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Effect of Chemical Concentration, Electric Current and Plating Time on Defect in Electroplating Industries

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Abstract:
This study aim to analysis of effect chemical concentration, electrical current and plating time on defect yellowish in electroplating product in barrel plating. After knowing the cause of the defect in the production process, improvement are made to prevent the occurance of defects. The observation was conducted on all the three manufacturing of electroplating company in west Java. The data was collecting during Jan-Jun (six months). There were chemical concentration, electric current and process plating time, for a total of 139 data was collected. By using partial least squares (PLS) method, the causes of defects in the plating product is performed. *From the analysis with SMART-PLS it was found that yellowish can be explained by its variability of 9.4% (R2 0.094). The concentration of chemicals and currents used had a significant effect on yellowish (P-Value 0.002 and 0.026), while operating time did not significantly affect yellowish (P-value 0.319). Improvements were made by changing the KOH and K2SnO3 supply frequency standards, additive volume changes, filter pump type changes and adjusting production order. Upon repair, yellowish can decrease from 148.16 ppm to 40.03 ppm*.

Keywords: *Electroplating, Defect, plating parameters, SMARTPLS, Yellowish*

INTRODUCTION

The electroplating industry is one of the finishes processes of metal by coating the surface of the work piece with electricity, metal coating on metal and non-metal materials through electrolysis, using direct current (DC) and chemical solution (electrolyte). Chemical solutions serve as a medium for supplying metal coating ions to form deposits (layers) on the cathode electrode (work piece). Electroplating provides material protection by using certain metals as protective layers such as zinc, cadmium, copper, nickel, chrome, gold, silver, tin, copper, bronze and so on. During the deposition process, chemical reactions occur on the electrode and electrolyte. These reactions are expected to continue and in certain directions remain. Therefore, an electric current is required towards a constant voltage (Saleh, 2017).

The plating process is usually intended to protect the coated objects from corrosion, decoration or appearance, and technical function (Kanani, 2014; Raymund, 2011). The electrolyte plating process requires electrolyte solution that acts as the medium for the process to take place. The solution varies depending on the nature of the electrolyte desired. In addition to the role of the anode as the electrode releases the metal ions and oxygen (reduction), the metal ions and hydrogen gas is stored in the cathode. The use of water in this plating process determines the quality of the product, the presence of heavy metals, iron and manganese impurities causing defects, including roughness,

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pores, scratches, black spots, dull, or crystalline colors, modular and porous. For this reason, pure water is required (reagent water) to make solutions and to replace evaporation solutions (Gabe, 1980).

There are several plating machines such as reel for reels, in line plating and barrel plating used for electroplating process. The choice of machine is determined by the dimensions, and types of material to be coated. Barrel plating has different advantages including the ability to produce with a wide variety of materials and can produce to larger quantities over time (Raymund, 1994).

Based on preliminary data from observations in the electroplating industry in some regions of Indonesia, discoloration is a problem that often has many disadvantages.

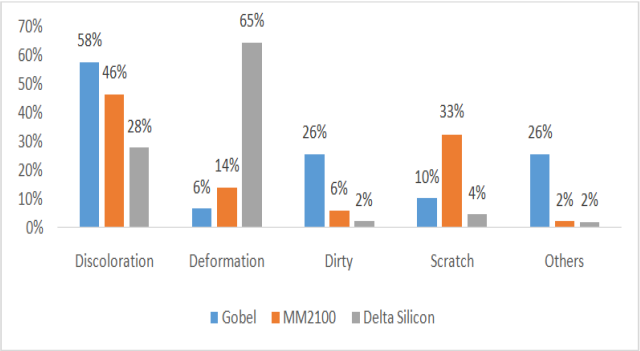

Fig 1. Total Defect on Plating Industry

Many factors can lead to failure of the electroplating process, such as poor pre-treatment, or post-treatment processes that cause many defects in the product. The pre-treatment process works to remove all impurities that are present on the work surface, either organic, or inorganic impurities, and also to obtain better physical surface conditions than the before plating process. The selection of pre-treatment and treatment processes depends on the selected plating process (Kanani, 2004).

1. ***Literature Review***

The choice of electrolyte solution for the plating product coating is based on the components, and objectives of the plating process. In general, the plating solution can be divided into three groups based on the pH properties of solution of electrolyte acid, neutral electrolyte and alkali electrolyte. To maintain the pH state does not change significantly during the production process it is necessary to add acid, alkali or buffer (Kanani, 2004).

The tin coating process can use a variety of solutions, acid solutions and alkali solutions. The economic factor of potassium stannite solution is more commonly used than sodium stannite. However, in their use there should be regular treatment to ensure that the reaction takes place in the direction of the tetravalent stannite, otherwise divalent stannite ions may result in incomplete, inconsistent or coherent plating (Saleh, 2017; Gabe, 1973; Yli-Pentti, 2014).

Stannite formation in electrolytes can be prevented by maintaining anode polarization. The anode must be placed in solution after the current is activated, the component is in solution, and must be periodically removed. The connection must be kept tight and clean, and any interruption during the anode in solution must be avoided. If the solution is slow, and the coarse and spongy coating that is usually due to stannite concentration can be removed by oxidation. For this reason, sodium perborate or hydrogen peroxide is used. The excess hydrogen peroxide will be protected by high temperature solution (Berger, 1945). The anode selection can be impacted to product after plated (Hopper, 2014).

Many factors influence electron deposition as solution, solute, pH of bath, bath temperature, current density, and time of process. Selection of solution and solute for electroplating process influence of plating layer (Ojo & Dharmadasa, 2018). The use of current, voltage and process time in accordance with the product to be coated will affect the thickness of the plating layer. The higher the current, voltage and plating time the more layers will stick to the product (Guler, 2016).

Fayomi, et al. (2011) conducted an experiment by studying the effect of plating parameters in the form of voltage, time and distance between the anodes and chatode on the thickness of the layer and surfaces morphology of the plating results on mild steel. Increasing the applied voltage, plating time and

decreasing the cathode distance from the anode will increase the thickness and change the surface morphology of the product at a certain voltage.

The success of the plating is greatly influenced by the material pre-treatment process before the plating process. The pre-treatment process can be done by ultrasonic agitate process, as well as mechanical and chemical processes (Chuang, et al, 2018; Uhlmann, 2018) The pretreatment process serves to clean the surface of material so that the plating and activation of the surface can be carried out, plating process, post treatment, and there is a rinsing process at each stage (Yli-Pentti 2014).

Due to the complex electrochemical specification, the pretreatment and treatment process during the plating process requires complete control of the plating process. As a result, some defects can occur during the plating process. Most defects occur during before plating processes such as pitting, sharp edges, bead making. During plating, uneven coating and loss of adhesion may occur. After the process of plating the problem becomes more complete including hydrogen cracking, dull and blurred deposits, blisters, and oxidation (Sharrettsplating.com). Ballast stick, crack, discoloration, unit coupling, missing plating and burn mark are reject at barrel tin plating product (Kanan, 2017).

Multivariate statistical methods such as partial least squares (PLS) have been widely used as powerful analytical methods to identify sources of deviations in process quality and failure and for product modeling, and product quality in various industries. The use of PLS has been successful in detecting causes of defects in the Terephthalic Acid manufacturing industry (Han, et al. 2003).

Fujii, et al. (1997) used PLS to estimate the composition of distillation towers and selected important variables to construct the model. Whereas Kawalla et al. (2018) used PLS to create models that could predict the relationship between the formation of the magnesium band thickness and its latent variables.

The PLS is widely used in science research, marketing, information management systems, business strategies. This is because PLS is a powerful analytical method that eliminates the assumptions of ordinary minimum data, does not need to be distributed normally, can test weak theory, small sample size. PLS can confirm that theory. However, PLS also has weaknesses such as requiring high structural bandwidth coefficients if the sample size is a small, there is a problem of multicollinearity if not used correctly, due to the use of a single arrow, thus unable to account for unmanaged correlations (Ken, 2013).

2. *Methodology*

This research was carried out in electronic component industry for solderless terminal products with a coating of tin coating using barrel plating process. The electrolyte solution used was alkaline potassium stannate. Data is extracted from field reports for six months, and then processed using smart PLS. Potassium stannate (CS) and hydrogen peroxide (CK) concentration data was obtained from daily measurements during the production process. The production time is divided into three stages, namely the pretreatment process for surface cleaning (TS), tin coating (PT) and post-treatment (AT), the length of each product is measured in minute. Then the current (A) is applied and the voltage (V) is generated. The selection process the selection process will be performed to determine the number of yellowish defects (DY). From the analysis using smart PLS, improvements will be made to determine the comparison of the defects produced after the improvements.The research hypothesis considers the factors that cause yellowish defects in the electrolyte soldering process. *As shown in Fig. 2. Research model of the study hypotheses are as follows:*

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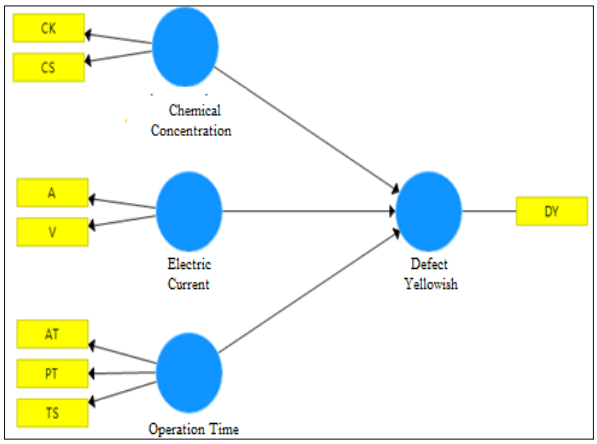

Fig 2. Research Model

H_1: Chemical concentration in plating tanks has a strong influence on the occurrence of yellowish defects

H_2: Current and applied voltage has a significant effect on yellowish defects

H_3: Pretreatment, plating, and post-treatment processes have significant effects on yellowish defects

To identify the hypothesis, data was collected for 6 (six) months of solder less terminal product process (139 data) at an electronic component company located in Cibitung Industrial Estate, West Java, Indonesia. The data obtained will be analyzed using Smart PLS 3.0 to assess the reliability and validity of the research model as well as to evaluate the research hypothesis. Variables that have a significant impact on corrective action will be taken to reduce defects.

Table 1. Research variables for SEM-PLS modeling an electroplating process analysis

Variable	Description
CK	Concentration of Potassium Hydroxide in tin plating tank (g/L)
CS	Concentration of Potassium stannite in tin plating tank (g/L)
A	Electric Current usage (A)
V	Voltage usage (V)
AT	Post treatment time (Minutes)
PT	Pre treatment time (Minutes)
TS	Plated time (Minutes)

Reject Ratio

Defects that lead to the plating process even though the selection process has been done 100% of all products, but some reach the consumer, causing consumer complaints. The following defects are being complained of by consumers in the solder less terminal plating products from January 2018 to December 2018. Defects that reach consumers must take immediate action to maintain consumer confidence in the quality of products sold. In Table 4.1 there are complaints from various users around the world. Defects are calculated based on the number of users who submit complaints (cases) either through sales or directly to the quality control department.

Table 2. Number of defects from customer complaints per year 2018

Type of Defect	Customer Claim at 2018 (Case)												Tot
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sept	Oct	Nov	Dec	
Yellowish	0	0	1	0	4	1	0	3	0	0	2	0	11
Deformation	0	0	0	1	0	0	0	0	1	0	0	0	2
Mix	0	1	0	0	0	0	0	0	0	0	0	1	2
Discoloration	0	0	2	0	1	0	0	0	1	0	0	0	4
Dirty	0	0	0	0	0	1	0	0	0	0	0	0	1

According to Table 2 many users complain of yellowish defects. Consumers complain of yellowish defects 11 times in 2018. Yellowish defect can be returned good form customer and replating, but the long limitation and the expensive shipping price makes a big loss from these defects. The number of products complained of by consumers varies from case to case. When viewed with Pareto graphs, most of the defects are as shown in Fig. 3 yellowish defects reach 55% of the total number of defects complained of by the user, for other cases defects do not reach half the yellow defects. The second most common defect is discoloration, which amounts to 4 cases or up to 20% of total defects. This means if you can eliminate yellowish defects it can solve half the problem of consumer complaints.

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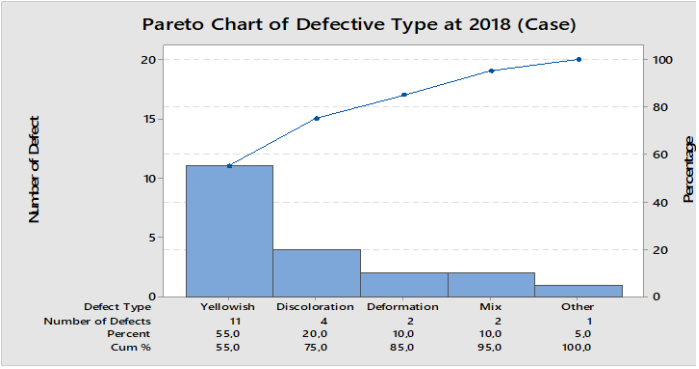

Fig. 3 Pareto Type Defects in non-solder terminal products

4.1 *Data analysis results using statistical methods (PLS)*

Prior to analyze the data using Least Square (PLS) partial data observations on yellow defects. The results of the data analysis amounted to 139 data over the 6 months of observation as a listed in Table 4.6 Production Process Examination. Here are the results of the PLS model scheme with the output data.

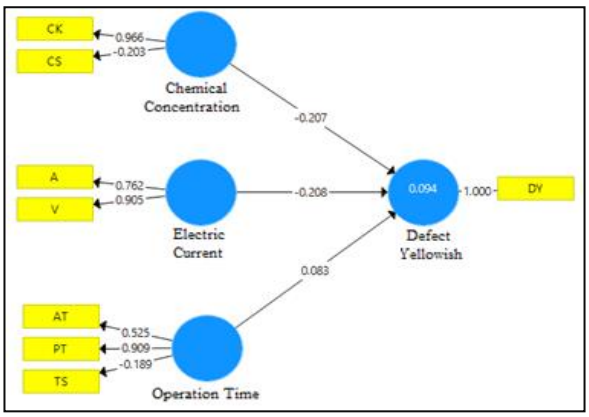

Fig. 4 Research Mode

In this study, a test statistics were performed using PLS smart program version 3.2.8 to find out what indicators are affecting Yellowish defects in solder less terminals of products that use adjustable plating. In this study the external model is formative, then the external model is evaluated on the formative model measurement results. There are 3 stages of formative model testing namely Convergence Conformity (using R-square values), Collinearity Issues (using VIF values), Significance and Relevance of Formative Indicators (using P-values). After examining the exterior model, it is then followed by an evaluation of the results of the model (inner model) measurement. There are 5 levels in this assessment namely Collinearity Assessment (using VIF value), Structural Model Path coefficient (using T test and P test), Determination coefficient (using R2 value), Effect Size (using f2 value), and Predictive Relevance using values Q2 (Hair, 2014).

Convergence validity can be measured by looking at the R-square value. When the R-square value is between 0.64 - 0.81 then it has met the criteria of suitability (Hair, 2014). From the test results R-square value for yellowish defect is 0.094

a. Collinearity issues

Collinearity issues can be measured using VIF values. If the VIF value is <5 then the variable meets the Collinearity Issue criteria. From the test results were obtained VIF values <5 (Hair, 2014)

b. Significance and relevance of the formative indicators

The significance and relevance of formative indicators can be measured using external P-weight values. Indicators are still used if the external P-value <0.05 and if the value is greater than 0.05 should be checked if the external P-value <0.05 is maintained and if the P-value <0.05 is considered to have been removed (Hair, 2014).

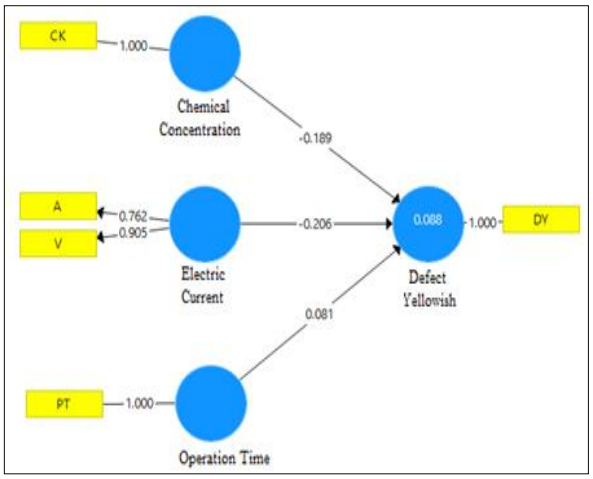

Fig 5. Scheme PLS Model

Table 3. VIF Test Results with smartPLS

Variable	*VIF*	*Remark*
A	1,206	< 5

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AT	1,075	*< 5*
CK	1,003	*< 5*
CS	1,003	*< 5*
DY	1,000	*< 5*
PT	1,057	*< 5*
TS	1,045	*< 5*
V	1,206	*< 5*

Table 4. P-value Test Results with smartPLS

Variable	Outer Weight	Remark	Outer Loading	Remark
A <- Electric Current	0,091	> 0,05	0,000	< 0.05
V <- Electric Current	0,002	< 0.05	0,000	< 0.05
AT <- Operation Time	0,422	> 0,05	0,242	> 0,05
PT <- Operation Time	0,069	> 0,05	0,040	< 0.05
TS <- Operation Time	0,686	> 0,05	0,728	> 0,05
CK <- Chemical Concentration	0,016	< 0.05	0,019	< 0.05
CS <- Chemical Concentration	0,512	> 0,05	0,631	> 0,05

Given that the results of the Outer P-value weight and Outer Loading (TS) operation time did not affect the yellow defect, it was considered eliminated. So the PLS model becomes like Figure 5.

Significant impact test was performed with P -values of outer weight to see significant variable values. Structural results (bootstrapping) without Operation Time (AT) as shown in Table 5.

Table 5. Bootstrapping results

Variable	Outer Weight	Remark	Outer Loading	Remark
A	0,069	> 0,05	0,000	< 0.05
V	0,001	< 0.05	0,000	< 0.05

Evaluation of structural model measurement results (Inner Model)

a. Collinearity assessment

To measure Collinearity Assessment by looking at VIF values. If the value of VIF is <5, it means no multicollinearity, so it can be continued to the next level (Hair, 2014).

Table 6. Collinearity Testing with smartPLS

Variable	Defect
Electric Current	1,023
Chemical Concentration	1,015
Operation Time	1,029

Structural Model Path Coefficient

Structural analysis coefficient analysis was used to determine which relationships had the greatest impact. The results of the structural coefficient analysis can be seen in Table 7. If the P value is <α (0.05) then the relationship is significant, whereas if the P value is α α (0.05) then the relationship is not significant (Hair, 2014).

Table 7. Structure and Effect Test of Structural Models

Variable	Original Sample	Sample Mean	Standar Deviation	T Statistic	P Value	Remark
Electric Current	-0,206	-0,219	0,088	2,332	0,020	<0,05
Chemical Concentration	-0,189	-0,185	0,085	2,230	0,026	<0,05
Operation Time	0.081	0,079	0,081	0,998	0,319	>0,05

After studying the road coefficients for the internal model, it is possible to look at the external model by examining the T and P-values. The statistical value of the T-variables was greater than 1.96 (T-table 5% significance) and P -value <α (0.05) so that the external model was significant. Therefore, the changing Chemical and Flow proportions have a significant effect on yellowish defects.

Coefficient of Determination

The coefficient of determination is used to measure the accuracy of the budget. In general, R2 values of 0.75 are considered to have high estimates of accuracy, R2 values of 0.50 are considered to have moderate prediction accuracy, and R2 values of 0.25 are considered to have poor prediction accuracy (Hair, 2014).Based on the value of R2 in the table above, it can be seen that the value of R2 for the construct variable is 0.088. This value indicates that

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the magnitude of the yellow defect can be explained by its variables (chemical concentration, operating time and ampere & voltage) of 8.8%

a. Effect Size

To evaluate the value of R^2 for all endogenous variables, f^2 can be used. The difference between f^2 and R^2 is that f^2 is more specific to each exogenous variable. Test results f^2 are as shown in Table 4.8. In general, a value of 0.02 is considered to have a small effect size, 0.1has a medium effect size, and 0.35 has a large effect size (Hair, 2014).Based on the value of f^2 in the table, it can be seen that electrical Current and Concentration of chemicals have a large effect on yellowish defects, while Operation Time has a small size.

Table 8 The Result of F^2

Variable	Defect
Electric Current	0,045
Chemical Concentration	0,038
Operation Time	0,007

Hypothesis test

H_1: Current consisting of amperes used and voltage affects yellowish defects.Table 9, shows that the P value for 0.020 Flow is smaller than the value (0.05) so, it can be concluded that the current has a significant effect on the yellowish defect

H_2: Chemical concentration (CK) affects yellowish defects. Based on Table 9 it can be seen that the P value of the chemical concentration is 0.026 smaller than the value (0.05) so, it can be concluded that the concentration of the chemical has a significant effect on the yellowish defect

H_3: Operating time affects yellowish defects. Based on Table 9 it can be seen that the value of P for operating time is 0.319 greater than the value (0.05) so, it can be concluded that operating time has no significant effect on yellowish defects.

Table 9. P value for hypothesis test

Hypothesis	Variable	T Statistics	P Values
H1	Electric Current -> Defect	2,332	0,020
H2	Chemical Concentration -> Defect	2,230	0,026
H3	Operation Time -> Defect	0,998	0,319

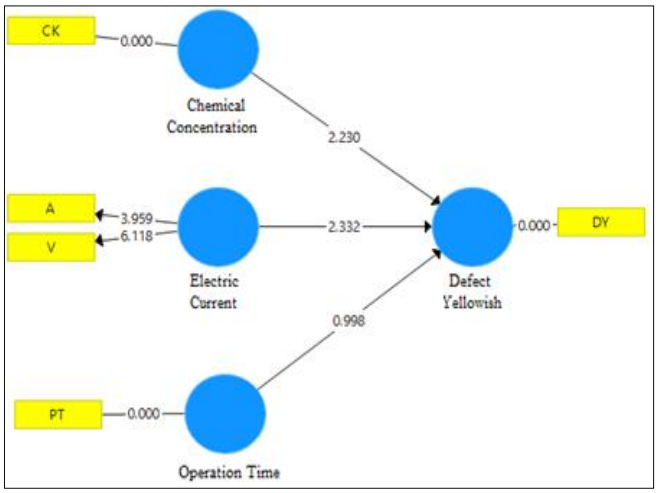

Fig 6.Result of Analysis PLS

3. **Corrective Action**

Having identified the dominant causes of yellow defects, the next step is to take corrective action. The corrective actions taken are as follows:

Corrective action for yellowish defects

a) Changes in supply standard and frequency of supply of KOH and K2SnO3 in the plating tank were performed once every five hours once the production process was over so that the concentration of the chemicals was within the standard limits and ensured that chemicals were fully dissolved during the production process

b) Change the volume of additive supply to the plating tank from 0.3 liters per hour to seven liters per hour.

c) Change chemical filter pump type to increase Sn chemical circulation capacity from 200 liters / minute to 300 liters / minute so that impurities in the chemical can be optimally filtered

d) Manage the running processed by ensuring high amperage at the start of production so that the chemicals do not react in a direction that may affect the coating.

e) Adjust the amount of current flowing by collecting high and low amperes according to the number of anodes used so that the coating layer is evenly distributed

f) Stop production every 24 hours to reactivate the chemicals using the highest current

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4. Assessment of Improvement Decisions

After improvements to plating process, evaluation is carried out to determine the effect of the improvement on the product being produced. Monitoring is done by comparing the number of defects before and after improvement. Based on Figure 7. Yellow defects can be reduced from 148.16 ppm to 40.03 ppm.

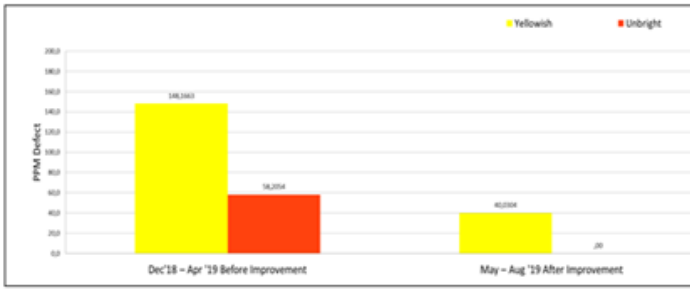

Fig. 7. Graph Before and After Improvement

5. Conclusion

Using PLS it can be concluded that the yellow defect is influenced by the concentration of the chemicals and the P-Value used (0.002 and 0.026), the operating time having no significant effect on the yellowish P-value of 0.319. Improvements were made to reduce yellowish by changing the standard supply and frequency of KOH and K2SnO3 supplies in the plating tank. Changes for additive supplies in the plating tank to 7 liters per hour. Change the type of chemical filter pump to increase the circulation the capacity of the chemical to 300 liters / minute.

Manage the running processed by setting high amperes at the start of production so that the chemicals do not react in the wrong direction that could affect the coating. Adjust the amount of current flowing by grouping high and low amperes according to the number of anodes used so that the amount of current per anode can be evenly distributed. Stop production every 24 hours to perform the reaction process once again on the chemicals that use the highest current. From the improvements made, it is found that yellow defects can decrease from 148.16 ppm to 40.03 ppm.

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