International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:3, No:3, 2009

A Study of Relationship between WBGT and Relative Humidity to Worker Performance

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Abstract**—**The environmental factors such as temperature and relative humidity are very contribute to the effect of comfort, health, performance and worker productivity. To ensure an ergonomics work environment, it is possible to require a specific attention especially in industries. The aim of this study is to show the effect of temperature and relative humidity on worker productivity in automotive industry by taking a workstation in an automotive plant as the location to conduct the study. From the analysis of the data, there were relationship between temperature and relative humidity on worker productivity. Mathematical equation to represent the relationship between temperatures and relative humidity on the production rate is modelled. From the equation model, the production rate for the workstation can be predicted base on the value of temperature and relative humidity.

Keywords**—**WBGT, Relative Humidity, Comfort, Productivity.

I. Introduction

IN industry the productivity can be increase in a variety of ways. A comfortable employee, the theory maintains, can produce more than a counterpart who struggles through the day. A comfortable working environment can do more than make workers happy, it can improve productivity as well. In fact, some studies claim that measures such as raising workplace temperature can have a drastic effect on office productivity. In general, studies of the ambient features in office environments including noise, lighting, temperature, existence of windows and others suggest that such as elements of the physical environment influence employee attitudes, behaviours, satisfaction and performance [6].

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There is a continuous and dynamic interaction between people and their surroundings that produces physiological and psychological strain on the person. This can lead to discomfort, annoyance, subtle and direct affects on performance and productivity, affects on health and safety, and death. Performance can be dramatically affected by loss of manual dexterity in the cold, noise interfering with speech communication or work time lost because the environment is unacceptable or distracting. Accidents can occur due to glare on displays, missed signals in a warm environment or disorientation due to exposure to extreme environments [7].

Workplace conditions such as extreme heat/cold, noise and poor lighting have direct or indirect effects on employee job performance. These conditions decrease employee concentration towards tasks which lead to low employee performance such as low productivity, poor quality, physical and emotional stress, which cause high cost [4]. The feelings of eye fatigue, distraction, difficulty of seeing letters, and annoyance were significantly influenced by fluctuating light levels [5]. Relative humidity was influencing employee perception on the comfortable during working [1]. Zaheeruddin and Garima (2006) were noted that work efficiency for the same exposure time would decrease with the rising of sound pressure level.

Effective applications of ergonomics in working conditions enhance employee job performance; provide worker safety, physical well-being, and job satisfaction [4]. As a conclusion the awareness of the effect of environment factors is important to improve workers performance and to prevent an accident in workplace.

II. Method of Study

A. Selection of Study Location

The workstation which has many problems with environment factors (temperature and relative humidity) is chose in this study. A workstation which produced an amount of products in a range of time and under the effects of temperature and relative humidity was chose. This criterion is essential to see the effect of the temperature and relative humidity on the worker productivity.

B. Information Gathering and Data Collection

The information of anthropometry data and measurement data are essential in this study. The information gathered is the anthropometry data of the workers and the measurements data of Wet Globe Bulb Temperature (WBGT), relative humidity,

and an amount of products were produced. WBGT and humidity are measured by using QuestTempº 36 equipment. The production rate is represented the productivity of the workers. The amount of the products are taken every 30 minutes were compared with the measurement value of the temperature and relative humidity. Fig. 1 shows flow diagram for study method those carried out.

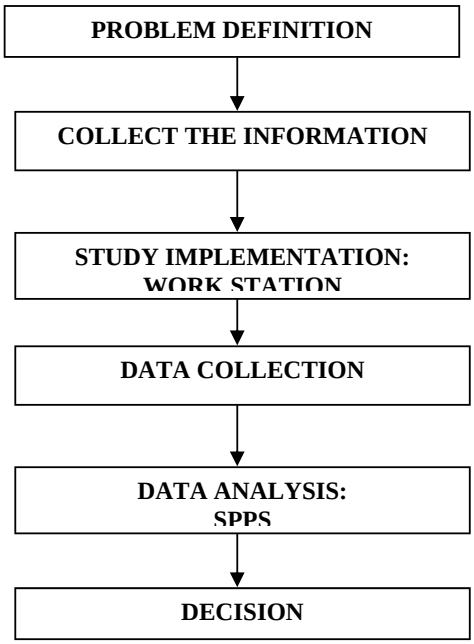

Fig. 1 Flow diagram for the methods of the study

III. Case Study

A case study was done to study the effect of temperature and relative humidity on the workers productivity. So a workstation in an automotive industry was taken as the location to do the study. The workstation was consist 5 male operators. A selected workstation is carried an assembly work for car door frame. Fig. 2 is showed the selected workstation area to carry the study and Fig. 3 is showed a layout of the workstation.

Fig. 4 is showed a process flow for the workstation in this study. This workstation is target to produce 30 unit of product in range of 30 minutes.

IV. Results and Discussion

All measurement data that acquired is analyses through statistical analysis to identify either existence a correlation between variable and parameters that studied. The analysis is carried using SPSS software by linear regression and correlation analysis. From this analysis, all of the data is composed by statistics and are presented in the graph to support analysis. T-test is made to support the hypothesis that proposed.

A. Effect of Temperature on Production Rate

Table I shows the data of the production rate, WBGT and the time taken for every 30 minutes. Fig. 5 shows the graph to describe the relationship between production rates versus WBGT. Based on the graph, we can note that the production rate were decrease as we increase the WBGT.

From the correlation analysis, the correlation coefficient r, is -0.807 which indicates a strong linear relationship between the production rate as dependent variables and WBGT as an independent variables to significant level of 0.01 ($p< 0.01$). It is found that there is a strong correlation where 99 percent confidence positively related to the study sample. A negative coefficient value represented a gradient which is decrease from left to right. It is showed that production rate is decrease when the temperature is increase.

For the regression model for the productivity and WBGT, $R^2 = 0.652$ and the output reports R^2 x 100% = 65.2%, implying that the regression model accounts for 65.2% of the observed variability in productivity.

The hypotheses were:
$H_o=\beta_1=0$ (The relationship between WBGT and production rate is not significant)
$H_a=\beta_1\neq0$ (The relationship between WBGT and production rate is significant)

Least square prediction equation:
Production rate = 153.851- 4.481[WBGT]

The SPSS output tell shows that the least square point estimates of the model parameter are $b_0 = 153.851$ and $b_1 = -4.481$.

p-value = 0.009
p-value < $\alpha = 0.05$
Reject H_0

Since the p-value is smaller than 0.05, we can reject H_0 at level of significant 0.05. Therefore, we have extremely strong evidence that the productivity-WBGT model is significant. That is can conclude that there is a linear relationship between productivity and WBGT.

95% confidence interval for β_1 is (-7.409, -1.554). Since this 95% confidence interval did not contain 0, we can reject H_0: $\beta_1=0$ in favour of H_a: $\beta_1\neq0$ at the 0.05 level of significance. The t-value for WBGT $t_1=-3.620$ has a p-value of 0.009, which indicates that the regressor WBGT contributes significantly to the model.

Based on the study from Alan Hedge, he was noted that workplace temperature can have a drastic effect of worker output (http:/ / www.wisegeek.com, 21 August 2007). The concentration to tasks of an employee who exposes to extreme temperature is decreases [4].

According to the previous studies, it can support the results of this study which is temperature has a significant relationship with workers productivity.

Fig. 2 Workstation Area

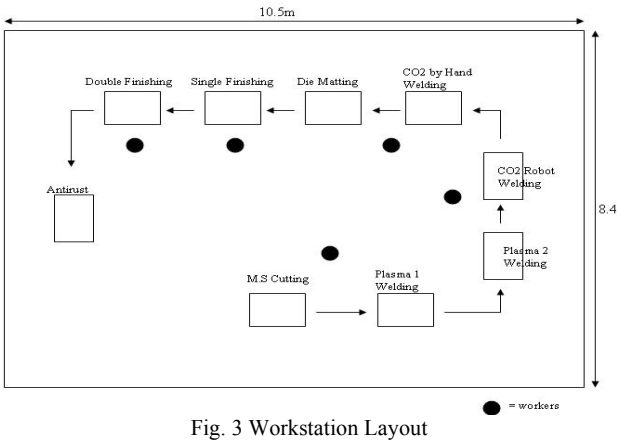

Fig. 3 Workstation Layout

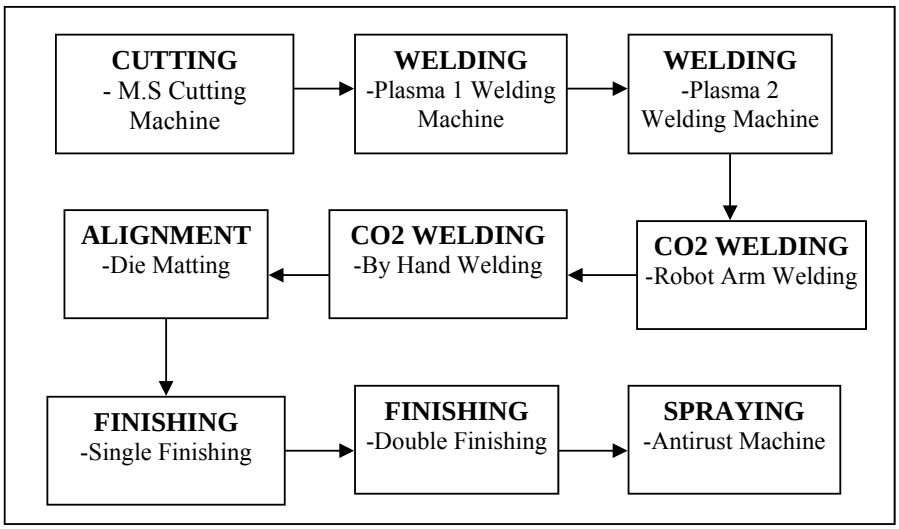

Fig. 4 Process Flow of the Studied Workstation

TABLE I
DATA ON WBGT, PRODUCTION RATE AND TIME

Time (Hrs)	Production Target (Units)	Production Rate (Units)	WBGT (ºC)
9.30-10.00	30	36	26.2
10.30-11.00	30	31	26.8
11.00-11.30	30	32	27.1
11.30-12.00	30	30	27.4
12.00-12.30	30	32	27.6
2.30-3.00	30	37	26.6
3.30-4.00	30	34	26.4
4.00-4.30	30	36	26.4
4.30-5.00	30	38	26.2

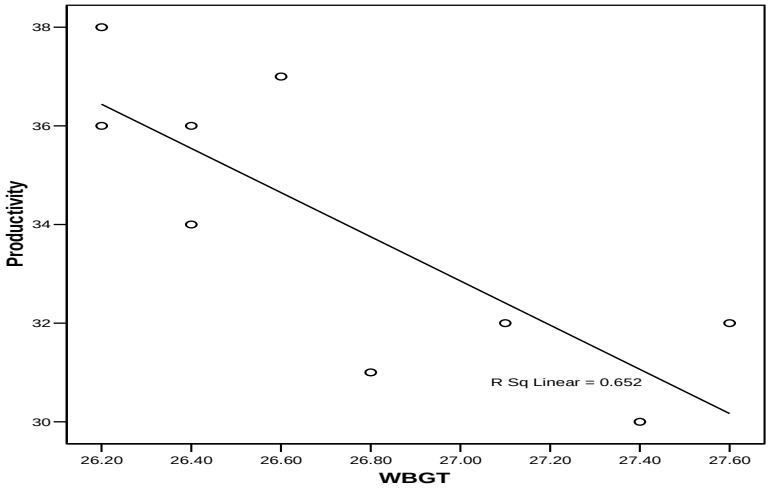

Fig. 5 Graph of Production Rate versus WBGT

TABLE II
CORRELATION ANALYSIS OF THE RELATIONSHIP BETWEEN PRODUCTIVITY AND WBGT

		Productivity	WBGT
Productivity	Pearson Correlation	1	-0.807(**)
	Sig. (2-*tailed*)	.	0.009
	N	9	9
WBGT	Pearson Correlation	-0.807(**)	1
	Sig. (2-*tailed*)	0.009	.
	N	9	9

** Correlation is significant at the 0.01 level (2-tailed)

TABLE III
REGRESSION ANALYSIS OF THE RELATIONSHIP BETWEEN PRODUCTIVITY AND WBGT
MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.944	0.891	0.825	1.200

ANOVA

Model		SS	df	MS	F	Sig.
1	Regression	43.021	1	43.021	13.105	0.009
	Residual	22.979	7	3.283		
	Total	66.000	8			

COEFFICIENTS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta				
1	Constan-t	153.851	33.113		4.646	0.002	75.552	232.149
	WBGT	-4.481	1.238	-0.807	-3.620	0.009	-7.409	-1.554

TABLE IV
DATA ON WBGT, PRODUCTION RATE AND TIME

Time (Hrs)	Production Target (Units)	Production Rate (Units)	Humidity (%)
9.30-10.00	30	36	74.1
10.30-11.00	30	31	69.8
11.00-11.30	30	32	67.3
11.30-12.00	30	30	64.8
12.00-12.30	30	32	63.9
2.30-3.00	30	37	77.8
3.30-4.00	30	34	76.3
4.00-4.30	30	36	76.1
4.30-5.00	30	38	77.0

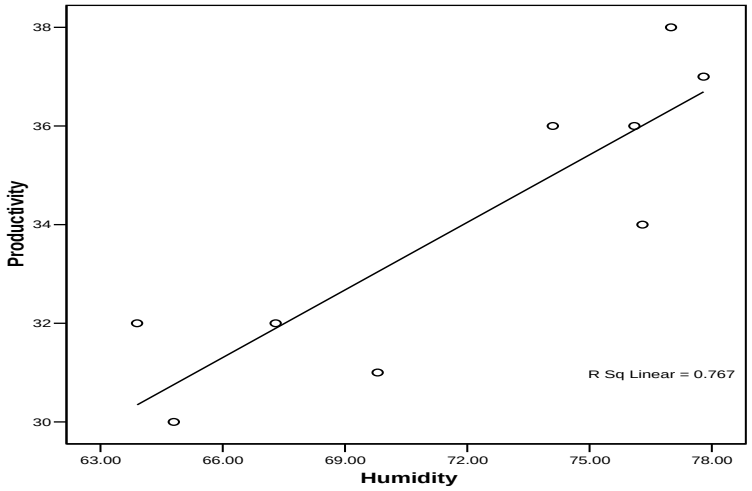

Fig. 6 Graph of Production Rate versus Humidity

TABLE V
CORRELATION ANALYSIS OF THE RELATIONSHIP BETWEEN PRODUCTIVITY AND HUMIDITY

		Productivity	Humidity
Productivity	Pearson Correlation	1	0.876(**)
	Sig. (2-*tailed*)	.	0.002
	N	9	9
Humidity	Pearson Correlation	0.876(**)	1
	Sig. (2-*tailed*)	0.002	.
	N	9	9

** Correlation is significant at the 0.01 level (2-tailed)

TABLE VI
REGRESSION ANALYSIS OF THE RELATIONSHIP BETWEEN PRODUCTIVITY AND HUMIDITY
MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.876	0.767	0.733	1.483

ANOVA

Model		SS	df	MS	F	Sig.
1	Regression	50.596	1	50.596	22.992	0.002
	Residual	15.404	7	2.201		
	Total	66.000	8			

COEFFICIENTS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta				
1	Constant	1.167	6.865		0.170	0.870	-15.066	17.401
	Humidit-y	0.457	0.095	0.876	4.795	.002	0.231	0.682

B. Effect of Relative Humidity on Production Rate

Table IV shows the data of the production rate, humidity and the time taken for every 30 minutes. Fig. 6 shows the graph to describe the relationship between production rates versus humidity. Based on the graph, we can note that the production rate were increase as we increase the humidity.

From the correlation analysis, the correlation coefficient r, is 0.876 which indicates a strong linear relationship between the production rate as dependent variables and humidity as an independent variables to significant level of 0.01 ($p< 0.01$). It is found that there is a strong correlation where 99 percent confidence positively related to the study sample. A positive coefficient value represented a gradient which is increase from left to right. It is showed that production rate is increase when the humidity is increase.

For the regression model for the productivity and humidity, $R^2 = 0.767$ and the output reports R^2 x 100% = 76.7%, implying that the regression model accounts for 76.7% of the observed variability in productivity.

The hypotheses were:

$H_o=\beta_1=0$ (The relationship between humidity and production rate is not significant)

$H_a=\beta_1\neq0$ (The relationship between humidity and production rate is significant)

Least square prediction equation:
Production rate = 1.167 - 0.457[Relative humidity]

The SPSS output shows that the least square point estimates of the model parameter are $b_0 = 1.167$ and $b_1 = 0.457$.

p-value = 0.002
p-value < $\alpha = 0.05$
Reject H_0

Since the p-value is smaller than 0.05, we can reject H_0 at level of significance 0.05. Therefore, we have extremely strong evidence that the productivity-humidity model is significant. That is can conclude that there is a linear relationship between productivity and humidity.

95% confidence interval for β_1 is (0.231, 0.682). Since this 95% confidence interval did not contain 0, we can reject H_0: $\beta_1 = 0$ in favour of H_a: $\beta_1 \neq 0$ at the 0.05 level of significance. The t-value for t_1= 4.795 has a p-value of 0.002, which indicates that the regressor humidity contributes significantly to the model.

From the result, it is the same with hypothesis of the study where exist a relationship between production rate and relative humidity. It is also has directly proportional where higher value of relative humidity contributes to higher of productivity. Attwood et al. (2004) were noted that relative humidity influencing employee perception on the comfortable during working.

V. CONCLUSION

Past research on the modeling relationship of workplace environmental factors to the productivity or performance is very limited. In addition they are characterized by a short time perspective, not enough engineering data regarding the lead time, expected output capacity or perception with emphasis on survey methods, statistical analysis, satisfaction and the preferences measurement. This study was done to prove empirically the previous perception studies which based on the role of environmental factors to productivity. It is hoped that this study would be beneficial to the automotive manufacturing industries in Malaysia.

The research findings are restricted to the Malaysian workplace environment, where the awareness among workers on improving productivity is still low. The results might vary for tests carried out for different sample sizes, types of industries and countries. The study could be more extensive if the fraction of defect rate for the product is included in the analysis. Nevertheless the authors believed the modeling of production rate, as a time series data is more than adequate to understand the affect of environmental factors towards productivity.

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