The Validation Modelling of Air Movement to Measure Thermal Comfort in Building Model

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Abstract: Discussing about passive cooling buildings cannot be separated from discussing thermal comfort, especially in tropical climates. Natural Ventilation is one of an answer to the energy conservation issues. NV can also help to achieve thermal comfort in a building. This study examines how air velocity affects indoor thermal comfort in a building model with dimensions 2.5 m x 2.5 m that uses natural ventilation. The research was conducted by taking 100 indoor air velocity (m/s) data and temperature (°C) from the two hot-wire anemometer (KRISBOW KW0600653 and LUTRON AM-4234SD) instruments with an interval of 5 minutes for each data. The data statistically analyzed by using linear regression modelling of SPSS 24 version software. The 100 data obtained, for indoor air velocity readings, the two brands have correlation of 75%, while for temperature readings is 92.6%. The building didn't achieve the thermal comfort because of ventilations location. The purpose of this research is to prove that without natural ventilation especially the air velocity, thermal comfort can't be achieved by using LUTRON AM-4234SD hot-wire anemometer and want to validate the reading values to KRISBOW KW0600653 or vice versa more easily with the equations found in this paper.

1 INTRODUCTION

Nowadays, buildings with an energy-saving concept is a primary consideration. This concept follows the Green Architecture and Sustainable Design concepts. Zhang et al (Zhang & Lin., 2020) stated that architecture and its construction play a big role in environmental damage and increased carbon dioxide emissions. Therefore, the architecture field should attempt to achieve thermal comfort in buildings by calculating energy usage and the Green concept. To improve understanding of thermal comfort in rooms, one should calculate the thermal comfort standard and consider the ventilation model of thermal comfort and thermal adaptation from psychology, physiology, and behavior of users (Xia, et al., 2020). The new challenge for designers and architectural researchers is to create flexible built environments according to the Energy Efficiency concept (Lau, et al., 2020).Natural ventilation is a method to achieve thermal comfort in a room without using much energy. It is proven in previous studies that air velocity in a room can reduce the standard effective temperature so that thermal comfort in the room can be achieved (Sekati, et al., 2018)(Sekatia, et al., 2019).

The air velocity measurement in a room should be conducted using a measuring instrument of hot wire anemometer. Hot wire anemometer is an essential instrument for measuring laminar, transition, and turbulent flows because of its accurate signal interpretation and simplicity of use. This measurement technique is an indirect method with an output of tension signals. Therefore, calibration is a critical way to measure speed effectively and accurately (Ozahi, et al., 2010). Hot wire anemometer also has an advantage of small probe sizes and frequency responses that enable speed fluctuation in a detectable high frequency (Benjamin & Roberts, 2001). Hence, for air velocity measurement in a room with substantially small airflow, a hot wire anemometer is required compared to traditional anemometers that can only be used outside of the room.

Hot wire anemometer's brands are massive in the market. The most used brands are KRISBOW KW0600653 and LUTRON AM-4234SD. Both brands have the same resolution. Therefore, this study

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aimed to validate both instruments, in which one instrument, i.e., KRISBOW KW0600653 had been calibrated and acquired a calibration certificate from the KAN (National Accreditation Committee). The validation was carried out in a model building with a size of 2.5m x 2.5m in Semarang City. The study results are two equation models to validate both instruments and measure thermal conditions in the model building.

2 RESEARCH METHOD

2.1 Climate Condition

Semarang City is geographically located at 109° 35‘ – 110° 50‘ East Longitude and 6° 50’ – 7° 10’ South Latitude with an area of 373.70 km2. According to the geographic site, it is affected by monsoons' tropical climate with two kinds of weather, i.e., dry weather from April – September and rainy weather from October – March with an average annual humidity of 77% (Pemerintah Kota Semarang, 2015).

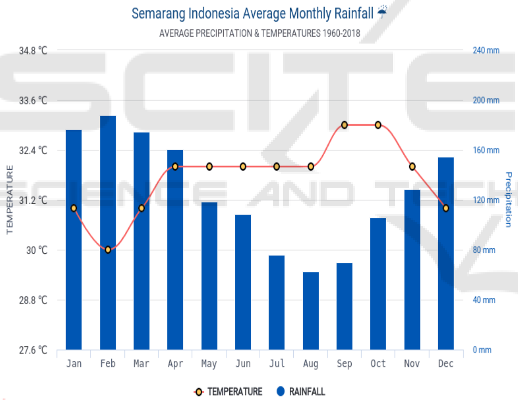

Figure 1: Semarang Average Precipitation and Temperature 1960 – 2018 (Hikersbay, 2020)

Figure 1 shows that the average temperature of Semarang City ranged from 30°C to 33.2°C. It was caused by the geographic condition of Semarang City, in which most of the areas are lowlands and beaches. Rainfall in Semarang City was rather high, ranging from 80 mm to 180 mm. The annual rainfall rate of Semarang City was 1528 mm. January, February, and March were months with the highest rainfall.

Table 1: Specifications of measurement instruments

Instrument	Manufacturer	Parameter	Resolution	Range	Accuracy
Hot wire Anemometer (KW0600653)	KRISBOW, China	Air velocity	0.01 m/s	0.1 - 25.0 m/s	± 5% ± 0.1m/s
		Air temperature	0.1°C	0 – 50°C	± 1.0°C
Hot wire Anemometer (AM-4234SD)	LUTRON, China	Air velocity	0.01 m/s	0.2 - 35.0 m/s	± 5% ± 0.1m/s
		Air temperature	0.1°C	0 – 50°C	± 0.8°C

The resolutions of the KRISBOW hot wire anemometer (KW0600653) in measuring air velocity and temperature are 0.01 m/s and 0.1°C. It is the same with the LUTRON hot wire anemometer (AM-4234SD) (see Table 1).With the same resolution, both instruments' validation is necessary to be discovered to ease researchers in reading the measurement result. Data were analyzed statistically using the linear regression software of SPSS version 24 to find the validation equation model between the KRISBOW hot wire anemometer (KW0600653) and LUTRON hot wire anemometer (AM-4234SD). The model building's thermal condition was analyzed using Szokolay’s standard (Szokolay, 2001) and the standard SNI 03-6572-2001 (SNI, 2010).

2.2 Data Collection and Measurements

In obtaining a reading validation of measurement results, 100 data were obtained on a model building with a size of 2.5m x 2.5m with two different variables, i.e., air velocity and temperature. Each data was taken with a 5-minute interval. Data were taken using two hot wire anemometer instruments with different brands, i.e., KRISBOW KW0600653 and LUTRON AM-4234SD (see Figure 2 and 3) at the same time and same height of 1.1m from the floor (Brager & De Dear, 1998). The ventilation height on the model building was constructed on 1.6m from the floor.

Figure 2: KRISBOW KW0600653

Figure 3: LUTRON AM-4234SD

The KRISBOW KW0600653 hot wire anemometer had been calibrated and acquired a calibration certificate no. S. 19 012 115 SNI ISO/IEC-17025-2008 from the KAN (National Accreditation Committee). KAN is a national institution in the research instrument accreditation and calibration field.

3 RESULTS

3.1 Air Velocity (M/S)

The form should be completed and signed by one author on behalf of all the other authors. Air velocity highly affects the standard effective temperature (SET) reduction (Sekatia, et al., 2018). Szokolay (Szokolay, 2001) stated that the air velocity comfort zone in tropical climate ranged between 0.2 m/s – 0.8 m/s. From the measurement conducted on the model building, obtained the average air velocity from both hot wire anemometers ranging between 0.028 m/s to 0.032 m/s. Therefore, the model building's air velocity didn’t meet the comfort zone standard in tropical climate because it was under 0.2 m/s. It was possible because there was ventilation on top of the building shaded by the model building’s eaves.

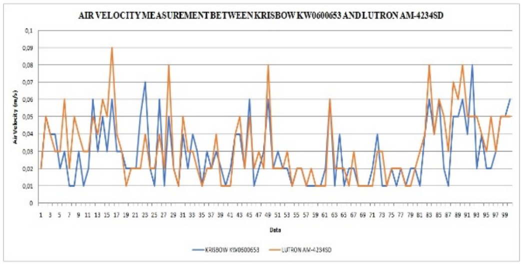

Figure 4: Air Velocity measurement between KRISBOW KW0600653 and LUTRON AM-4234SD

From Figure 4, it is discovered that both instruments only had a slight difference in air velocity reading. LUTRON AM-4234SD tended to read more sensitively and higher than KRISBOW KW0600653. Nevertheless, KRISBOW KW0600653 often read the air velocity higher than LUTRON AM-4234. Hence, from the data obtained, a statistic test using linear regression was carried out to validate both instruments into an equation so that the LUTRONAM-4234SD’s reading result could be represented into the KRISBOW KW0600653’s reading result where this instrument had been calibrated.

3.2 Validation and Regression Model of Air Velocity between KRISBOW KW 0600653 and LUTRON AM-4234SD

The first regression model shows the air velocity reading correlation of both hot wire anemometers, i.e., KRISBOW KW0600653 and LUTRON AM-4234SD.

Table 2: Model Summary Regression 1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.750a	.562	.558	.01165
a. Predictors: (Constant), LUTRON VEL				

In Table 2, R is the correlation coefficient. It can be interpreted that the correlation coefficient of air velocity on KRISBOW and LUTRON hot air anemometers was 0.750, meaning that the relationship between air velocity reading of KRISBOW and LUTRON hot wire anemometers was 75%. R square is called the Determination Coefficient. From Table 1, it is discovered that the R square value was 0.562, meaning that 56.2% of the variations occurred on KRISBOW KW 0600653's air velocity reading was caused by LUTRON AM-4234SD's air velocity reading, while the rest was unexplainable.

Table 3: Regression Model 1

a.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.017	1	.017	125.837	.000b
	Residual	.013	98	.000		
	Total	.030	99			

a. Dependent Variable: KRISBOW VEL

b. Predictors: (Constant), LUTRON VEL

b.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.007	.002		2.996	.003
	LUTRON VEL	.682	.061	.750	11.218	.000

a. Dependent Variable: KRISBOW VEL

In Table 3.a., it is discovered that the probability or Sig value was 0.00, where Sig value <0.05 means that the regression model is accepted. Table 3.b. shows a constant of 0.007 with air velocity reading coefficient of hot wire anemometer LUTRON of 0.682. From this regression result, obtained an equation to validate the air velocity reading of KRISBOW KW0600653 against LUTRON AM-4234SD as follows:

$$KRISBOW\ VEL = 0.007 + 0.682\ LUTRON\ VEL \quad (1)$$

Where KRISBOW Vel is the air velocity reading in hot wire anemometer KRISBOW KW 0600653 (m/s), and LUTRON Vel is the air velocity reading inhot wire anemometer LUTRON AM-4234SD (m/s). The equation above eased air velocity reading in hot wire anemometer LUTRON Am-4234SD to obtain a validated value in KRISBOW KW 0600653, which had been calibrated.

3.3 Air Temperature (°C)

The temperature shown in hot wire anemometers should not be used to measure thermal comfort in a room. Thermal comfort can be determined using the standard effective temperature. SET is an imaginary environment temperature in 50% RH, <0.1 m / s (20 fpm) in the average air velocity, where the total heat loss from imaginary occupant skin with an activity rate of 1.0 met and clothing rate of 0.6 clo, equals with the actual environment wearing the actual clothes and conducting the actual activity [14]. However, in Indonesia, SNI 03-6572-2001 regulates the air temperature declared as comfortable in a room, ranging between 25.8°C to 27.1°C[12]. From the measurement conducted on the model building, obtained an average air temperature ranging between 27.54°C to 28.2°C. It was influenced by the small amount of air velocity entering the model building; thus, the air temperature did not meet the comfort zone according to SNI 03-6572-2001.

Figure 4. Air temperature measurement between KRISBOW KW0600653 and LUTRON AM-4234SD

It can be seen in Figure 4 that the air temperature reading in the model building only had a slight difference, ranging from 0.1°C to 0.7°C. Again, LUTRON AM-4234SD had a higher reading tendency than KRISBOW KW0600653. It proves the possibility of LUTRON AM-4234SD having higher sensitivity. The authors conducted a linear regression statistic test to validate and formulate an equation for both instruments from obtained data.

3.4 Validation and Regression Model of Air Temperature between KRISBOW KW 0600653 and LUTRON AM-4234SD

The second regression model shows the air temperature reading correlation of both hot wire anemometers, i.e., KRISBOW KW0600653 and LUTRON AM-4234SD

Table 4. Model Summary Regression 2

Model Summary Regression 2				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.926a	.858	.856	.08727
a. Predictors: (Constant), LUTRON TEMP				

In Table 4, it can be interpreted that the correlation coefficient of air temperature on KRISBOW and LUTRON hot air anemometers was 0.926, meaning that the relationship between air temperature reading of KRISBOW and LUTRON hot wire anemometers was 92.6%. From Table 4, it is discovered that the R square (determination coefficient) value was 0.858, meaning that 85.8% of the variations occurred on KRISBOW KW 0600653's air temperature reading was caused by LUTRON AM-4234SD's air temperature reading.

Table 5. Regression Model 2

a.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.502	1	4.502	591.128	.000b
	Residual	.746	98	.008		
	Total	5.248	99			

a. Dependent Variable: KRISBOW TEMP

b. Predictors: (Constant), LUTHRON TEMP

b.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.123	.881		6.949	.000
	LUTHRON TEMP	.759	.031	.926	24.313	.000

a. Dependent Variable: KRISBOW TEMP

In Table 5.a., it is discovered that the Sig value was 0.00, where Sig value <0.05 means that the regression model is accepted. Table 5.b. shows the constant of 6.123 with air temperature reading coefficient of hot wire anemometer LUTRONAM-4234SD of 0.759. From this regression result, obtained an equation to validate the air temperature reading of KRISBOW KW0600653 against LUTRON AM-4234SD as follows:

$$KRISBOWTEMP = 6.123 + 0.759\ LUTRONTEMP \quad (2)$$

Where KRISBOW Temp is the air temperature reading in hot wire anemometer KRISBOW KW 0600653 (°C), and LUTRON Temp is the air temperature reading in hot wire anemometer LUTRON AM-4234SD (°C). With the equation above, air temperature validation in hot wire anemometer LUTRON Am-4234SD against KRISBOW KW 0600653 would be easier.

4 CONCLUSIONS

The measurement and analysis data above, it can be concluded that the model building's thermal condition was not in the comfort zone of tropical climate; hence, not achieving thermal comfort in the building. It was caused by the open natural ventilation height. This fault caused small airflow, which could not reduce the air temperature in the model building. Air velocity and temperature reading validations on hot wire anemometer LUTRON AM-4234SD against KRISBOW KW0600653 from two regression models resulted in two equations, i.e.,

(1) $KRISBOWVEL = 0.007 + 0.682\ LUTRONVEL,$

(2) $KRISBOWTEMP = 6.123 + .759\ LUTRONTEMP\ .$

Both equations eased the measurement using hot wire anemometer LUTRON AM-4234SD and validate the reading result intohot wire anemometer KRISBOW KW0600653 calibrated by the KAN. This research can help researchers to make validation of the same instrument without have to calibrate all the instruments again to the calibration committee. The researchers can follow this research method to validate their instruments as well.

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