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DESIGN OF INSPECTION AND CLASSIFICATION PROTOTYPE FOR CERAMIC TILES BASED ON THE DIGITAL IMAGE PROCESSING

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ABSTRACT

This research is focused on designing an inspection and classification tools based on digital image processing. By using Automated Multiple View Inspection, which is an automated non-contact inspection that observed from two or more points of view and using Digital Image Processing, Seven Tools of Quality, RCA, this system is applied to a manufacturing company, which is floor Tiles Company. The designed mechanism consists of the inspection process, grading, and classification process. The integrated prototype and Eclipse software also supports the system. The designed prototype performs the function of grading and classification process. Prototype designed in this study requires a cost of 11.118.450 rupiah. The testing mechanism of inspection and classification system on the instrument was conducted on 150 samples of ceramics floor. Those ceramics are classified into three types, they are Primary, Economy, and KW, and into the accepted or rejected products. From the testing process, it is found that the speed of manual inspection performed by operator is the same with this prototype, which is 3 seconds per ceramic tile. The error level of this prototype is 2% because from the testing, there were 3 ceramics that was identified mistakenly. Therefore, the accuracy level of this prototype is 98%.

Keywords*: Image Processing*, *Automated Multi-View Inspection System, Seven Tools of Quality,* RCA

1. INTRODUCTION

1.1. Background and Purpose

Nowadays, the development of the property industries is extremely fast. The property industries are potential to create a foreign exchange. Besides, the property industries may absorb labours. The improvement in property industries is continuously upgraded by many companies to support the business process.

One of sub sectors of property industry is ceramic industry. The ceramic industries play a significant role in national development because the ceramic industries also contribute high GDP.

The main operational problem in the ceramic companies is quality control of the products. This is an important matter encountered by many ceramic companies in Indonesia because the demand of the various kinds of ceramic tiles recently is getting higher. The problem of quality control appears to be the most critical problem to be solved. This may be due to lack of productivity control in every workstation and the absence of the inspection tools or the inspection tools that are not optimal.

Many companies still use the manual inspection. The operator inspects the ceramic tiles one by one. This is so ineffective and not efficient because the production of the ceramic tiles is too large. The manual inspection may also have the error. Company Ceramic X is one of many companies that produce the ceramics in Indonesia.

Melvyn L Smith and Richard J Stamp (2000) have ever conducted the research of ceramic inspection. In their research, the ceramic inspection was done by using topography method. The topography method detects the defects by using the light. L Kehoe, G Coyle, S.Murray, C.M. Flannery, and G.M. Crean (2000) have also conducted another research about ceramic inspection. In their research, the inspection of ceramic was done by using the ultrasonic laser. Nevertheless, the accuracy level by using the ultrasonic was found to be 60 – 100 %.

The inspection process in Company Ceramic X is still executed manually. The operator performs the final inspection of the ceramic. The operator should identify the defects of the ceramic one by one. There are about 26 types of defects should be identified by the operator in every ceramic tile. The operators have only three seconds to identify and inspect the ceramic tile. The inspection process of the Company Ceramic X is ineffective and may cause inaccuracy in classifying the defects of the ceramic tiles. Therefore, it requires the inspections tools that can help the Quality Control Division in classifying the defects of the ceramic tiles. From this problem, this research aims to design the inspection tools, which is still designed in prototype. This prototype is designed to be the automatic inspection tools that will help the company to classify the defects of the ceramic tiles easily with the high level of the accuracy. This automatic inspection prototype is also designed to be able to inspect the multi various ceramic tiles, so this prototype may be the multifunction inspection tools for many kinds of ceramic tiles.

2. DESIGN OF RESEARCH

2.1. Design of Prototype

The design of this prototype comprises the important equipment such as webcam camera, conveyor, and limit switch. Below is the figure of the prototype:

Figure 1. Design of Prototype

2.2. Design of Software

In this research, in designing the prototype, the Eclipse software is used to identify the type of the defects that have been captured by the web camera. Generally, the mechanism of the eclipse software can be seen in this flow chart below:

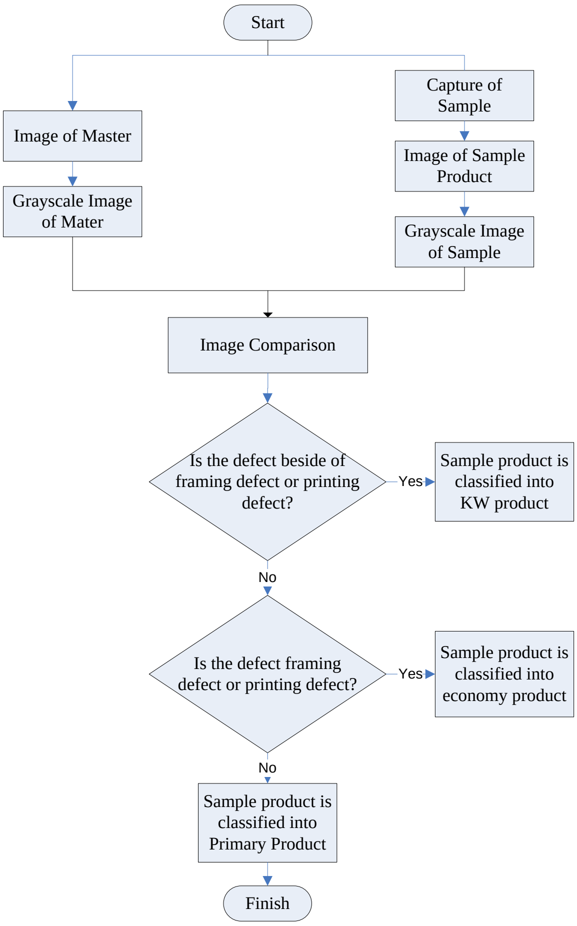

Figure 2. Flow Chart of Software Mechanism

The mechanism of the Eclipse begins with inputting the data of the master's image. The image of master is then converted into the grayscale image. Then, the image of master will be compared with the image of the sample product. The image sample product is then captured and classified. The same as the image of master product, the image of the sample product is then converted into grayscale image. If the software captures the crack defect from the inspected sample product, which is beside of the framing and printing defect, the product is then classified into the KW class. If the software captures the framing and printing defects from the inspected sample product, then the product is then classified into the economy class. The sample product without any defects is classified into the primary class.

3. RESEARCH ELABORATION

3.1. Verification of Software

The verification is executed to ensure that the system of the prototype is applicable and may perform its function as expected without any errors. The verification involves the verification of the censor, camera, motor, conveyor, and limit switch. This verification also confirms that the software has been successfully synchronized with the prototype. Below is the sample of the error box that indicates that the software and the prototype are not synchronized yet. If this dialog box does not appear, the software and the prototype have been synchronized.

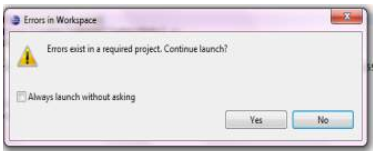

Figure 3. *Textbox Error*

If this dialog box appears, the software and the prototype should be rechecked. The indication of error can be seen from the basis. If the mark ‘X’ appears in the basis, the error happens. Below is the sample of the error indication:

Figure 4 Error Indication with Mark ‘X’

3.2. Software Testing

Software testing is done by capturing the image of the ceramic tiles. Below is the example of the captured images of the ceramic tiles with the type of the defects that have been processed by the Eclipse software:

Figure 5 Interface Scaling Glaze

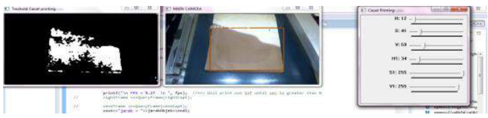

Figure 6 Interface of Printing Defect

After the interface of all the defects have been obtained, the sample products of the ceramic tiles can be classified into the class. The mechanism of the prototype is classifying the sample products of ceramic tiles into three classes. The products will be delivered by the conveyor and passed the camera. The camera will capture the image and the image will be processed by the software. After that, the product will be continuously delivered by the conveyor into its class. The switch limit will block the product and direct it into the proper class.

3.3. Validation Process

The validation process is done by using two steps. The first step is validation of the manual classification process. The second step is the validation of inspection performed by the operator and the prototype.

From the prototype running process, there are three misidentified products. This misidentification always happens when the prototype identify the framing defects. The framing defects are usually at the edge of the ceramic tiles and the line of the frame is very thin. The camera is unable to capture the framing defect, which is at the edge of the product. Three of 150 products mean that this prototype can classify the products accurately.

The inspection performed by the operator results in two misidentified products from 15 (fifteen) sample products. This may happen because the operator is confused to identify the type of the defect. The misidentification of classification may cause the lost of profit 374.774.400 rupiah because the price of the ceramic tiles is based on its class. From this matter, the inspection performed by the prototype is better than the inspection performed by the operator.

3.4. Control Charts, Pareto Chart, Cause and Effect Diagram

The data processing is done by using the S and P control charts. S chart is used to process the variable data and the P chart is used to process the attribute data of the ceramics.

X *Bar*-S *Chart* is obtained by processing the data of length of side A and B of ceramics and the width area of the ceramic tiles. This X-bar S chart processing is done by using the Minitab software. In the X bar chart, it is found that the UCL of the side A is 10.49 and its LCL is 9.29 centimeter. The UCL in the S chart is 1.21 and its LCL is B 0.33. In the X bar chart, it is found that the UCL of the side B is 10.58 and its LCL is 9.45 centimeters. The UCL for S chart of side B is 1.07 and LCL is 0.26. In the X chart for width area, the UCL is 107.26 and its LCL is 90.84 centimeter square. For s chart, its UCL is 16.36 and its LCL is 4.46. Below is the plotting of X-bar S chart:

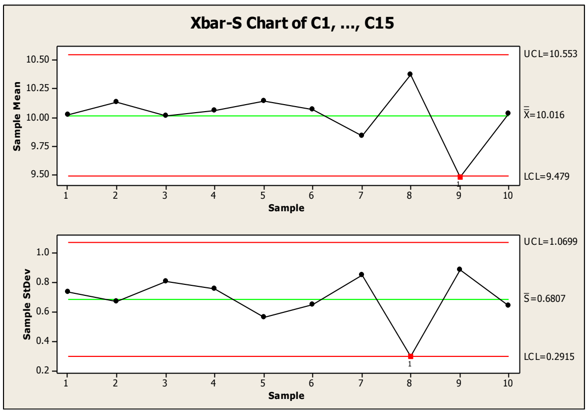

Figure 7. X bar S Chart for Side A

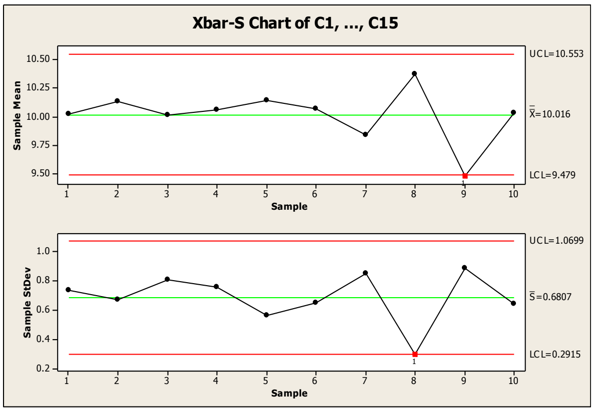

Figure 8. X bar S Chart for Side B

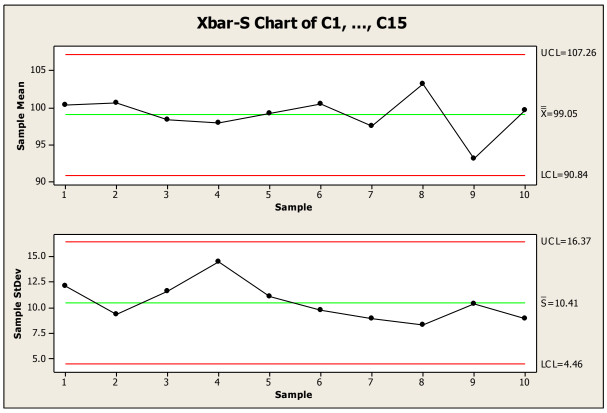

Figure 9. X bar S Chart for Width Area

Based on the graph, it can be seen that there are some out of control points. They are in 8th observation for side A and in 9th observation for side B. This means that there are many out of expected dimension samples in the eighth and ninth observation. From the X bar S chart for width area, it can be seen that there is no out of control points so this chart is reliable. The UCL and LCL of this chart can be recommended as the new specification dimension of the products if the repair and revision cannot be carried out into the specification.

The next step is calculating the capability process to measure the production process of the ceramic tiles whether it is capable or not. Below is the calculation of the capability process:

$$\text{Cp} = \frac{\text{USL} - \text{LSL}}{6 \times \hat{\sigma}} = \frac{99{,}50 - 98{,}75}{6 \times 10.55} = 0{,}01$$

Notes:

USL = 99.50 and LSL= 98.75 and $\hat{\sigma}$= 10.55

To ensure the fraction of nonconforming product, the estimation of nonconforming product is calculated by using the formula below:

$$p = P\{x < LSL\} + P\{x < USL\}$$
$$= \Phi\left(\frac{LSL - \bar{x}}{\sigma}\right) + 1 - \Phi\left(\frac{USL - \bar{x}}{\sigma}\right)$$
$$= \Phi(-0{,}028) + 1 - \Phi(0{,}043) = 0{,}972 = 97.2\%$$

This indicates that the production process of the ceramic tiles is in bad condition or critical.

Cp value is used only for estimation so that the actual capability process should be calculated. Below is the calculation of the actual capability process (Cpk):

Cpk = min (*Cpu*, *Cpl*)

$$= \min\left(Cpu = \frac{\text{USL} - \mu}{3\sigma}, Cpl = \frac{\mu - \text{LSL}}{3\sigma}\right)$$
$$= \min\left(Cpu = \frac{99{,}50 - 99{,}05}{3\text{x}10{,}55}, Cpl = \frac{99{,}05 - 98{,}75}{3\text{x}10{,}55}\right)$$

= min (*Cpu* = 0.0142, *Cpl* = 0.0095) = 0,0095

The value of the Cpk is apparently lower than the Cp value, Nilai tersebut lebih kecil dibandingkan nilai Cp. The actual capability process and estimation are below one, which are very low. This happens because the specification used by the company is very tight, with the tolerance score of out control is only 0.2 centimeters for both side.

After processing variable data by using the S chart, the attribute data is then processed by using the P chart. The processing of attribute data by using P chart is done by Minitab software. Below is the plotting of P chart from the attribute data:

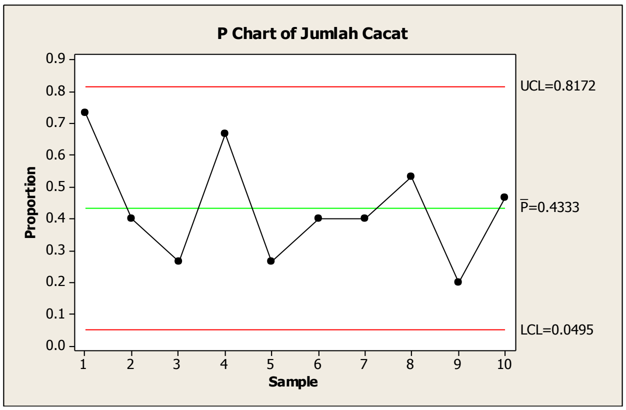

Figure 10. Quality Control Map by using P *Charts*

From the P Chart, it can be seen that there is no out of control point. Nevertheless, the first observation seems to have more defects in it. This may happen because at the first observation, there are many defects in the sample products. The Pareto Chart is then used to know the type of defects.

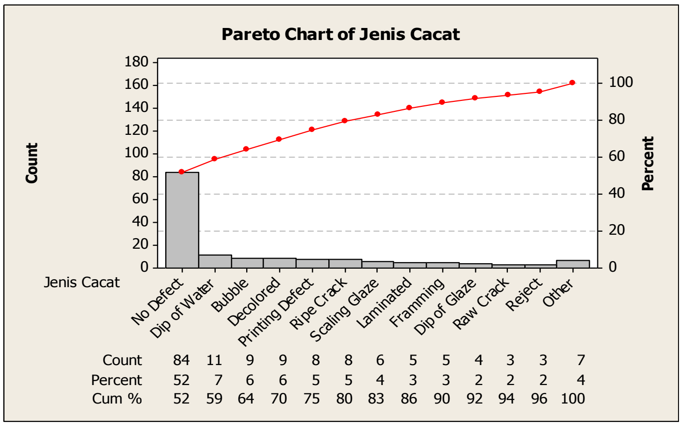

Figure 11. Pareto Chart

From the Pareto chart, it can be seen that the defect caused by the drip of water is the most frequent defect happens in the production process of the ceramic tiles. To identify how and why the defect caused by drip of water happens, the cause and effect diagram is composed.

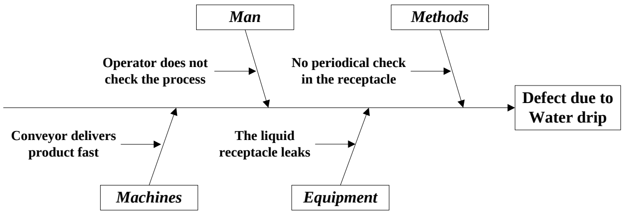

Figure 12. Cause and Effect Diagram of Defect Due to Water Drip

The defect due to water drip is caused by the drip of water that fall on the surface of the ceramic. These drips fall on the biscuit tile and leave a crater or bad print after burning process of ceramic.

3.5. Economical Value of Prototype

This process requires the data value of defender and challenger. The defender data is the inspection by using the operator and the challenger data is the inspection by using the prototype. The lifespan of designed prototype is set to be three years. The present value or present worth is calculated by using formula A*(P/A, 6.2%, 12). It is known that the interest rate of Bank of Indonesia is 6% per year and it is compounded per month, and so the effective interest per month is equal to 6.2%. By using that formula, the result is 19.963.234 rupiah. This P value is designed to be the same in the second and third year and it is so called A1 value. Based on the information of the Company Ceramic X, there are about 3.744 defect products in average and it is equal to 34.070.400 rupiah lost of profit. The next step is calculating the present worth of the prototype and it is known that the total investment cost is 120.072.664 rupiah.

By using this prototype, the Company Ceramic X might earn 932.434.504 rupiah. From this data, it is known that the outflow of the company by using the manual inspection is 61.920.000 rupiah, which is the cost that should be paid the company to pay the salary of the operator during economical lifespan. While, by using this prototype, it is known that the inflow of the company is 932.434.504 rupiah. Therefore, the inspection by using this prototype will be more advantageous.

3.6. Sensitivity Analysis

This sensitivity analysis is executed to know the effect of the change of parameter. By using the tornado graphic for defender, it is known that if the salary cost is decreased 10%, the salary cost will decrease 597.951 rupiah. While, if the salary cost is increased 10%, the salary cost will increase 586.883 rupiah. If the interest is decreased 10%, the cost will increase 5.336.196 rupiah. If the interest is increased 10%, the cost will decrease 10.672.392 rupiah.

From the tornado graphic of challenger, if the operational cost is decreased 10%, the cost will decrease 2.085.877 rupiah. If the operational cost is increased 10%, the cost will increase 2.047.269 rupiah. If the interest is decreased 10%, the cost will increase 18.614.538 rupiah. If the interest is increased 10%, the cost will decrease 37.229.277 rupiah. It can be concluded that the salary and operational cost is more sensitive than the interest.

4. CONCLUSION

The conclusions of this research are:

1. The designed prototype is able to identify the accepted and rejected products and able to classify the products into three classes.
2. By using the RCA, it can be identified that the most affected causes are the careless operator, the machine that is not reliable anymore, and the high temperature in production floor that will disturb the operator.
3. The capability process of the production process of the ceramic tiles is in bad condition because the specification of the company is too tight, which the tolerance score of 0,2 cm.
4. The prototype has the accuracy level 98% and so the products can be classified effectively and accurately.

The suggestion that can be given fron the improvement is:
The speed of the conveyor can be improved and it is possible to integrate the web camera that can measure the dimension of length of both side and the width area automatically into the prototype.

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