

Changing lamp type and position to improve lighting quality

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Abstract. This study investigates the lighting quality on the production floor in a cigarette paper industry by measuring illumination level and luminance. Cigarette paper inspection is performed manually by operators, and the criteria of defects are the cigarette paper has a hole, is rough and dirty. Operators complain that the room is pretty dark, which makes them unable to see clearly the cigarette paper defect. The government of Indonesia Health Ministerial Decree No 1405 The Year 2002 states that illumination level for continuous manual labor is 200 lux. Illumination level is measured for four days at 08.00, 10.00, 12.30, and 14.00 o'clock with 4 in 1 environmental meter. From the measurement result, it is found that using 7 LED lamps of 60 Watts can produce average illumination level of 70 lux. Low illuminance is caused by illumination level that does not meet the need of 569.759 lumen. Alternatives that can be used to increase lumen number are changing lamp type and position. One of the possibilities is using 24 LED of 138 Watts set 5.7 meters apart from one another can meet this demand. Another is using 5 LED of 150 Watts installed above the field of work.

1. Introduction

Indonesian cigarette paper industry has incorporated automatic machine in an industrial process to increase efficiency. However, paper inspecting stage is still performed manually by operators in close distance for a long period. Roll slitter station has four machines, cutting paper roll into a smaller roll that can be handled by operators. Operators are in charge of adjusting machine speed, sorting, and mark defect papers using naked eye and repairing defect paper roll marked. The criteria of defect paper are it has holes, rough surface, cracked, and dirty. From the previous observation conducted at roll slitter station, it was found that the light intensity on the production floor was 70 lux. The amount of defect cigarette paper that passes the inspection is only 5% of the total defect cigarette paper. However, the amount of defect cigarette paper that passes the inspection is larger than that, which makes production target can not be achieved. This study will show that most the defect cigarette paper that passes the inspection is caused by operators tiredness.

The study regarding lighting level in work environment is found in several kind of literatures. Lighting quality is essential, since it can alleviate health problem among workers and has an impact on products quality and production performance. Lighting affects illuminance system with design indicator of luminaire surface field, temperature color choice, light source, and dazzle resistance [1]. Insufficient lighting will cause eye fatigue, stress, headache, and even accident, yet excessive lighting will cause dazzle that may disrupt health and safety. Good lighting characteristics include appropriate light intensity for the work being performed, does not induce shadow and dazzle [2]. Inspection work



unit is one of the most difficult works in the industry, which in turn requires enough light intensity. Study regarding the effect of light color, light intensity, and text color toward visual work shows that work environment factors that affect employees performance are lighting, noise, color, and air quality [3]. The minimum standard of lighting in the industry is regulated by Indonesian Government of Health Ministerial Decree No 1405 The Year 2002 [4]. A study related to lighting condition and speleologist visual performance using the optical filter on lighting condition similar to that of cave environment shows the increase in contrast sensitivity [5]. Good lighting adjustment made workers able to see better, more thoroughly, faster, and reduce mistakes. Light intensity affects human in performing activity relying on visual information [6]. Larger resolution and contrast level will reduce eyes fatigue level [7]. Measurement of average illuminance is based on measuring lighting, standard reflectance, distance criteria, and lamp condition. Illuminance that does not meet the standard can be improved by increasing the number of the lamps, increasing reflectance number, and changing the type of lamp [8]. Proper lighting design is very important to ensure high-performance work, so that no mistake happening because of visual fatigue [9]. Lighting control system with luminaire sensor is used to adjust artificial lighting to environment lighting changes. Consequently, illumination condition needed can be met with low energy consumption [10].

It is imperative to use diverse energy source and sustainable energy source aside from local resource. In the last few years, LED for interior usage has increased as its advantages, such as low energy consumption, high efficiency of flux lighting, and efficiency. Ability to maintain constant light flux for a long period [11]. Human behavior significantly affects energy consumption related to lighting. A human can choose lighting with more efficient energy during daily interaction[12]. Color temperature is one important lighting factor that will affect subjective perception related to workers comfortability, which will affect performance. Correlation analysis between rendering quality test and color temperature shows that low color temperature is considered as more comfortable and is preferred for relaxing, while the higher color temperature is preferred for working[13]. Heat from Light Emitting Diode (LED) affects room thermal condition in the building and increase the work of air conditioner in summer. Integration of LED lighting system with heater, ventilation, and air conditioner can perform heat exchange [14].

2. Method

The study is held at roll slitter station in cigarette paper industry in Medan, North Sumatra, Indonesia. The study conducted is descriptive correlative which explaining facts obtained from the object studied and identify the relation between the variable in the study based on correlation coefficient, i.e. the effect of illumination level toward roll slitter station work result. The study is conducted in roll slitter station to measure illumination level, luminance, reflectance of the room, and to identify defect products which pass the inspection, correlation between illumination level, the number of lamp and type of lamp.

Illuminance, luminance, and reflectance of the sorting rooms are measured using 4 in 1 environment meter for five days with four times of measurement per day. Measurement is held on 09.00, 11.00, 13.00, and 15.00 o'clock. Measurement points are established using SNI 16-17062-2004, i.e. dividing rooms' length and width by grid based on an area of the room [15]. Roll slitter station of 780 m² have 4 points of measurement with the 6m x 6m grid. Room area smaller than 10 m² uses 1m x 1m grid, room area of 10-100 m² uses 3m x 3m grid, and room area larger than 100 m² uses 6m x 6m grid. Several parameters and formulas are used to analyse this study. Flux luminous is calculated using

$$F = \frac{(E) \times (A)}{(CU) \times (LLF)} \quad (1)$$

Where F(lumen), E (lux) represents average illumination level, A (m²) represents the area. CU represents the coefficient of utilization, LLF represents light loss factor.

Percentage of the defect products that pass the inspection is calculated using,

$$\text{Percentage} = \frac{\text{The number of defect product at roll slitter}}{\text{Total defect products}} \times 100\% \quad (2)$$

The number of lamps needed at roll slitter station is calculated using

$$\text{Number of lamp} = \frac{F}{F_1} \quad (3)$$

where F (lux) is flux luminous dan F_1 (lux) is nominal luminous flux lamps.

3. Results and Discussions

Results that will be discussed include the average level of illumination, the reflectance of object material, defect cigarette paper that passes the inspection, a correlation between illumination level, the number of defect cigarette paper that pass the inspection, number of lamp calculation, and type of lamp.

3.1. The average illuminance

Average illuminance calculation on the production floor is performed to obtain the amount of light that falls on the surface and compare it with the minimum standard of lighting in an industry regulated by Indonesian Government of Health Ministerial Decree number 1405 the year 2002. Illumination level on cigarette paper production floor is affected by lamp wattage, the lamp to work space distance, and production floor area. Illumination level calculated at 18 measurement points at roll slitter station for four days shows that the average level of illumination is 70 lux. The 18 measured points are presented on a paper machine as shown in Figure 1.

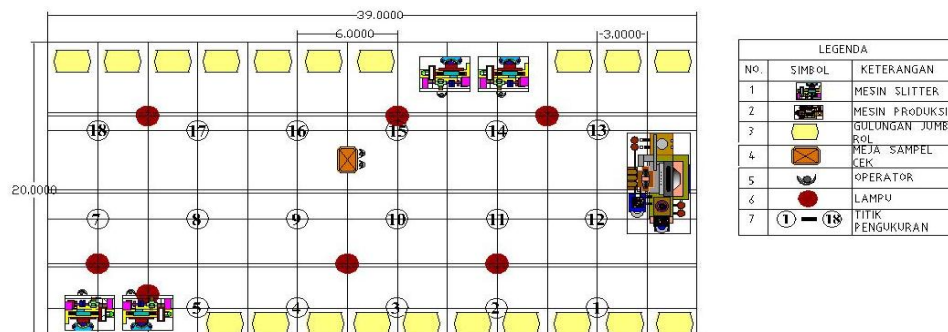


Figure 1. Layout of illuminance measurement points on a paper machine

The level of illumination at roll slitter station of cigarette paper industry can be seen in Table 1. The average illuminance at roll slitter station in the morning is 65.17 lux and 74.64 lux in the afternoon. Illuminance in the afternoon is higher than in the morning, yet still below the standard set by Indonesian Government of Health Ministerial Decree. For blue-collar type work and continuous work, the national standard illuminance set by Indonesian government is 200 lux. In roll slitter station, 7 LED lamps of 60 watts produce average illuminance of 70 lux. These lamps are installed on the roof, 10 meters high from the floor and distributed across the 20 m x 39 m room. Illuminance is higher in the afternoon as more sunlight enters the room and greatly help in lighting the room.

Table 1. The average illuminance in paper of cigarette paper industry

Time	illuminance (lux)				Average (lux)
	Day of measurement				
	1	2	3	4	
08.00	60.8	62.5	59.5	59.5	70
10.00	70.1	71.5	68.7	69.1	
12.00	77.5	78.5	75.8	75.7	
14.00	73.2	74.6	70.7	71.6	
Avare	70.4	71.8	68.7	69.0	

3.2. Reflectance object materials

The reflectance of object materials measured is the wall, floor, ceiling, paper roll, slitter machine, and sample check table. The ceiling has reflectance number below that recommended for lighting in the industry because the ceiling in roll slitter station is made of zinc, which makes reflected light can be reflected back properly. The ceiling need to be replaced with P lafond painted white. Object materials which reflectance number is higher than the recommended number are wall and floor. Wall at this station has bright color, increasing its reflectance number. The floor at this station has no broken area, which affects its reflectance number. Reflectance number of paper roll almost exceed the recommended range, while roll slitter machine and sample check table meet the recommended range.

3.3. Defect cigarette paper that pass the inspection

Defect cigarette paper that passes the inspection fluctuates during four days of observation. Less cigarette paper passes the inspection in the afternoon compared to in the morning because illuminance is higher in the afternoon. The amount of defect cigarette paper that passes roll slitter station during four days of observation is 1,262 kg out of the total amount, 3,489 kg. Meanwhile, the allowed amount by the industry is only 5% of the total defect paper. During these four days, 36.71% defect paper passes the inspection at roll slitter station caused by low level of lighting on a production floor. It can be concluded that there exists a correlation between the amount of defect cigarette paper that passes the inspection with low-level lighting at roll slitter station, causing a decrease in performance and concentration of workers.

3.4. Correlation between illuminance and defect cigarette paper that passes the inspection

The low average illuminance at roll slitter station results in thoroughness decrease of workers. Correlation coefficient testing aims to know relation degree between illumination level with defect cigarette paper passing the inspection. Correlation aims to measure the relation strength between two variables or more. The result of Pearson correlation test shows that correlation coefficient (r) is -0.88 . This means there is a strong inverse relation between illumination level at roll slitter station with defect cigarette paper that passes the inspection. The negative sign means inversely proportional, which means the higher the illuminance at roll slitter station, less defect cigarette paper passes the inspection.

3.5. Number and Type of Lamps

Based on number and type of lamps calculations, the actual number of lamps on production floor does not meet the minimum requirement. Moreover, the type of lamp used is not suitable for factory room condition because it has closed luminaire suitable for outdoor usage. LED lamp recommendation is chosen because of low energy usage, dim level, and shining duration can be changed without using cables, and easy to use. Lumen requirement is calculated at roll slitter station using equation (1) and the obtained flux luminous (F) is of 569,759 lumens. The type of lamp use is 60 watts Philips LED with nominal luminous flux 1450 lumens each. The number of lamps needed based on equation (2) is 393 lamps.

The 1st alternative is using LED lamp type GRN250S/840 WB GC ACW with nominal luminous flux 25000 lumens each. Thus 24 lamps are required (equation 3). Lamp position is arranged using uniformity principle according to spacing criteria, i.e. maximum distance between lamp. From $A\ell = (39 \times 20)/24 = 32.5$; we obtain $S \approx \sqrt{A\ell} \approx \sqrt{32.5} \approx 5,7$ m. Therefore, 24 lamps are arranged with the maximum distance between two lamps to be 5.7 m as shown in Figure 2.

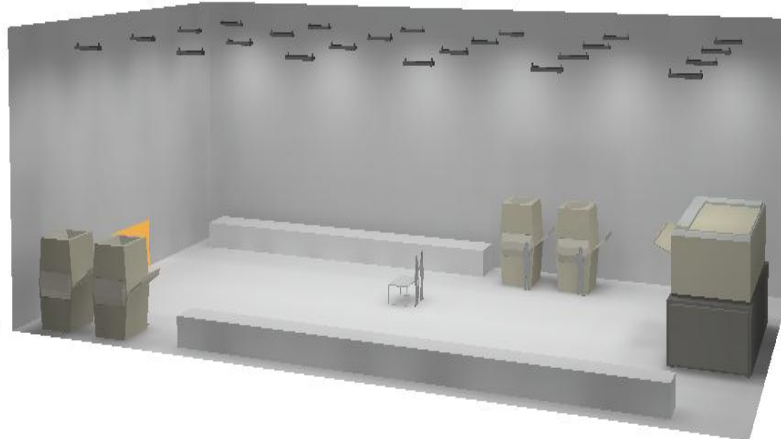


Figure 2. The first lamp arrangement at roll slitter station(1st alternative)

Lighting contour is analyzed using dialux software, and the lighting distribution from the 1st alternative arrangement is shown in Figure 3.

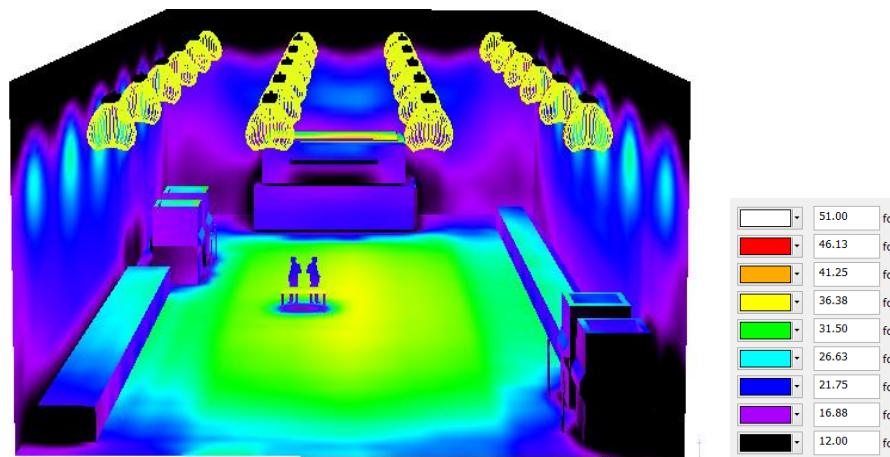


Figure 3. Lighting contour at roll slitter station (1st alternative)

Roll slitter station meets the lighting standard by using 24 lamps. Blue color shows the standard illuminance. Lighting distribution at roll slitter station already meets the standard illuminance recommended. The energy consumption for LED lamp type GRN250s/840 WB GC ACW SI for 8 hours is 26.5 kWh. The 2nd alternative changing the type of lamp to meet the standard lumen only at roll slitter station and sample check table. The suggested lamp is Philips LED lamp type MBS205 1xMHN-TD150W-730 with 13,800 lumens for each lamp. Lamp position is arranged as shown in Figure 4.

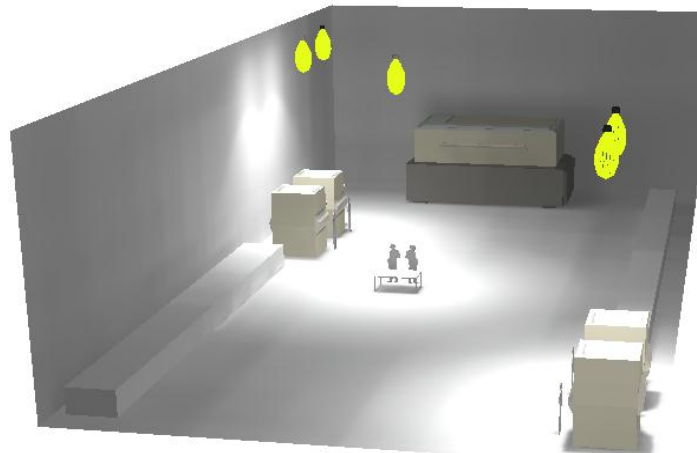


Figure 4. Lamp position arrangement at roll slitter station (2nd alternative)

On the 2nd alternative, it can be seen that 5 lamps are positioned above the roll slitter machine and sample check table, hence light falls only on the inspection area. Lighting contour analysis performed using dialux software shows light distribution from the lamps as shown in Figure 5.

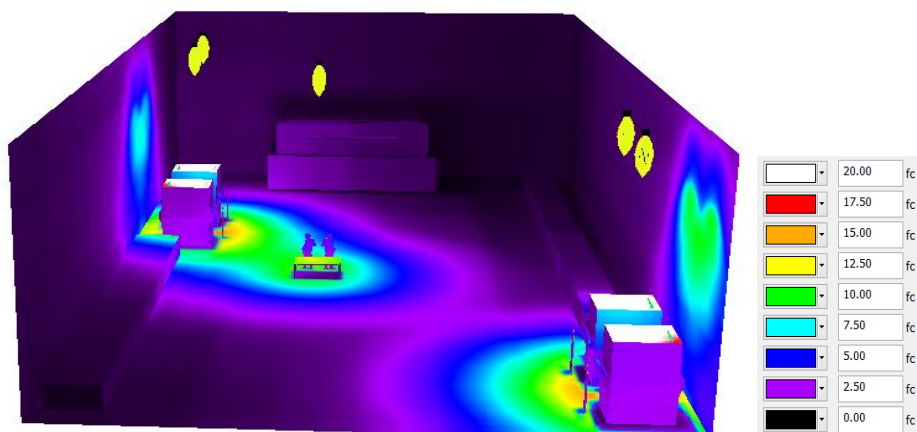


Figure 5. Lighting contourat roll slitter station (2nd alternative)

Roll slitter station meets the standard by using 5 lamps. Red and white area shows the standard illuminance. Black area is area where lamps does not fall over. Energy consumption for Philips LED type MBS205 1xMHN-TD150W-730 for 8 hours is only 6.64 kWh.

4. Conclusions

This article aims to understand lighting quality effects on defect cigarette paper that passes the inspection at roll slitter station in a cigarette paper industry. The main parameters to obtain are illumination quality at roll slitter station, correlation between illuminance with defect products that pass the inspection, and type and number of lamps to improve lighting quality. The average light intensity at roll slitter station in cigarette paper industry is far below the standard recommended by Indonesian Government of Health Ministerial Decree No 1405 The Year 2002, 200 lux, so that lighting improvement is needed. There is a strong inverse relation between illumination level at roll slitter station with defect cigarette paper that passes the inspection, therefore lighting improvement need to be done to minimise defect cigarette paper that passes the inspection. Lamp position arrangement and

type of lamp use at roll slitter station have 2 alternatives. The 1st alternative is using 24 LED lamp type GRN250s/840 WB GC ACW SI distributed evenly with maximum distance of 5.7 m consuming 26.5 kWh of energy for 8 hours usage. The 2nd alternative is using 5 Philips LED lamp type MBS205 1xMHN-TD150W-730 installed only above roll slitter machine consuming 6.64 kWh of energy for 8 hours usage.

References

- [1] Zhang G 2013 *Applied Physics Research* **5** (5) 55-59.
- [2] Uttam D 2015 *International Journal of Advance Research in Engineering and Applied Sciences* **4** (2) 17-26.
- [3] Benedetto and S *et al* 2014 *Journal of Computer in Human Behavior*, 41 pp 112-119.
- [4] Government of Indonesia Health Ministerial Decree No 1405 Year 2002 Health Requirements of Work Environment at Office Complex and Industry.
- [5] Huang CK, Chien JH and Siu KC 2017 *International Journal of Industrial Ergonomics* **6** 1126-130.
- [6] Wezel C, Verhelst ELMZ, Sturm J and Hoof J 2016 *Journal of Technology in Society* **47** 60-65.
- [7] Lee EC, Park KR, Whng M, Min K 2009 *International Journal of Industrial Ergonomics* **39** 798-806.
- [8] Wasilah, Prijotomo J and Rachmawati M 2013 *International Journal of Engineering Science and Innovative Technology (IJESIT)* **2** (4) 64-71.
- [9] Leccese F, Salvadori G, Montagnani C, Ciconi A and Rocca M 2017 *International Journal of Industrial Ergonomics* **57** 42-54.
- [10] Pandharipande A, Caicedo D 2015 *Journal of Energy and Building* **104** 369-377.
- [11] Kiyak I, Oral B and Topuz V 2017 *Journal Energy and Building* **148** 342-347.
- [12] Heydarian A, Pantazis E, Carneiro JP, Gerber D and Gerber BB 2016 *Journal of Environmental Psychology* **48** 212-223.
- [13] Wang Q, Xu H, Zhang F and Wang Zhehong 2016 *International Journal for Light and Electron Optics* **129** 21-29.
- [14] Ahn BL, Yoo S, Kim J, Jeong H, Leigh SB and Jang CY 2016 *International Journal Energy and Buiding* **127** 1159-1170.
- [15] Indonesian National Standard 2004 Lighting Intensity Measurement at Work Place.