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Thermal Environment Analysis And HVAC (Heating, Ventilating, Air Conditioning) Installation Basen On CFD (Computational Fluid Dynamics) At PTPN III PKS Rambutan Work Station

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ABSTRACT

This research was conducted based on observations at the PTPN III work station, the operator who did not feel comfortable with the thermal environment was the operator of the sterilizer station. The sterilizer station has heat radiation from the sterilizer machine, heat radiation of machine support equipment and heat conduction of the station roof. All the heat radiation affects the station air temperature. Based on data collection, the average air temperature at the station is 34.59 oC. The operator's reaction to this heat exposure is to take breaks during working hours and when operating machinery. Overall, the proportion of work of machine operators and track control operators who are at the sterilizer station is small. The method used to analyze the impact of heat exposure is the calculation of the Heat Stress Index (HSI) and the proposed repair of HVAC (Heating, Ventilating, Air Conditioning) installations simulated with CFD (Computational Fluid Dynamics). Based on the analysis of the processed data, the average HSI of operators at the sterilizer stations in 13 work areas is 83.62%, which indicates that all operators are exposed to heat. There is a fairly strong positive correlation between HSI and the operator's physiological response of R2 = 0.303. This indicates that the HSI felt by the operator can increase the physiological response in the form of an increase in the number of metabolic activities. There is a very strong negative correlation between the Heat Stress Index value and the total proportion of work operators of R2 = 0.914. This indicates that the increase in HSI makes the operator work proportion decrease. Improvements made were the installation of Air Conditioning in the form of the installation of the L-90 Turbine Ventilator. Based on the simulation, it is known that this improvement will reduce the perception of heat for the operator and reduce the level of operator discomfort.

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1. INTRODUCTION

Environmental conditions in the workplace are closely related to the operator's ability to carry out work. Indoor environment that meets comfortable conditions, very supportive of the operator's work. This comfortable condition is related to environmental thermal conditions, energy consumption and ergonomics. Thermal comfort is a condition in which the mind expresses satisfaction from the conditions of the thermal environment and this is assessed by subjective evaluation.

According to Fanger's approach, the six main factors that influence thermal sensation are air temperature, average radiation temperature, air velocity, relative humidity, metabolic rate and clothing insulation. These six factors are time dependent, but thermal comfort is only assessed assuming steady-state conditions. Moreover, thermal comfort assessment models usually do not apply to sleep activities or bed rest.

Recent surveys of indoor environmental conditions have shown that humans prefer thermal comfort as possessing a higher urgency rating than visual comfort and comfort.

Currently, there is a strong demand for comfortable workspaces to improve health and work productivity. In providing this, HVAC (Heating, Ventilation, Air Conditioning) facilities and lighting systems use about 50–60% of the building's energy consumption to maintain thermal and visual comfort for occupants.

The control method was developed to design a building HVAC facility on a mock model simulation. The control method was obtained from literature review and research on the factual environmental thermal conditions. The control method is a method of controlling the thermal parameters. Thermal parameters are obtained from literature studies found in previous research. The simulation results can be taken into consideration in the design of building HVAC facility improvements.

The simulation results were analyzed using CFD (Computational Fluid Dynamics) software. The results of this simulation will be presented through a temperature contour image and a two-dimensional or three-dimensional temperature distribution pattern. The temperature contour shows certain areas that have high air temperatures. The contour will show the coordinates of the room that needs to be installed with ventilation or conditioning facilities. The design of the air flow system obtained through the simulation is an installation using a turbine ventilator. Application of the turbine ventilator analyzed the results and performance of the thermal environment using Computational Fluid Dynamic (CFD) software.

Based on observations at the PTPN III work station, the production station flow through which Fresh Fruit Bunches (FFB) is passed to be processed into CPO (Crued Palm Oil) at PTPN III PKS Rambutan consists of a fruit reception station and a loading ramp.), stewing station (sterilizing station), thressing station (thressing station), kempah station (pressing station), oil purification station (clarification station). The following is the condition of the thermal parameters contained in each station.

The sterilizer station operator is required to always be in the work station, because many operations are manual, especially the rail control operators and semi-automatic sterilizer machines. This is because the activities at the sterilizer station are the beginning of CPO processing activities and become the determinant of the CPO processing time at the next station. Another reason is that the fruit stockpiling station has the capacity to accommodate FFB, so the FFB must be immediately transferred to a sterilizer station for immediate processing. This is because it will hinder the process of stockpiling FFB that will soon come from the garden. Thus, the sterilizer operator is the longest exposed to heat from his work station, which is 1 shift. This of course affects the perception of the operator's thermal comfort at the sterilizer station to be not good.

The sterilizer station has been attempted to have a very wide air gap by not having a station wall. However, turbulent air flow is obtained due to heat sources trapped on the roof of the work station. As a result, the air velocity moving horizontally from the vent is very low at 0.4 m/s. This causes the cooling of the air temperature inside the station through convection with the air outside the station to be ineffective.

The Sterilizer Station has 3 units of sterilizer machines. Each sterilizer has a boiling capacity of 21 tons with a FFB boiling temperature of 130 oC. The external surface temperature of the machine is 60 oC with a machine surface area of 1701.53 m2. The air temperature at the Sterilizer station is in the range of 33 to 35 o C. The heat radiation emitted by the machine in the production area causes an increase in air temperature. Steam from boiling that ranges from 45 to 50oC greatly affects the increase in air temperature of approximately 4oC.

At the sterilizer station, the lorries exit the sterilizer machine and carry the boiled FFB. Boiling steam affects the air temperature when the door of the sterilizer machine is opened. Another factor causing heat gain is heat radiation from the inlet, exhaust, and condensate pipes as well as hot steam coming out of the exhaust pipe. Exposure to the sun's heat causes heat from the roof to affect the air temperature at an altitude of 5 meters.

2. RESEARCH METHOD

The type of research used is survey research, namely research that seeks to describe problem solving to an existing problem in a systematic and factual manner based on direct observation and collecting actual field data. So this research includes the process of collecting data on thermal comfort variables, namely air temperature, relative humidity, air velocity, radian temperature, subjective response and physical response, and data processing in the form of calculating HSI (Heat Stress Index), cooling load for HVAC installations (Heating, Ventilation, Air Conditioning), as well as analysis and discussion after conducting a 3D simulation of the sterilizer station model before and after the simulation.

Data collection methods used are observation and interviews. Observations were made with the help of measuring instruments at the sterilizer station, observations were made to determine the magnitude of the research variables and the proportion of operator work. Interviews were conducted with the help of a questionnaire given to the operator. Interviews were conducted to determine the operator's subjective response.

Subjective data collection of responses and physiological responses to heat exposure were taken from the population. The population of this study were all operators at the sterilizer work station, namely 6 people who worked in 13 different work areas. Sampling used using total sampling technique which means the number of samples taken is the same as the total population.

The collection of work and idle data is taken by means of random activity sampling with respect to the working time. The population in this data collection is the total working time of shift 1 operators at the sterilizer work station. While the number of samples taken from the population used the Slovin formula sampling technique.

3. RESULTS AND DISCUSSIONS

3.1 Thermal Work Environment Analysis

In measuring the air temperature at the sterilizer station, the average air temperature was 34.59 oC. The maximum air temperature is in work area 4, which is 35.05 oC and the minimum air temperature is in work area 1, which is 33.73 oC. Based on observations, it is known that the largest source of heat radiation comes from the sterilizer machine. Then based on the measurement height, it is also known that there is an increase in temperature from a height of 0.1, 1.1 and 1.7 m.

Figure 1. Heat Mapping of Sterilizer Station Side View

3.2 Relationship Analysis Condition Environment Thermal with Operator Inconvenience

The relationship between HSI and physiological load is shown in Figure 2.

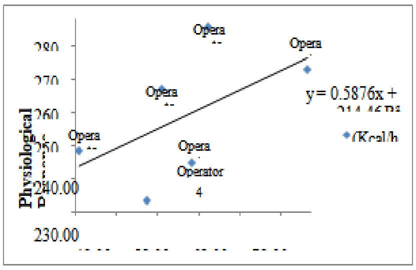

Figure 2. Comparison Graph of HSI and Physiological Load

The graph above shows that there is a fairly strong positive correlation between HSI and the operator's physiological response of R2 = 0.303. This indicates that the greater the HSI felt by the operator, the higher the physiological response in the form of an increase in the amount of metabolic activity.

The relationship between the magnitude of the Heat Stress Index (HSI) of workers and the comfort of the operator is shown in Figure 3.

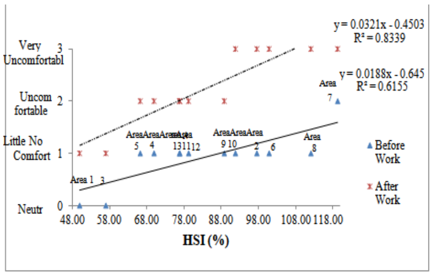

Figure 3. Relationship of Heat Stress Index with Operator Comfort Sensation Before and After Work

The graph above shows that there is a strong positive correlation between the HSI value and operator discomfort of R2 = 0.615 before working and R2 = 0.833 after working. The greater the value of HSI, the greater the scale of operator discomfort. The following is a detailed explanation of the thermal conditions of each operator.

3.3 Analysis of the Relationship between Work and Idle Proportions with Heat Exposure Levels

The relationship between the proportion of workers' work and HSI is shown in Figure 4.

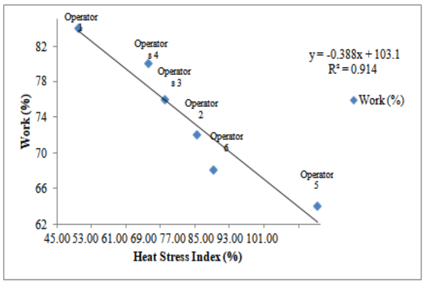

Figure 4. Relationship of Work Proportion with Physiological Load

The graph above shows that there is a very strong negative correlation between the Heat Stress Index value and the total proportion of work operators of R2 = 0.914. The greater the value of HSI, the smaller the proportion of work operators.

3.4 HVAC Installation Analysis (Heating, Ventilating, Air Conditioning)

The sterilizer station has been strived to have good air conditioning for the thermal comfort of its workers, this is in the form of not constructing a wall covering the station, so that the construction of the building is only the roof and pillars of the special building for the sterilizer station. The air temperature outside the station is not cold enough in the range of 29-34 0C to reduce heat through convection between fluids. The average air speed in the low station is 0.41 m/s. As well as the large sources of heat flow in the sterilizer station and the proximity of workers, causing workers to still feel hot. The required HVAC installation is a cooling installation. The facilities contained in the sterilizer station can be seen in Table 1.

Table 1. Physical Facilities of Sterilizer Station

Physical Facilities	Specification						
	Height (mm)	Long (mm)	Width(mm)	Diameter(mm)	Area/ Unit (m 2)	Amount	Large Whole (m2)
Sterilizer Station	9900	66900	14800	-	990.12	1	990.12
Building	4900	66900	14800	-	990.12	1	990.12
Roof	5000	66900	18800	-	1257.72	1	1257.72
Production Floor	-	66900	14800	-	990.12	1	990.12
Sterilizer Machine	2700	28500	2700	2700	76.95	3	230.85
Rail	150	66900	1000	-	66.9	3	200.7
Lori	1450	4020	1700	-	6,834	21	143.514
inlet pipe	-	18500	-	152.4	2.8194	3	8.4582
Exhaust Pipe	-	18500	-	101.6	1.8796	3	5.6388
Condensing Pipe	-	18500	-	61.6	1.1396	3	3.4188
Manual Machine Control Area	5000	13000	1000	-	13	1	13
Automatic Sterilizer Machine Control	1650	600	600	-	0.36	3	1.08
Seat	600	1000	300	-	0.3	6	1.8
Towing Machine Lori	1000	1500	600	-	0.9	2	1.8

In determining the right HVAC installation for the sterilizer station, it is necessary to calculate the cooling load. In calculating the cooling load, it is important to know the thermal balance of the building with the equation.

a. Calculation of Internal Heat Gain

In the calculation of internal heat gain, the amount of heat generated by equipment, facilities and people in the station is calculated. Calculation of Internal Heat Gain is as follows. Qi = Amount of Heat (People, Machines and Facilities) Qi = eóA (T 4-T 4)

Information :

e = emissivity of the object's radiation = Steffan-Bolzman constant (5.67 x 10-8) A = Cross-sectional area (m2) Tout/in = Surface temperature outside/in the object (K)

b. Calculation of Conduction Heat Flow

In the calculation of conduction heat flow, the amount of heat that propagates into the sterilizer station is calculated through solids. At the sterilizer station, heat flows through the top surface of the roof due to exposure to the sun's rays until it propagates to the bottom surface of the roof that is in contact with the air at the sterilizer station.

Qc = Heat through the roof

Qc = A roof x U roof x (Tout-Tin) A roof = Roof cross-sectional area U roof = Transmittance (W/m2oC)

Figure 5. Sterilizer Station Roof

Conduction Heat Flow calculation data can be seen in Table 2.

Table 2. Recapitulation of Calculation of Conduction Heat Flow for Sterilizer Stations

Conduction Heat Flow	
Source of Conduction Heat Flow	Roof
Area (Meters2)	1257.72
Mean Intensity of Solar on Earth Surface (Watt/Meter2)	600
Ingredients	Plated Steel Zinc
Transmittance (W/meter2oC)	8.52
Resistivity (m oC/W)	0.013
Thickness(m)	0.1
Conductance (W/meter oC)	7.692307692
Absorption Number of Sun's Surface and paint	0.365
Come Corner	35
Tin	46
Tout	92.1214
Qc(Watt)	**247113.2588**

Source: Data Processing

c. Calculation of Convection/Ventilaton Heat Flow

In the calculation of convection heat flow, the amount of heat that flows into or out of the sterilizer station is calculated through the confluence of two air with different temperatures. This convection heat flow is very dependent on the high and low air outside the sterilizer station because it affects the direction of the heat flow that occurs. Qv = Air Temperature Convection through the Air Gap Qv = 1300 x V x (Tout-Tin) 1300 = Air Specific Heat Constant (Joule / meter3oC) V = Ventilation Speed (W/meter2oC)

Table 3. Calculation of Convection Heat Flow of Sterilizer Station(At 08:00-12:00 WIB)

Convection Heat Flow	
Source of Convection Heat Flow	Water Gap
Air Convection Meeting Area / Ducting Area (Meter2)	508.56832
Average Speed (m/s)	0.41
Ventilation Speed /Air flow Rate (meter3/s)	236,7641978
Air Specific Heat (J/meter3oC)	1300
Average air temperature outside the station (08:00-12:00 WIB)	29
Average air temperature near the air gap (08:00-12:00 WIB)	31
Qv (Watts)	**-542744.1111**

Source: Data Processing

From the calculation results above, it is known that the hot air flow of 542744.1111 Watt by convection flows out of the station due to encountering colder air from outside.

Table 4. Calculation of Convection Heat Flow at the Sterilizer Station (12:00-16:00 WIB)

Convection Heat Flow =Qv=1300.V.(Tout-Tin) Afternoon-Afternoon	
Source of Convection Heat Flow	Water Gap

Area of Air Convection Meeting (Meters2)	508.56832
Average Speed (m/s)	0.41
Ventilation Speed (meter3/s)	208.747735
Air Specific Heat (J/meter3oC)	1300
Air temperature outside the station outside the station (12:00-16:00 WIB)	33.8
Average air temperature near the air gap (12:00-16:00 WIB)	32
Qv (Watts)	189960.4389

From the results of the above calculations, it is known that the hot air flow of 189960.4389 Watt by convection flows into the station. From the two calculations above, it is known that Total Qv = Qv = -542744.1111 + 189960.4389 = -352783.6722 watts It can be concluded that by convection the convection of two air sterilizer stations with outside air from morning to evening causes heat loss of 352783.6722 watts from the sterilizer station.

d. Calculation of Solar Heat Flow

In the calculation of Solar Heat Flow, the solar heat radiation power is calculated which is reflected through the glass. Since the Sterilizer Station does not have a glass window, the solar heat flow is 0. The need for cooling loads to make the sterilizer station comfortable to live in is.

Qm = Qi + Qs ± Qc ± Qv

Qm = 261157.2656+ 0 + 247113.2588- 352783.6722 = 155486.8572 watts

4. CONCLUSION

The results of the study of Heat Stress Index (HSI) and Thermal Comfort of Operators are the following results: The average HSI of operators in the 13 work area sterilizer work stations is 83.62%, based on the HSI categorization standard according to Neville Staton et al, all get heat exposure. There is a fairly strong positive correlation between HSI and the operator's physiological response of R2 = 0.303. This indicates that the greater the HSI perceived by the operator, the higher the physiological response in the form of an increase in the amount of metabolic activity. There is a very strong negative correlation between the Heat Stress Index value and the total proportion of work operators of R2 = 0.914. The greater the value of HSI, the smaller the proportion of work operators.

The results of the study of the proposed improvement design using 4 Turbine Ventilator L-90 have provided cooling of 141292 watts from a cooling load of 155486 watts.

The results of the simulation study of the HVAC (Heating, Ventilation, Air Conditioning) repair design in the form of a Turbine Ventilator L-90 showed that the average air temperature of the station was 28.79 oC and relative humidity was 54.9%, and the air velocity was 0.706 m/s. Based on the simulation design, the improvement succeeded in reducing PMV and PPD to 1.44 (slightly warm) and 48% from the original 3.26 (Hot) and 100%.

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