LOGIC
Journal of Engineering Design and Technology
Vol. 21 No.1 March 2021; p. 64 - 69

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs.pnb.ac.id/index.php/LOGIC

EFFECT OF HEAT RADIATION ON WORKLOAD AND GAMELAN CRAFTS PRODUCTIVITY

I Ketut Gde Juli Suarbawa [1], M. Yusuf [2]

1,2) Mechanical Engineering Department, Politeknik Negeri Bali, Indonesia

Correponding email [1]: julisuarbawa@pnb.ac.id

Abstract. The production process of making gamelan in Tihingan Village still uses the traditional way, namely using prapen with an open flame both for the melting process and in the formation process. This causes the workload of craftsmen to be quite heavy due to exposure to radiant heat and dust. The results of microclimate measurement of the work environment obtained an average dry temperature of 33.2ºC, an average wet temperature of 24ºC. The average globe temperature was 33ºC, WBGT 26.3ºC and the mean humidity (RH) was 59.0%. The average light intensity at work reaches 319.2 lux. The average temperature of the furnace at low heat is 340ºC and during the combustion process it reaches 860 ºC. The results of measurements of air quality in the workplace include levels of NO2 17.00 µg /m3 (increased by 112.50%), SO2 5.33 µg/m^3 (increased by 45.23%), CO 407.16 µg/m^3 (increased by 217, 99%), oxidants (Ox) 61.00 µg/m^3 (increased by 1.67%) and dust 48.50 µg/m^3 (increased by 125.58%). The mean pulse of the nguwad workers reached 125.81±1.35 beats/minutes (heavy workload). This causes the productivity of craftsmen to be low due to the increase in musculoskeletal disorders and craftsmen fatigue. To overcome this condition, the workings of the craftsmen need to be improved immediately through the application of appropriate technology in the form of furnace repair so that the flames and dust produced can be removed from the workplace, then exposure to heat air and combustion dust will no longer expose the craftsmen.

Keywords: heat temperature radiation, workload, productivity

1. INTRODUCTION

Gamelan is one of the traditional music that is very well known and almost owned by every traditional village in Bali. Gamelan has a very important meaning and role for the Balinese people as a means of traditional and religious ceremonies. Gamelan can also be used as a means of entertainment such as the gong kebyar festival, bleganjur competition which can also help the tourism industry in Bali. Apart from Bali, gamelan is also well known on the islands of Java, Madura and Lombok. One of the places that is famous as a gamelan craftsman village in Bali is Tihingan Village, which is located in Banjarangkan Subdistrict, Klungkung Regency, which is 3 km to the west of Semarapura City. In this village the population is mostly (almost 90%) gamelan craftsmen who produce various types of gamelan such as: gamelan gong kebyar, gamelan semar pegulingan, gender wayang, kelentang/angklung and others.

From all stages of the process of making gamelan instruments, the process of melting and nguwad is a work process with the heaviest workload felt by the craftsman. The open flame of the perapen causes the radiant heat temperature and the hot dust from the combustion to directly expose the craftsmen. Likewise, the way and work posture that is not natural causes more rapid increase in complaints of skeletal muscles and craftsman fatigue.

Exposure to hot temperatures will affect the conditions of workers, especially on work productivity [1], [2]. If exposure to hot temperatures is allowed and no repairs are made, it will result in poor health conditions for workers and a decrease in work productivity [3], [4].

Based on the description above, it is deemed necessary to conduct research to determine the effects of exposure to hot temperatures and a work attitude that is not yet ergonomic in affecting the workload and

productivity of craftsmen. Improvement of working conditions and environment through improvement of workplace perapen, work organization, and work environment through ergonomic intervention with the concept of applying appropriate technology and the SHIP (Systemic, Holistic, Interdisciplinary and Participatory) approach [5] is very necessary to be able to reduce workload, musculoskeletal complaints. and fatigue which in turn will increase work productivity and crafters' income. In addition, the quality of nguwad products has also increased, which is marked by a decrease in the number of defective products.

2. METHODS

This research is a one-short case study with a pre and post test group design which is conducted observational to crafters in the nguwad process. The workload of the crafter is measured from the pulse of work. The microclimates in the workplace measured are wet temperature, dry temperature, humidity, noise intensity, and light intensity and air quality. Subjective complaints were predicted from a 30 item fatigue questionnaire with four Likert scales, and skeletal muscle complaints were predicted using a Nordic Body Map questionnaire. Statistical analysis was carried out descriptively and inferential to workload, skeletal muscle complaints, and fatigue. The pre and post difference test was carried out with the t-test at a significance level of = 5%.

3. RESULTS AND DISCUSSION

3.1 Work Time

The nguwad work process usually starts at 07.00 a.m. in the morning and breaks at 11.00 a.m. - 12 p.m. then the next work starts again at 12.00 to 15.00. This nguwad job requires a large amount of energy to forge the raw materials to form the desired mortar. The working tools used are generally still classified as traditional working tools which are a legacy of the work tools of their predecessors consisting of large hammers for forging workers. The prying tool is for man who the grill and the clamp tool in the form of long pliers for man who the clamp. The hammer used weighed 4.5 - 5.5 kg and the prying tool used by the man who the grill weighed about 2.1 kg and the long pliers used by the man who the clamp weighed 0.5 kg. The use of traditional equipment requires patience and accuracy and requires considerable energy and a lot of calorie intake to be able to compensate for the amount of calories and energy that is expended while doing the job [6], [7].

3.2 Crafter Characteristics

The characteristics of gamelan craftsmen in the gamelan ngiwad process in Tihingan Village, which include age, weight, height, body mass index (BMI) and work experience, are presented in the Table 1.

Table 1. Subject Characteristics Data

Variable	Mean	SD	Range
Age (years)	26.64	5.81	19.50 - 35.50
Weight (kg)	58.32	3.91	56.05 - 64.32
Height (cm)	163.20	3.01	159.05 - 169.01
Body Mass Index (kg/cm^2)	22.31	1.31	19.61 - 23.10
Work Eksperience (years)	2.24	0.03	1.50 – 2.51

Note: SD = standard deviation

Table 1 shows that the conditions of the research subjects were normal, healthy, in productive conditions for work, and had sufficient work experience as gamelan craftsmen. Normal worker's body condition can lead to good work productivity as well [2], [8].

3.3 Environmental Conditions

Environmental conditions greatly affect the comfort and health of gamelan craftsmen in the nguwad process which results from the influence of physical and psychological conditions as well as exposure to hot temperatures from perapen and non-ergonomic work postures. If environmental conditions are not good, it will cause health problems, dissatisfaction, decreased motivation and low work productivity. In this study, environmental conditions were measured from morning to noon. Environmental conditions include dry air temperature, wet air temperature, air humidity, wind speed, globe temperature, WBGT (wet bulb globe temperature), and dust in the air.

Table 2. Working Environment Conditions

Variable	Before Work		After Work		p
	Mean	SD	Mean	SD	
Dry Temperature (°C)	30.05	1.08	35.20	0.47	0.000
Wet Temperature (°C)	26.05	0.72	24.03	0.98	0.000
Globe Temperature (°C)	29.06	0.74	33.09	0.52	0.000
WBGT (°C)	27.05	0.54	26.76	0.59	0.031
Relative humidity (%)	70.01	0.74	59.09	0.71	0.000
Wind velocity (m/dt)	0.613	0.016	0.651	0.047	0.068
Light intensity (lux)	316.78	6.34	319.88	4.62	0.166
Sound intensity (dB)	67.10	1.74	85.64	1.04	0.000

Note: SD = standard deviation

Table 3. Air Quality Conditions

variable	Before Work		After Work		p
	Mean	SD	Mean	SD	
NO_2 (µg/m^3)	8.00	0.32	17.00	1.56	0.000
SO_2(µg/m^3)	3.67	0.07	5.33	0.13	0.014
CO (µg/m^3)	128.04	2.34	407.16	5.84	0.002
Ox(µg/m^3)	60.00	2.87	61.00	3.07	0.027
Total dust (µg/m^3)	21.5	1.79	48.50	2.24	0.000

Note: SD = standard deviation

Table 2 and Table 3 show that the working conditions of the gamelan craftsmen are hot. The working room temperature is 35°C, the humidity is low, and the noise is high enough (85.64 dB). The noise threshold is 85 dB [9], while a comfortable working room temperature is 24 - 30°C [10]. The results of measurements of air quality in the workplace include levels of NO2 17.00 µg /m3 (increased by 112.50%), SO2 5.33 µg/m^3 (increased by 45.23%), CO 407.16 µg/m^3 (increased by 217, 99%), oxidants (Ox) 61.00 µg/m^3 (increased by 1.67%) and dust 48.50 µg/m^3 (increased by 125.58%). The dust from the gamelan production process is high enough so that it can affect the health of workers if allowed to continue. Dust will be a problem for the health of workers so it is necessary to provide an immediate solution [11],[12]. Therefore it is necessary to have an ergonomic intervention as a solution to this problem.

3.4 Workload

Workload is calculated objectively by measuring the working pulse frequency (DNK) with the ten pulse method which is calculated based on the increase in the work pulse, namely the difference between resting pulse and working pulse rate. The resting pulse of the craftsman (pulse before work) is as follows.

Table 3. Resting pulse and work rate of craftsmen

craftsman	Resting Pulse (bpm)			Work Rate (bpm)			p
	Mean	Min	Max	Mean	Min	Max	
Perapen craftsman	73.30 ± 1.44	72.07	74.68	115 ± 3.78	112.28	119.68	0.000
Flops craftsman	73.73 ± 1.54	71.89	75.83	113.96 ± 4.96	110.39	118.21	0.000
Nguwad craftsman	74.18 ± 5.26	70.64	79.48	125.81 ± 1.35	124.28	127.81	0.000

Information: Min = minimum value, Max = maximum value, p = significance

The mean pulse rate of the fishermen reached 115 ± 3.78 beats per minute, the clamp workers reached 113.96 4.96 beats per minute and the nguwad workers reached 125.81 1.35 beats per minute. Due to high environmental temperatures, body temperature will increase [3], [13]. Subjective disorders generally felt by all respondents were feeling thirsty, hot skin, and sweating a lot. Meanwhile, what workers have little complaint about is the cramps in

the arm and leg muscles. The increase in body temperature did not exceed the normal body temperature limit of 37°C. Increased body temperature only occurs in workers who have a heavy workload.

An increase in body temperature can cause the hypothalamus to stimulate the sweat glands so that the body produces sweat. In sweat contains various kinds of salt, especially sodium chloride salt. The release of sodium chloride salt with sweat will reduce its levels in the body, thus inhibiting the transportation of glucose as an energy source. This causes a decrease in muscle contraction so that the body experiences fatigue [14]. Therefore, to avoid the occurrence of health problems due to exposure to high heat, the length of work in a hot place must be adjusted to the level of work and the heat stress faced by the workforce. The conditions of a comfortable work environment allow daily work to be done as well as possible and here there is almost the same temperature between the body's metabolism and the surrounding environment [3], [14].

3.5 Musculoskeletal Disorders

Musculoskeletal disorders data obtained subjectively from filling out a Nordic Body Map questionnaire using a Likert scale. The crafter will cross the available numbers from 0-27 according to their perceived complaints. Before testing the effect of using the stirrer, the data obtained is tested by the normality test. Based on the normality test with Shapiro-Wilk, the following results were obtained.

Table 4. Musculoskeletal Disorders

	Before work		After Work		p
	Mean	SD	Mean	SD	
Musculoskeletal disorders	27.42	4.54	56.03	3.93	0.000

Note: SD = standard deviation, p = significance value.

Table 4 shows that the data from musculoskeletal disorders after work are normally distributed. The analysis of significance using the independent samples t-test shows that the value of p = 0.000. This means that the mean score of musculoskeletal complaints after using the mixer is significantly different (p <0.05) or indicates that there is an effect of improving working conditions and environment on reducing musculoskeletal complaints.

The activities of gamelan craftsmen in the work process of nguwad involve more static muscles, resulting in excessive loading on the muscles with a long and repetitive duration of loading so that blood circulation to the muscles decreases, oxygen supply decreases, metabolic processes are inhibited and there is accumulation of lactic acid, causing pain/pain in the skeletal muscles [3], [13], [15].

3.6 General Fatigue

Crafters' fatigue after work is recorded by filling in 30 items of rating scale before and after work. The results of the normality test for the mean fatigue score are presented in Table 5.

Table 5. General Fatigue Craftsman

	Mean	SD	Mean	SD	p
General Fatigue	31.05	4.67	51.49	3.66	0.000

Note: SD = standard deviation, p = significance value

Table 5 shows that the p value of fatigue before work and after work is p <0.05, this indicates an increase in craftsmen fatigue after work. This is caused by repetitive work with exposure to heat and dust and the presence of an ergonomic work posture. Fatigue that occurs in nguwad work processes is caused by repetitive work processes over a long period of time with static work activities. Fatigue caused by static work activities is considered to have a greater influence than dynamic work activities.

Manual and repetitive work in hot environmental conditions is one of the factors that has the potential to increase physical workload and the occurrence of work accidents so that it can cause occupational diseases (musculoskeletal complaints and fatigue) [7], [16], [17]. The temperature conditions of the hot work environment are often referred to as heat stress on workers. This heat pressure is a combination of air temperature and humidity, air flow velocity, radiation temperature with heat generated by the body's metabolism [14], [18].

3.7 Work productivity

Work productivity is measured from the ratio between the output and input per unit time. The work productivity of nguwad is measured from a physiological aspect. Work productivity from a physiological aspect, as the input is the average work pulse (bpm) of the crafter in the nguwad process. Time is measured from the length of the

nguwad process (minutes) and the output is the circumference of the resulting mole (cm). The productivity of nguwad craftsmen is presented in Table 6.

Table 6. Work Productivity

	Nguwad-1	*Nguwad*-2	*Nguwad*-3	*Nguwad*-4
Work time (minutes)	57,75	58,96	59,74	60,12
Work Productivity	1,04	1,02	0,99	1,01

The mean pulse of the nguwad workers reached 125.81±1.35 beats/minutes (including heavy workload) as Table 3. This causes the productivity of craftsmen to be low due to the increase in musculoskeletal disorders and craftsmen fatigue. Heavy workload will cause work productivity to decrease and cause health problems for workers [3], [19], [20]. To overcome this condition, the working conditions of the craftsmen need to be improved ergonomically and the application of appropriate technology in the form of furnace improvements and work layouts so that the flames and dust produced can be removed from the workplace, then exposure to heat air and combustion dust will no longer expose the craftsmen.

4. CONCLUSION

From the results and discussion, it can be concluded that in the process of working on the gamelan:

a. There was a significant increase in the microclimate components of the working environment, workload of craftsmen, musculoskeletal disorders and general fatigue.
b. exposure to hot temperatures causes the work productivity of craftsmen to be not optimal or low.
c. The working conditions of the craftsmen need to be improved ergonomically and the application of appropriate technology in the form of furnace improvements and work layouts.

5. REFERENCES

[1] T. Budiyanto and M. Yusuf, "Improvement of Wok Molding Station Increases Work Comfort and Productivity of the Workers," *Int. J. Psychosoc. Rehabil.*, vol. 24, no. 4, pp. 8883–8892, 2020.
[2] M. Edem, E. Akpan, and N. Pepple, "Impact of Workplace Environment on Health Workers," *Occup. Med. Heal. Aff.*, vol. 05, no. 02, 2017.
[3] K. H. E. Kroemer and E. Grandjean, *Fitting The Task To The Human, Fifth Editione A Textbook Of Occupational Ergonomics*. London: CRC Press, 2009.
[4] A. P. Sarode and M. Shirsath, "The Factors Affecting Employee Work Environment & It's Relation with Employee Productivity," *J. Sci. Res.*, vol. 3, no. 11, pp. 2735–2737, 2014.
[5] A. Manuaba, "Total approach is a must for small and medium enterprises to attain sustainable working conditions and environment, with special reference to Bali, Indonesia," *Ind. Health*, vol. 44, no. 1, pp. 22–26, 2006.
[6] I. G. Santosa and M. Yusuf, "The Application of a Dryer Solar Energy Hybrid to Decrease Workload and Increase Dodol Production in Bali," *Int. Res. J. Eng. IT Sci. Res.*, vol. 3, no. 6, Nov. 2017.
[7] C. Caruso, E. D. Hitchcock R. Russo. J. Schimt, J., and Anonymous, *Overtime and Extended Work Shifts: Recent findings on illness, injuries and health behaviours.*, vol. 143. Columbia: U.S. Department of Health and Human Services, 2004.
[8] Deouskar N, "The Impact Of Ergonomics On The Productivity Of People," *Int. J. Mark. Financ. Manag.*, vol. 5, no. 6, pp. 59–63, 2017.
[9] BSN, *Threshold value for working condition under heat, noise, vibration hand-arm, and ultraviolet sun light exposure, SNI 16-7063-2004*. Jakarta: Badan Standarisasi Nasional, 2004.
[10] A. Manuaba, "Research and application of ergonomics in developing countries, with special reference to Indonesia," *Indones. J. Ergon.*, vol. 1, no. 1, pp. 24–30, 2000.
[11] A. Wibolo and I. N. L. Antara, "DESIGNING PLASTIC CUPES RING CUTTING MACHINE TO INCREASE PRODUCTIVITY," *Log. J. Ranc. Bangun dan Teknol. Vol 18 No 2 Juli 2018*, 2018.
[12] W. Susihono and I. P. Gede Adiatmika, "Assessment of inhaled dust by workers and suspended dust for pollution control change and ergonomic intervention in metal casting industry: A cross-sectional study," *Heliyon*, vol. 6, no. 5, p. e04067, 2020.
[13] R. S. Bridger, *Introduction to Ergonomics, 3rd Edition*. London: Taylor & Francis, 2008.
[14] S. Pheasant and C. M. Haslegrave, *Bodyspace: Anthropometry, Ergonomics and the Design of Work, Third Edition*, 3rd ed. Boca Raton: CRC Press., 2016.
[15] D. P. Sutjana, "Application of Ergonomics at the Bali Sanur Bungalows Hotel," *Indones. J. Biomed. Sci.*, vol. 2, no. 1, pp. 1–11, 2008.
[16] M. Yusuf, N. Adiputra, I. Dewa, P. Sutjana, and K. Tirtayasa, "The Improvement of Work Posture Using

RULA (Rapid Upper Limb Assessment) Analysis to Decrease Subjective Disorders of Strawberry Farmers in Bali," *Int. Res. J. Eng. IT Sci. Res.*, vol. 2605, no. 9, pp. 4290–2016, 2016.

[17] S. R. Kamat, N. E. N. Md Zula, N. S. Rayme, S. Shamsuddin, and K. Husain, "The ergonomics body posture on repetitive and heavy lifting activities of workers in aerospace manufacturing warehouse," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 210, no. 1, 2017.

[18] N. D. Irwanti, M. Yusuf, N. Y. Anggreni, and L. S. Widiastuty, "Workload Analysis of Front Office Staff at Water Mark Hotel And SPA Jimbaran-Bali," *Int. J. Multidiscip. Educ. Res.*, vol. 7, no. 8(1), p. 63, 2018.

[19] I. K. G. J. Suarbawa, M. Arsawan, M. Yusuf, and I. M. Anom Santiana, "Improvement of environment and work posture through ergonomic approach to increase productivity of balinese kepeng coin workers in Kamasan village Klungkung Bali," in *Journal of Physics: Conference Series*, 2018, vol. 953, no. 1.

[20] A. Manuaba, "Accelerating OHS-Ergonomics Program By Integrating 'Built-In" Within The Industry's Economic Development Scheme Is A Must-With Special Attention To Small And Medium Enteprises (SMEs)," in *Proceedings the 21st Annual Conference of The Asia Pasific Occupational Safety & Health Organization*, 2005.