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Analysis of Lighting Condition in Cutting Area

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Abstract. Working environment factors such as temperature, humidity, lighting condition, sound level, and etc can give impact to work result. Bad lighting conditions can lead to faster fatigue, decreased work productivity or even to work accident. This research was conducted in coachbuilder/ auto body manufacturer. Objective of this research is to analyze lighting condition in cutting area. Based on initial measurement, lighting level is only 30 lux, while the standard of lighting level based on Indonesian regulation is 200 lux. This lead to 40% of work accident in 2015 in the manufacturer plant. Lighting level was measured by lux meter in several points of measurement based on Indonesian Standard in SNI 16-7062-2004. From the research, the required of lumen and number of bulb was calculated for cutting area. Based on the analysis result, this research recommend adding 4 LED lamps in operator's working area. The usage of LED lamps can lead to reduce energy consumption.

1. Introduction

Lighting condition in a workplace is a measure of the sufficiency of illumination in a working environment. Lighting is one of the working environment factors which need special attention from the management. Lighting conditions as well as temperature and humidity workspace, giving effect to the work result of a worker as well as in the cutting area [1-3].

Previous research in rubber processing plant using Macroergonomics approach shown that environmental factors such as hot, smelly and dark as variances (are not sufficient to support good working condition) [4]. Insufficient lighting can effect to eye fatigue for the operators and effect to the performance by decreased work productivity [5]. Lack of lighting can also lead to work accidents [6].Another research conducted in sorting station at printing industry and plastic packaging industry indicates low lighting can lead to increased number of defective products which passed inspection [7]. Previous research in printing industry also shown that the light bulb used are not met the lighting needs [8]. The higher level of illumination does not mean to provide the best possible impact for workers, because the excessive light will cause glare, in addition to high energy costs. This research was conducted at the cutting station at a coachbuilder industry (auto body manufacturer) in North Sumatra. Not many research was done in coachbuilder industry such as previous research cited. At the initial observation, the illumination level is 30 lux at the cutting station, is under the terms of the government regulation at 200 lux, so it is necessary to design the lighting improvements [9]. The effects of this condition are cases of occupational accidents that occurred in 2015 that approximately 40% were located

in the cutting station. The accident cases such as entrapment of hand in the cutting machine, operator struck down by an aluminium plate and severed fingertip by cutting machine.

Lighting shares a large part in the global energy consumption, lighting consumption can be easily reduced with the use of efficient light sources [10]. Therefore, we need a system that can reduce lighting energy consumption in buildings [11]. With the increasing awareness about energy conservation and optimization usage, there are high demands for efficient ways of building which also assist in reducing cost [12]. Light-emitting diodes (LED) are becoming an increasingly common lighting option for industrial applications, offering superior power efficiency and longevity relative to conventional fluorescent technologies [13]. The aim of this study is to analyze lighting condition in cutting area and propose LED lamps uses in improving lighting condition to reduce energy consumption.

2. Methods

The study was conducted at the cutting station in coachbuilder industry. The subject of this research is room area in cutting station [14]. Area of the workstation is 95 m2, with incoming light from two lamps and each lamp has 23 watts. The distance from the lamp to the working surface is 9 m.

Measurement points were determined by following the provisions of SNI 16-7062-2004 which divides the workspace on grids with certain size depending on the area. For room under 10 m2, the size of the grid is 1 m x 1 m; room with an area between 10-100 m2, grid is 3 m x 3 m; for a room with area exceed 100 m2, grid is 6 x 6 m [15].

Characteristic of the research object was illumination that pointed at the area of the operator's view. Measuring instrument for this research is 4-in-1 environment meter. Grid size is 3 m x 3 m since area in cutting machine is 95 m^2, and gained 6 points of measurement.

The measurement of Illumination performed thrice at any point during the three days of observation from 9:00 a.m. until 4:00 p.m. in West Indonesia Time. The luminance measurements were also conducted on a number of material objects in the cutting station. From the measurement results will be calculated the average value of illumination, the number of reflectances, the number of lumens required at the cutting station and energy needs to fulfill them.

Lights lumen calculated using the number of illumination needed (F) in lumens, recommended illumination level (E) in lux, working space (A) in square meter, Utilization Factor (UF) in percent, and Light Loss Factor (LLF) in percent. Lights lumen needed is calculated as follow:

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

$$F = \frac{E \times A}{(UF) \times (LLF)} \quad (2)$$

The calculation for the number of light bulb required using this formula:

$$N = \frac{F}{(FL)} \quad (3)$$

Where: 1 lux = 1 lumen/m2

Selection for the type of light bulb can be considered based on the number of lumens and lower energy needs. LED lamps used as alternatives, so that operating costs will be lower.

3. Results and discussion

3.1. Illuminance and luminance measurement

During 3 days the measurement of illumination was performed in the cutting workstation and cutting machine area, and the data were presented in Table 1.

Table 1. The average of Illumination level in the cutting station (lux).

Point of measurement	SK	AK
1	28,16	21,81
2	38,77	21,39
3	41,87	28,44
4	25,51	24,87
5	48,61	32,91
6	40,39	36,94

SK = Illumination level in Cutting Station
AK = Illumination level in operator's cutting machine area

Illumination level in Table 1 varied from 21,81 lux until 48,61 lux, that proofing in this cutting area need to improve the lighting condition.

The illumination data in operator's cutting station area, cutting machine and number of illumination level required by government regulations can be seen in Figure 1. From the figure, can be seen that the existing illumination is still below the requirements.

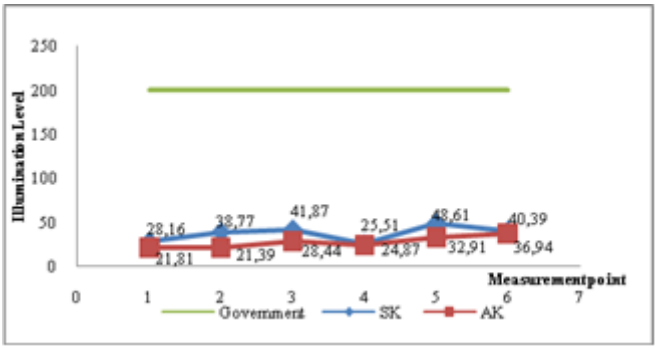

Figure 1. Illumination level in cutting station and work area.

Illuminance and luminance measurements carried out on the object material in the cutting station, such as left, right, front and back of the wall, as well as floor and ceiling. The wall was formed of stone wall except on the right side formed of an iron door. The floor was also made of cement, and the ceiling is made of aluminium.

Comparing the luminance to the illumination level can be obtained a number of reflectance as in Table 2. From the table, can be seen that number of reflectance of the floor is lower than the wall and ceiling. It happened because the material used on the floor has a gray color. The darker a material is, the lower number of reflectance will be.

Table 2. Number of reflectance of each object material in the cutting station.

No	Measurement area	Num. Of reflectance	Color explanation
1	Wall	0,50	Beige
2	Floor	0,38	Gray
3	Ceiling	0,53	Dull white

3.1.1. Lumens and number of required lamps. The type of existing lamps has luminous flux about 1,900 lumens. The calculation result of required lighting (flux luminous) amounting to 79,835.90. If used the same type of light bulb with current, the required light bulb will be equal to:

$$N = \frac{F}{F_i} = \frac{79.835{,}90}{1.900} = 42 \text{ lamps}$$

The type of LED lamp is recommended in this study because it has higher efficacy (115-180 lm/watt), longer-lived (35,000-50,000 hours) and shock-resistant. Using the actual height of the lamps to the working surface, 9 meters, then 12 units of LED light bulbs need to be used for the 88 watts lamp (nominal luminous flux of 6,300 lumens). While using 74 watts LED lamps of different types with a nominal luminous flux of 9,000 lumens, the number of light bulbs required is 8 units only.

In the working area of the operator, placement of the light bulbs by a distance of 30 cm from the working area (placed on the cutting machine, closer to the operator will receive a higher level of lighting). If 8 watts of LED lamp with an equivalent value of 112 lux, the light bulbs required to meet the standard of 200 lux is 2 units.

3.1.2. Energy usage. As in the previous description, it was gained 3 lighting alternatives to meet the standard of 200 lux., as shown in Table 3.

Table 3. Lighting alternatives for working room and working area of operator.

Alternative	Number of Lamps	Power / lamp (watt)	Illumination level (lux)	Power needs (KW)
I	12	88	1279	1,056
II	8	74	316	0,592
III	4	8	224	0,320

From alternatives above, it appears that the third alternative has the lowest required energy. If alternative III is implemented then the fulfillment of the lighting in the cutting station is simply, by adding 4 light bulbs 30 cms above working area operator. This solution will have much cheaper costs consequences compared to two other alternatives.

4. Conclusions

This research analyses that average of existing illumination is 30 lux and recommend improving lighting condition by adding 4 LED lamps in operator's working area to fulfill government regulation and SNI regarding lighting recommendation in room area. The use of LED lamps is proposed to be used in order to lower the operating cost.

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