Design models of automatic humidity control system in flash off painting line room to reduce defect products at PT. Kubota Indonesia

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Abstract. The main challenge often faced by PT. Kubota Indonesia in connection with the quality of production is still a lot of level of disability in the production process, especially in the painting process. The process of painting is highly required according to the standard of both the process and condition of the room so that the painting results do not occur defects. Based on production data in the period from October 2018 to January 2019 there were 80% defective products with blistering defects of the total defective products, this needs a deeper analysis of the causes of product defects. Blistering defects in the form of bubbles on the surface of the painting result occur because the standard of air humidity is not achieved when the flash off process is caused because there is no tool to condition the air in the flash off the chamber. The purpose of this research is to design an automatic humidity control system model that can be used as an alternative to PT. Kubota Indonesia as a method for reducing humidity so that it can reduce the potential causes of blistering defects. Research methods include problem identification, literature study, design, and manufacture of models and testing. Problem identification is done by using the 5M + 1E method to find the root of the problem. The process of designing and making models is divided into 3 important activities namely designing 3D design concepts using solid works software, designing a control system software with Arduino Uno and designing hardware models. Tool testing is done by testing the automatic humidity control system model on the prepared test chamber model. The results obtained from this study are models of automatic humidity control systems that can condition the humidity in the test room and maintain the humidity according to the setpoint.

1. Introduction
The main challenge often faced by PT. Kubota Indonesia in connection with the quality of production is still a lot of level of disability in the production process, especially in the painting process. Based on production data in the period September 2018 to February 2019, there are 5% defective products, this needs a deeper analysis of the causes of these product defects.

One of the departments with the most stringent quality control standards is the painting department. This painting department is part of the production department which is responsible for the process of painting components before they are assembled on the assembling line and the painting process for spare parts that are not included in the assembling process. The process of painting is highly required according to the standard of both the process and the condition of the room so that the painting results do not occur defects. But the condition of the painting process room (flash off process) still does not
meet the standards. Ideally, the best condition for spraying paint is when the relative humidity is between 40-50% [1]. Humidity in the room is still dependent on the conditions of the surrounding environment and is still frequently encountered the humidity in the room is above the specified standard. This is certainly not in accordance with the work standards at PT Kubota Indonesia where every job must follow the specified standards. Humidity in the flash off room that is not suitable also results in defects in the material of painting [2]. The problem in this study is how to control the relative humidity in the painting room of the flash off a process in order to obtain a standard condition that is the relative humidity value between 40-50%.

In order to overcome the problem in the flash off space, the purpose of this study is to design a model of a relatively automatic humidity control system in the flash off the room to reduce product defects. With the availability of this system, the painting process is expected to run according to standards and be able to reduce the product defect ratio painting.

2. Literature review
Humidity is the concentration of water vapor in the air [3]. This concentration can be expressed in absolute humidity, specific humidity or relative humidity. A tool for measuring humidity is called a hygrometer. A humidistat is used to regulate the level of humidity in a building.

Absolute humidity is analogous if all the water in one m3 is condensed into a container, the container can be a scale of absolute humidity. Absolute humidity has values that range from 0 gram / m3 when the air is dry to 30 grams / m3 when the water vapor becomes saturated at 30 °C. Relative humidity is very important in estimating weather [4].

The relative humidity is the ratio between the actual humidity and the capacity of the air to hold water vapor. When the actual humidity is expressed by the actual vapor pressure, the air capacity to collect water vapor is saturated vapor pressure. So that relative humidity can be written with percent [5].

Relative Humidity is the ratio between the actual water vapor pressure at a certain temperature and the saturated water vapor pressure at that temperature. Another understanding of RH is the comparison between the amount of water vapor contained in the air at a certain time with the maximum amount of water vapor that can be accommodated by the air at the same pressure and temperature [5].

The humidity of the air in a closed room can be adjusted as desired. The regulation of the humidity of the air is based on the principle of equal water potential between the air and solution or with certain solid materials. The high moisture content in the air can cause various kinds of problems both for humans and for the material in surrounding areas, including making physiological pressure and discomfort, causing disease, accelerating mold growth and increasing insect population, accelerating metal corrosion, reducing electrical resistance to insulators, damaging the surface finishing process, causing structural failure, causing paint failure and wall fouling in buildings [6].

3. Research methods

3.1. Problem analysis
Problem identification is the first step of the research carried out with the aim of knowing and understanding the problems that occur. Identification is done through field observations and direct brainstorming at the study site with the operators and leaders of the relevant departments.

3.2. Literature review
Literature studies are needed to look for clues to solving problems and provide a theoretical basis by referring to scientific journals, handbooks, and manual books.

3.3. Design concept
The design concept is an outline of the design plan that will be created. This design concept is further adjusted to the component to be selected according to specifications. The design concepts and
components that have been selected are then carried out in a three-dimensional (3D) tool design process using Solidworks.

3.4. Hardware and software design
Hardware and software design is used to determine the components needed in the manufacture of humidity control equipment as well as programs to control it.

3.5. Testing
In the testing phase, a series of tests are performed on the equipment that has been made.

- Simulation Tools. Automatic humidity control system simulation is done by placing the device in a flash off a room or another room measuring 6m x 6m then the device is set to the value of the humidity in accordance with existing standards. Then the device will read the actual humidity in the room and will start to condition the humidity to the determined humidity value and keep the humidity in the room to remain constant.
- Moisture Value Validation. The automatic humidity control device is installed with a temperature and humidity sensor to read the actual humidity value in the room, then the humidity value is displayed via the LCD. From the humidity value displayed on the LCD compared to the humidity value displayed by the temperature and humidity reader in the room.

4. Results and discussion

4.1. Identification of problems
Problems found in research conducted at PT. Kubota Indonesia is the absence of air conditioning systems in the flash off space painting process so that the moisture in the flash off space does not match the working standard chart (WSC) which results in the final product being painted there is a product defect in the form of blistering defects. Here are the data that support the identification of problems in PT. Kubota Indonesia.

4.2. Data defect product in the painting department
Painting department of PT. Kubota Indonesia is divided into 2 painting lines, each of which goes through stages of the work process starting from Parkerizing, Oven, Loading, Under Coating, Flash Off, Top Coating, Oven, Unloading and Nishugata. Each process must be carried out in accordance with a working standard chart (WSC) to avoid unexpected product defects. Actually, after checking during the final painting process, product defects are often encountered. Here are the results of defect product on Table 1 Data Defect Product Department of Painting, October 2018 - January 2019.

| Month  | Blistering | Sagging | Mottle | Etc |
|--------|------------|---------|--------|-----|
| October| 2459       | 487     | 2092   | 29  |
| November| 2194      | 809     | 1042   | 123 |
| December| 1517      | 585     | 917    | 508 |
| January| 1808       | 145     | 1132   | 64  |

4.3. Test room model data and components of the automatic humidity control system model
In this study, a trial room model and a component of the humidity control system were made in order to determine the effectiveness of the system to be made before it was applied directly to the flash off space of PT. Kubota Indonesia. The trial room model will be made using acrylic material with dimensions of
1500 mm × 500 mm × 800 mm with the acrylic thickness of 5 mm. The following is a description of the model of the trial room which can be seen in Figure 1:

Figure 1. Testing room model.

The design of the automatic humidity control system model was made by adjusting the test chamber model, but still using the same work system that should be applied to the flash off space of PT. Kubota Indonesia. Following is the design of the automatic humidity control system model that will be created as shown in figure 2.

Figure 2. Humidity controller.

4.4. Test and analysis results
Calculation of cooling load is needed to analyze the factors that influence heat transfer that occurs in the test room so that we know the amount of heat energy that must be removed in the room. Cooling loads that are affected are, among others, external heat loads caused by heat entering through conduction (walls, ceilings, glass, partitions, floors), radiation (glass), and convection (ventilation and infiltration) and internal heat loads caused by heat that arises because of people/occupants, lights, and equipment/machinery.

| No. | Source of Cooling Load                  | Total Cooling Load (Watts) (Watt) |
|-----|----------------------------------------|-----------------------------------|
| 1   | External Factor                        |                                   |
|     | Cooling load from the wall             | 31.51                             |
|     | Cooling load from the roof             | 11.59                             |
|     | Cooling load from infiltration         | 7.33                              |
| 2   | Internal Factors                       |                                   |
|     | Cooling load of LCD I2C                | 5                                 |
|     | Q total                                | 55.43                             |
|     | Q safety (10%)                         | 5.543                             |
|     | Q                                      | 60.973                            |

4.5. Calculation of thermoelectric cooler performance
The specifications of the thermoelectric cooler used in this study are as follows:

\[ Q_{\text{max}} = 55.74 \text{ W} \quad \Delta T_{\text{max}} = 73.38 \text{ °C} \]
\[ I_{\text{max}} = 6.4 \, \text{A} \quad V_{\text{max}} = 16.04 \, \text{V} \]
\[ R = 2.24 \, \Omega \]

Next, the Seebeck coefficient of the module when operated at \( T_h = 28 \, ^{\circ}\text{C} \) is as follows:

\[ \alpha = \frac{V_{\text{max}}}{T_h} = \frac{16.04 \, \text{V}}{(28 \, ^{\circ}\text{C} + 273 \, ^{\circ}\text{C})} = 0.053 \, \text{V/K} \]

So, the coefficient produced by the module at the average temperature is 0.053 V/K.

Calculate thermal resistance

\[ \theta = \frac{\Delta T_{\text{max}} \cdot V_{\text{max}}}{I_{\text{max}} \cdot (T_h - \Delta T_{\text{max}})} = \frac{73.38 \, ^{\circ}\text{C}}{6.4 \, \text{A} \cdot 16.04 \, \text{V}} \times \frac{2(301 \, \text{K})}{(28^{\circ} \text{C} + 273^{\circ} \text{C}) - 73.38^{\circ} \text{C}} = 1.89 \, \text{K/W} \]

Calculate electrical resistance

\[ R = \frac{V_{\text{max}}}{I_{\text{max}} \times \frac{(T_h - \Delta T_{\text{max}})}{T_h}} = \frac{16.04 \, \text{V}}{6.4 \, \text{A}} \times \frac{(28^{\circ} \text{C} + 273^{\circ} \text{C})}{(28^{\circ} \text{C} + 273^{\circ} \text{C})} = 1.89 \, \Omega \]

Calculate the amount of current

Using a thermoelectric cooler performance graph with a \( T_h \) data of 28 \, ^{\circ}\text{C} is as follows:

\[ \text{Figure 3. Curve flow.} \]

The known \( T_h \) from the figure 3 above is aimed at temperatures of 25\,^{\circ}\text{C} and 50\,^{\circ}\text{C}. Whereas the average \( T_h \) the test is 28\,^{\circ}\text{C} so the current sought must be interpolated. The \( \Delta T \) value is obtained from the reduction between \( T_h \) and \( T_c \) by 3\,^{\circ}\text{C}. Thus, the result of the interpolation of the current value at \( T_h = 28^{\circ} \text{C} \) is 4.69 \, \text{A}.

Calculate the voltage:

\[ V = IR + \alpha \Delta T \]

\[ = 4.69 \, \text{A} \cdot 1.89 \, \Omega + 0.053 \, \text{V/K} \cdot (301 \, \text{K} - 298 \, \text{K}) = 9.02 \, \text{V} \]

Calculates the heat released \( q_{\text{em}} = \alpha I T_h - \frac{\Delta T}{\theta} + \frac{I^2R}{2} \)

\[ = 0.053 \frac{\text{V}}{\text{K}} \cdot 4.69 \, \text{A} \cdot (273^{\circ} \text{C} + 28^{\circ} \text{C}) \]

\[ = -\frac{3 \, ^{\circ}\text{C}}{1.89 \, \frac{\text{K}}{\text{W}}} + \frac{(4.69 \, \text{A})^2 \cdot 1.89 \, \Omega}{2} = 94.02 \, \text{W} \]

Calculates the heat absorbed

\[ q_{\text{abs}} = \alpha I T_c - \frac{\Delta T}{\theta} - \frac{I^2R}{2} \]

\[ = 0.053 \frac{\text{V}}{\text{K}} \cdot 4.69 \, \text{A} \cdot (273^{\circ} \text{C} + 25^{\circ} \text{C}) \]
\[-\frac{3 \, ^\circ \text{C}}{1.89 \, \text{K/W}} - \frac{(4.69 \, \text{A})^2 \cdot 1.89 \, \Omega}{2} = 93.27 \, \text{W}\]

So, the heat absorbed by the thermoelectric cooler is 93.27 W. While the heat released by the module into the environment is 94.02 W.

5. Conclusion
The automatic humidity control system created and tested in the test chamber model can be used as a new alternative method in the air conditioning process replacing conventional methods using conventional air conditioners. From the results of the analysis of the calculation of the cooling load and the performance of the thermoelectrical device, the system is able to transfer heat according to the expected target. The cooling load that must be transferred is 60,973 Watts, while the performance of the thermoelectrical device is able to transfer heat reaching 93.27 watts of heat absorbed and 94.02 watts of heat released.

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