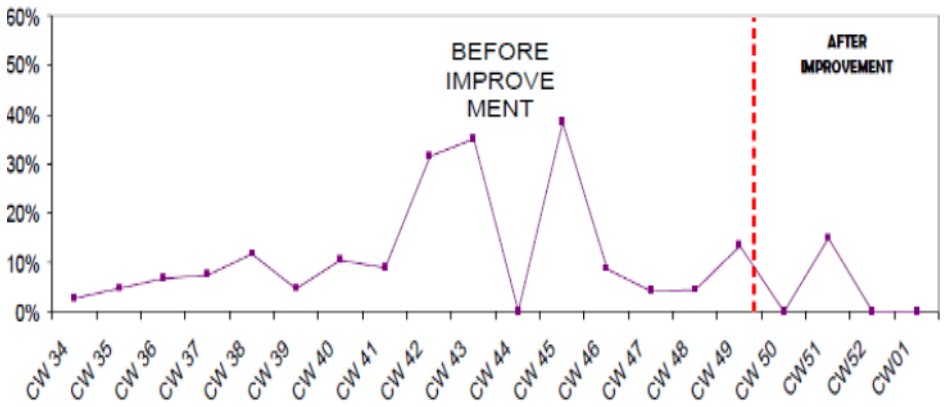

Figure 10. Blister data after improvement

4.0 CONCLUSIONS

Based on the case study in automotive paint shop production, it is concluded that the implementation of improvement through the root cause is found to be very useful and effective in identifying and removing blistering defects from the manufacturing process. This paper presented the systematic approach to find the root cause on one of the major defects (blister) and presented the significant impact of blister to the major production of automotive paint company. Based on the results and discussions regarding the implementation of improvement to reduce in-line defect at preparation process by the human, the company can reduce the blister defect up to 30% compared to before any trial and implementation of improvement. After achieving this objective, the production will further explore how to maintain and care through the implementation of total productive maintenance to maintain and improve the improvement that has been done.

It is recommended to continue the activity not only in preparing process but also in all stages of automotive paint production process such as body shop process, water jet process before electro deposition dipping, spraying process and repairing process. This is important to eliminate the painting defect to minimal level and avoid any repair process after finishing the product.

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