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MICROCLIMATE ASSESSMENT ON FATIGUE AND WORKLOAD IN THE PRODUCTION SECTION AT CV. WANA INDO RAYA LUMAJANG

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ABSTRACT
Microclimate is an environmental factor that plays an important role in determining the level of thermal comfort of workers and has a direct impact on fatigue and workload. The main objectives of this microclimate assessment are: (a) Identifying microclimate conditions in the work area, (b) Assessing the impact of the work environment on worker fatigue, both physically and physiologically, (c) Evaluating workload based on thermal conditions, to determine whether the work environment causes additional workload due to heat or cold stress, (d) Providing a scientific data basis for improving the work environment, such as ventilation arrangements, adding personal protective equipment, or ergonomic work scheduling, (e) Supporting productivity and work safety by ensuring the work environment meets thermal comfort standards and does not cause long-term health problems. The average air temperature measurement result was 30.69 °C, higher than the ergonomic standard of 21 °C – 24 °C. The average air humidity measurement result = 31.46%, lower than the ergonomic standard of 40 – 60%. The average wind speed measurement result = 0.51 meters/second, higher than the ergonomic standard of 0.15 – 0.25 meters/second. The level of fatigue was objectively measured based on the percentage increase in the work pulse rate (Heart Rate Reserve). Work fatigue was measured based on the Percentage Increase in Work Pulse Rate (PDNK) or Heart Rate Reserve (HRR). The results of the measurement and analysis of the average PDNK or HRR = 39.12% included in the category of "SEVERE" work fatigue. Workload is measured based on the Working Pulse Rate (DNK) or Heart Rate (HR). The average measurement result of the Working Pulse Rate (DNK) or Heart Rate (HR) = 145.99 Beats/Minute is included in the "HEAVY" workload category

Keywords: Microclimate; Microclimatic Ergonomics; Work Fatigue; Workload

INTRODUCTION

The work environment is one of the main determinants in maintaining the health, safety, and productivity of workers. One important aspect of the work environment is microclimate, namely, the physical condition of the work environment, which includes air temperature, humidity, wind speed, and heat radiation (1–3). Microclimate conditions that are not up to standard can cause heat stress, increase physical fatigue, reduce productivity, and even cause long-term health problems (4–6).

CV. Wana Indo Raya Lumajang is a company engaged in the wood forest product processing sector, which has an intensive production process and is carried out in a closed work environment and lacks an optimal air circulation system. Workers in the production section are exposed to hot temperatures from machines and heavy physical activity (7), so they have the potential to experience increased physiological workload and fatigue (8–10).

This community service activity was carried out as an effort to assist the management of CV. Wana Indo Raya in identifying and evaluating work microclimate conditions and their impact on workload and work fatigue. By using

an ergonomic and work physiology approach, it is hoped that the results of this assessment can be the basis for improving working conditions that are more comfortable, healthy, and productive.

LITERATURE REVIEW

The literature review in this study describes the theories and results of previous studies on microclimate variables, consisting of air temperature theory, air humidity theory, wind speed theory, and lighting theory, which are described as follows:

2.1 Microclimate

Microclimate is an environmental condition in a workspace that can affect the health and performance of workers. Microclimate in a workplace that is not ergonomic can cause health problems, work accidents, and even work-related diseases (11). Microclimate analysis in the production space is intended to determine whether the condition of the workspace is by ergonomic standards (12). If a workspace microclimate is not ergonomic, efforts or engineering adjustments need to be made so that workers can work optimally, safely, and comfortably. There are 4 (four) important microclimate variables that need to be analyzed, namely: air temperature, air humidity, air circulation/wind speed, and lighting / light intensity (13). The 4 (four) environmental variables in a safe and comfortable workspace are often called "Microclimatic Ergonomics". The limits of the microclimatic variable values indicate the comfort zone for carrying out work activities (14), as shown in Figure 2.1, Microclimatic Ergonomics Diagram, as follows:

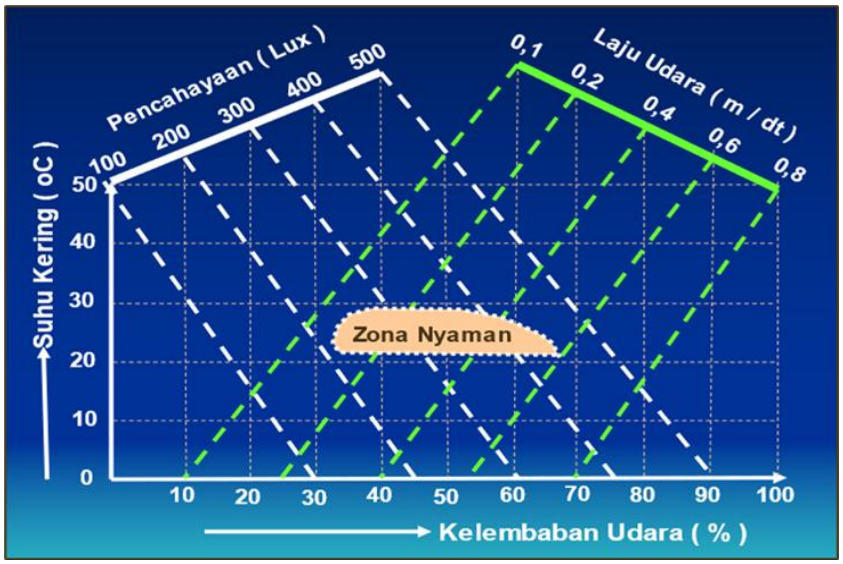

Fig. 2.1 Microclimatic Ergonomics Diagram
(Source: Sajiyo, 2024 (12))

Based on the microclimatic ergonomics diagram above, the comfort zone for carrying out work activities in the room is as follows, air temperature: 21 oC - 24 oC, air humidity: 40% - 60%, wind speed: 0.15 m / sec - 0.25 meters/sec, and light intensity: 300 lux - 500 lux (12).

2.2 Air Temperature in the Workspace

The air temperature in the workspace is the heat or coldness of the air in the workspace. Changes in air temperature in the workspace are influenced by the speed of air movement, the amount of water content in the air, differences in cooling processes, and differences in heating processes in a place (15). Air temperature plays a major role in water evaporation and can hold water in the air, and can process materials in the air chemically (16). The higher the air temperature, the higher the water evaporation, the higher the water vapor held in the air, the faster the chemical reaction. The tool used to measure temperature is a thermometer

Based on the Decree of the Minister of Health of the Republic of Indonesia No. 1405 of 2002 concerning the requirements for office and industrial work environments, the standard air temperature in the workspace is 18 °C - 30 °C (17). Based on the Regulation of the Minister of Manpower No. 5 of 2018, the standard air temperature in the workspace is 23 °C - 26 °C (18). According to Sajiyo et al. (2022) the standard for Ergonomic Microclimate in the workspace is as follows in winter (rainy), 20 °C - 24 °C, in summer (dry) 23 °C - 26 °C, and the difference in air temperature inside and outside the room should not be more than 5°C (19).

High air temperatures will cause the body to sweat a lot, potentially losing a lot of fluids and electrolytes, besides that it can also cause blood vessels to enlarge, so that blood pressure in the body will decrease, which is indicated by a dizzy head, in acute conditions it can damage the brain and other organs of the body (20). If the air is too cold, it causes the heart to work harder to keep the body warm. This can cause blood vessels to narrow, the process of sending oxygen to the heart becomes weaker, and the most fatal impact is heart attacks and strokes (21). High air temperatures in the workplace can cause increased workload and work accidents (22).

2.3 Air Humidity in the Workspace

Air humidity is the water vapor content in the air, which can be expressed as absolute humidity, relative humidity, or water vapor pressure deficit. Absolute humidity is the water vapor content that can be expressed as the mass of water vapor or water pressure per unit volume (23). Based on the Decree of the Minister of Health No. 1405 of 2002 concerning "Health Requirements for Office and Industrial Work Environments," it states that the threshold value (NAB) for air humidity in the workspace is between 65% - 95% (17). According to Sajiyo et al. (2022), the air humidity in an ergonomic workspace is as follows: in winter (rainy), 40% - 50%, in summer (dry), 40% - 60%. Human productivity will reach its highest level at temperatures around 24 °C - 27 °C (19).

High humidity can cause respiratory infections. If the humidity is low, it can cause respiratory irritation due to a lack of mucus to catch dust (particles), viruses, and microorganisms (24). Air humidity occurs when warm and humid air comes into contact with a cold surface, and the vapor in the air turns into liquid (25). The function of air humidity in the workspace is to keep the room temperature from being too high due to the influence of human work processes or work equipment activities. The relationship between humidity and body temperature, the higher the air humidity, the higher the body temperature when doing activities, the lower the air humidity, the lower the body temperature when doing work activities. Humidity in the workspace needs to be guaranteed to maintain worker health by opening windows for air circulation, choosing bright curtain colors, using anti-fungal wall paint, using silica gel to absorb moisture, and utilizing a dehumidifier to maintain humidity stability. According to Ricky (2021), air humidity exceeding the Threshold Limit Value can increase worker fatigue (26).

2.4 Wind Speed in the Workspace

Air circulation is the process of changing air in a room by bringing in air from outside and removing air from inside. The workspace requires adequate air flow by creating sufficient and proper air ventilation. Ventilation functions for the process of exchanging air so that it enters the workspace from outside and removes dirty air from inside to outside (27). Ways to create better air circulation in the workspace are as follows: (a) Placement of doors and windows that allow for air exchange from outside to inside and preferably, (b) Cross ventilation system, (c) Understanding air movement, (d) Higher room ceilings, ≤ 3 M, (e) Provide green open space around the workspace, (f) Limit exposure to direct sunlight, (g) Arrange the room with an ergonomic concept, and (h) Use anti-toxin materials (12).

Air movement is the process of moving wind from a high-pressure area to a low-pressure area. The process of air movement due to differences in air pressure in two different places. Air flow speed is measured with an Anemometer. According to SNI 03-6572-2001, the ergonomic wind speed in the workspace is 0.15 m/s - 0.25 m/s (28). Based on the Regulation of the Minister of Health No. 1077 of 2011, the standard quality standard for wind speed in the workspace is 0.15 m/s - 0.25 m/s (29). According to Sajiyo et al. (2022), the ergonomic wind speed in winter (rainy) is 0.15 m/s, in summer (dry), 0.25 m/s (19). Good air circulation in the workspace will create a balance of oxygen and carbon dioxide levels that make the room feel fresher and more comfortable to breathe. If air circulation is not good, it can trigger asthma attacks, lung cancer, increase the risk of infection and inflammation of the lung tissue.

2.5 Light Intensity in the Workspace

Lighting or illumination is the deliberate use of light to achieve practical contrast effects and/or aesthetic effects. The function of lighting for lighting, every workspace needs lighting (30). Lighting quality is the level of lighting that can affect the sense of sight (eyes). Inadequate lighting will cause the iris muscle to adjust the pupil according to the intensity of the existing lighting (31). According to Satwoko, 2004, there are 4 (four) factors that affect lighting, namely: contrast, glare, light reflection, and light color quality (32). The benefits of lighting are creating beauty, improving mood, forming perception, separating space. The lighting standard according to the Occupational Safety and Health Administration (OSHA) standard is a minimum of 250 Lux, and based on the National Environmental Quality Standards (NEQS) is a minimum of 300 Lux.

According to the World Health Organization (WHO), the ideal light intensity in a workspace is 60 lux – 120 lux. Based on the Regulation of the Minister of Health No. 70 of 2016, it is a minimum of 200 lux. Based on the Regulation of the Minister of Health No. 48 of 2016, comfortable light intensity for working in a general workspace is 300 lux. Poor lighting can cause eye irritation, double vision, decreased accommodation power, decreased perception, decreased visual acuity, and headaches.

METHODS

The type of research used to evaluate the microclimate in the production room at CV. Wana Indo Raya is an observational research type. In this study, observations and measurements were made on 4 (four) microclimate variables, namely, air temperature, air humidity, air circulation, and lighting. Measurements were made at 4 (four) workstations, namely: Rotary 9 Fit Workstation, Rotary Spendles 9 Fit Workstation, Hot Press Workstation, and Sorting Workstation. Each workstation was measured at 5 (five) points in the operational area where workers carry out their activities, as shown in Figure 3.1 Microclimate Measurement Plan below

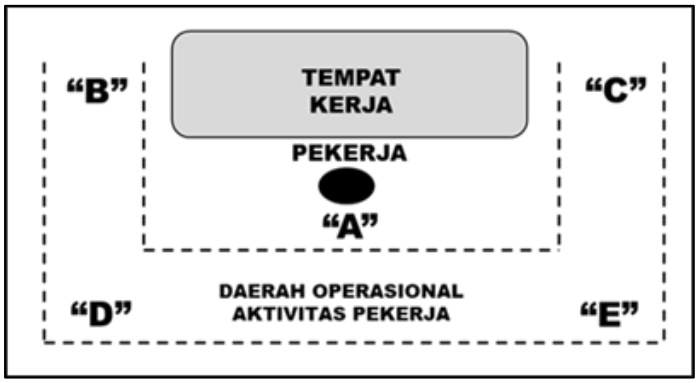

Fig. 3.1 Microclimate Measurement Point Layout

Image caption:
---- = Operational area boundaries of work activities, A, B, C, D and E = Microclimate measurement points. Microclimate measurements are carried out every day for 6 (six) working days in the morning at 08.00, afternoon at 11.30, and evening at 15.30. To facilitate the implementation of the research, a sequence of research processes was made, a Research Flow Chart was made as in Figure 3.2 below.

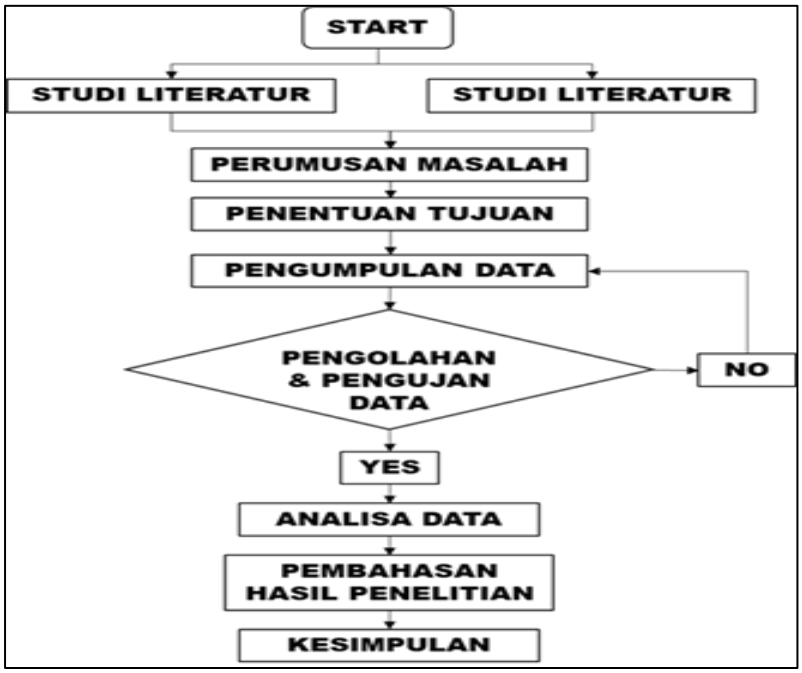

Fig. 3.2 Research Flow Chart

RESULTS AND DISCUSSION

The evaluation results and discussions are presented sequentially based on microclimate variables, namely: air temperature, air humidity, wind speed, and light intensity as follows:

4.1 Air Temperature Evaluation Results

The results of air temperature measurements and evaluations at each workstation are as shown in Table 4.1 Air Temperature Evaluation Data and, and Figure 4.1 Air Temperature Graph Figure below:

Table 4.1. Air Temperature Evaluation Results Data

NO	WORKSTATION	WORK RESULT	STANDARD DEVIATION	STANDARD
1	Rotary	31,69 °C	0,88	20 °C – 26 °C
2	Sepndles	30,35 °C	0,76	
3	Hot Press	31,32 °C	0,91	
4	Sortir	29,32 °C	0,83	
∑		122,68 °C	3,30	
AVARAGE		**30,67 °C**	**0,85**	

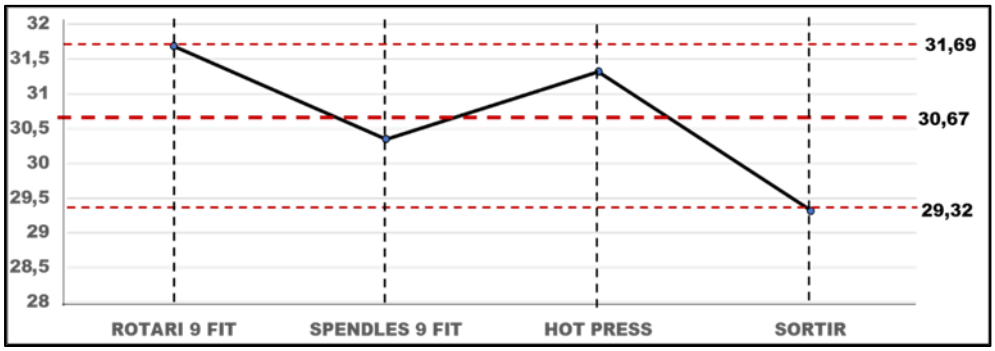

Fig.4.1 Air Temperature Graph

The highest air temperature at the Rotary workstation is 31.69 oC, the lowest at the Sorting workstation is 29.32 oC, and the average of 30.67 oC with a standard deviation (δx) of 0.85. The evaluation results show that the air temperature at all workstations is above the standard of the Minister of Manpower Regulation No. 5 of 2018, the standard air temperature in the workspace is 23 oC - 26 oC (18). High air temperatures exceeding the health threshold according to ergonomics and WHO cause dehydration and loss of electrolytes, thermal stress, decreased concentration, and sleep disorders, which can result in chronic fatigue. For this reason, engineering is needed to lower the air temperature at all workstations. In addition, high air temperatures (hot) can increase the workload of the heart, interfere with muscle work efficiency, and excessive energy use, so that high air temperatures can increase the workload

4.2 Air Humidity Evaluation Results

Air humidity at each workstation is shown in Table 4.2 Air Humidity Evaluation Data and, and Figure 4.2 Air Humidity Graph below:

Table 4.2 Air Humidity Evaluation Result Data

NO	WORK STATION	WORK FRESULT	STANDARD DEVIATION	STANDARD
1	Rotary	32,41 %	0,54	65 % - 95 %
2	Sepndles	31,71 %	0,74	
3	Hot Press	31,57 %	0,94	
4	Sortir	30,31 %	0,75	
∑		126,00	2,97	
AVARAGE		31,50 %	0,74	

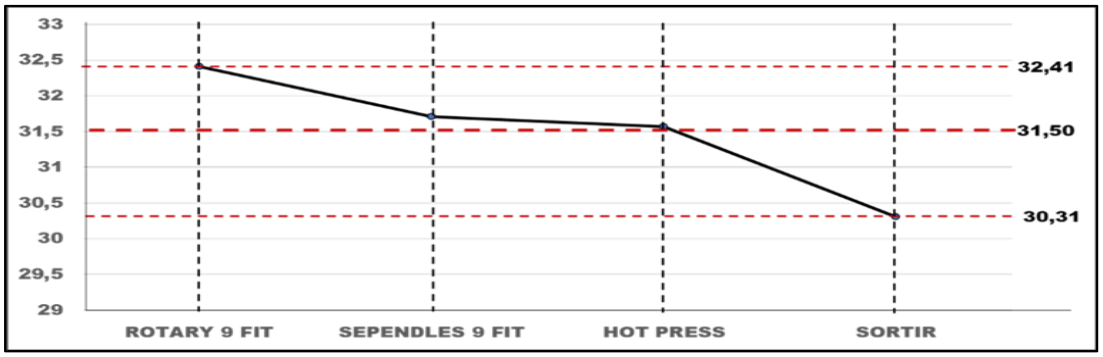

Fig. 4. 2 Air Humidity Graph

The highest air humidity is at the Rotary workstation 32.41%, the lowest is at the Sorting workstation 30.31%, the average is 31.50% with a standard deviation (δx) of 0.75. The evaluation results show that the air humidity at all workstations is lower than the standard of the Minister of Health Decree No. 1405 of 2002, the standard for air humidity in offices and industries is 65% - 95% (17). Low air humidity accelerates dehydration of dry air and accelerates evaporation of body fluids, causing irritation to the eyes and throat, sleep disturbances, and decreased concentration which results in increased fatigue. In addition, in low humidity, sweat evaporates faster in cold sensations, burdening the respiratory system and disrupting motor coordination, so that workers feel a heavier workload .

4.3 Wind Speed Evaluation Results

The wind speed at each workstation is as shown in Table 4.3 Wind Speed Evaluation Data and, and Figure 4.3 Wind Speed Graph Figure below:

Table 4.3 Wind Speed Evaluation Results Data

NO	WOTRK STATION	MEASUREMENT RESULT	STANDARD DEVIATION	STANDARD
1	Rotary	0,45 M/S	0,03	0,15 – 0,25 M/S
2	Spendles	0,44 M/S	0,07	
3	Hot Press	0,41 M/S	0,02	
4	Sortir	0,46 M/S	0,02	
∑		1,76	0,14	
AVARAGE		0,44 M/S	0,04	

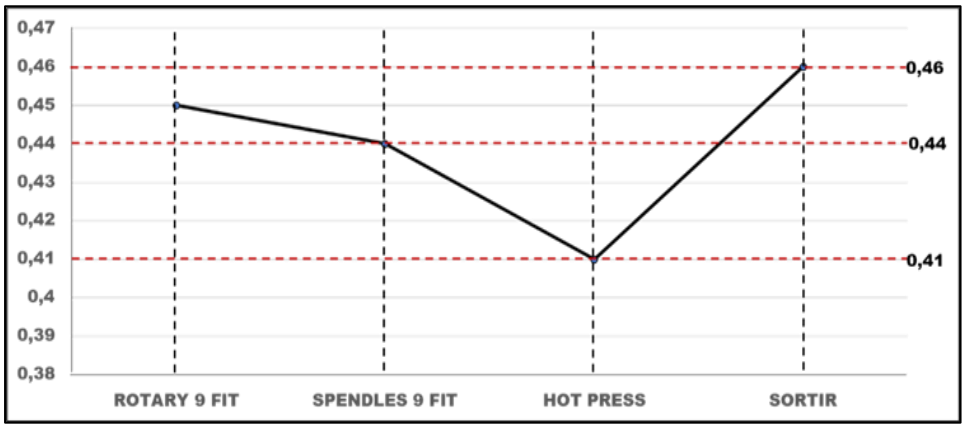

Fig. 4. 3 Wind Speed Graph

The highest Wind Speed is at the Sorting workstation 0.46 m/s, the lowest at the Hot Pressr workstation 0.41 m/s, an average of 0.44 m/s, with a standard deviation (δx) of 0.04. The evaluation results show that the Wind Speed at all work stations is higher than the standard of the Minister of Health Regulation No. 1077 of 2011, the standard Wind Speed in the work room is 0.15 m/s - 0.25 m/s (29). High wind speed causes increased thermal stress, accelerates sweat evaporation, the body feels cold, triggers muscle tension and fatigue, besides that it also causes eye and respiratory irritation which triggers general fatigue.

4.4 Light Intensity Evaluation Results

The light intensity at each workstation is as shown in Table 4.4 Light Intensity Evaluation Data and, and Figure 4.4 Light Intensity Graph Figure below:

Table 4.4 Light Intensity Evaluation Results Data

NO	WORK STATION	MEASUREMENT RESULT	DSTANDAR DEVIATION	STANDARD
1	Rotary	298,96 Lux	2,26	
2	Spendles	294,28 Lux	4,69	
3	Hot Press	298,76 Lux	1,96	
4	Sortir	298,10 Lux	2,61	
∑		1190,10	11,52	
AVARAGE		297,53 Lux	2,88	

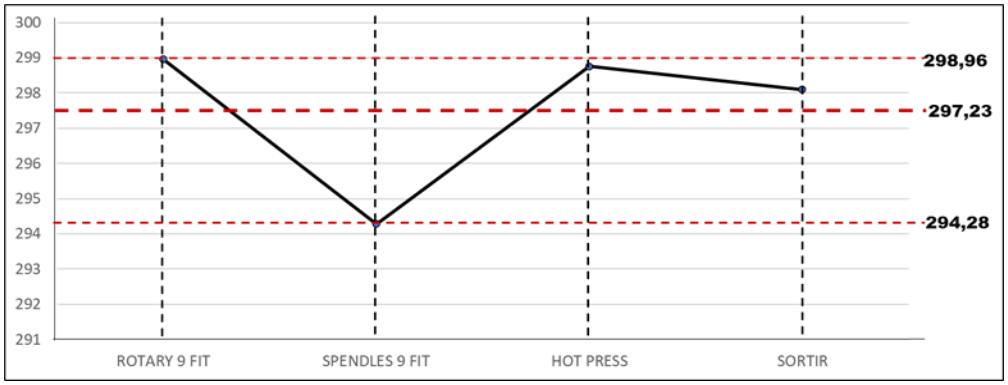

Fig. 4. 4 Light Intensity Graph

The highest light intensity at the Rotary workstation 298.96 Lux, the lowest at the Spendles workstation 294.28 Lux, an average of 297.23 Lux, with a standard deviation (δx) of 2.88. The evaluation results show that the light

intensity at all workstations is in accordance with the Occupational Safety and Health Administration (OSHA) standard of at least 250 Lux. This means that the light intensity at all workstations is ergonomic enough, no engineering efforts are needed

CONCLUSION

1. The highest air temperature at the Rotary workstation is 31.69 oC, the lowest at the Sortir workstation is 29.32 oC, an average of 30.67 oC with a standard deviation (δx) of 0.85. The evaluation results show that the air temperature at all workstations is above the standard of the Minister of Manpower Regulation No. 5 of 2018, the standard air temperature in the workspace is 23 oC - 26 oC. for that there needs to be engineering to lower the air temperature at all workstations.
2. The highest air humidity is at the Rotary workstation 32.41%, the lowest is at the Sorting workstation 30.31%, the average is 31.50% with a standard deviation (δx) of 0.75. The evaluation results show that the air humidity at all workstations is lower than the standard of the Minister of Health Decree No. 1405 of 2002, the standard for air humidity in offices and industries is 65% - 95%. This means that the air in the workspace is dry, so engineering is needed to increase the air humidity at all workstations.
3. The highest Wind Speed at the Sorting workstation 0.46 m/s, the lowest at the Hot Pressr workstation 0.41 m/s, an average of 0.44 m/s, with a standard deviation (δx) of 0.04. The evaluation results show that the Wind Speed at all workstations is higher than the standard of the Minister of Health Regulation No. 1077 of 2011, the standard Wind Speed in the work room is 0.15 m/s - 0.25 m/s. This means that the Wind Speed in the workroom is too strong, this causes the air to become dry, for that there needs to be engineering to reduce the Wind Speed at all workstations
4. The highest light intensity at the Rotary workstation 298.96 Lux, the lowest at the Spendles workstation 294.28 Lux, an average of 297.23 Lux, with a standard deviation (δx) of 2.88. The evaluation results show that the light intensity at all workstations is in accordance with the Occupational Safety and Health Administration (OSHA) standards between 300 - 500 Lux. This means that the light intensity at all workstations is ergonomic enough, no engineering efforts are needed

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