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THE DEVELOPMENT OF GREEN TECHNOLOGY MODEL IN THE PROCESS OF MAKING *GAMELAN*, KLUNGKUNG REGENCY, BALI

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Abstract. The work bent on the smelting process which is very low and with the flame still open so that the heat from combustion is wasted into the environment has the potential to pollute the environment and expose the craftsmen to cause an increase in workload, subjective disorders and a decrease in work productivity. For this reason, one short case study was conducted with a pre and pos test group design that was carried out observationally on craftsmen in the bronze smelting process for gamelan raw materials. The workload was predicted by calculating the working pulse, fatigue and complaints of skeletal muscle craftsmen recorded by questionnaire. The results of the research data were analyzed descriptively to obtain a new design of the bronze metal smelting furnace model so that the work posture was more ergonomic. The results showed that the work pulse increased to 132.42 ± 4.41 per minute or increased by 58.21 beats per minute, including in the category of "heavy" workload. The mean score of musculoskeletal disorders after work increased to 49.30 ± 4.98 and the mean score of fatigue complaints after work also increased to 50.12 ± 1.23. Work productivity decreased from 101.21 ± 5.21 at the beginning of work to be 95.42 ± 2.12 at the end of work. For that, a bronze metal smelting furnace is redesigned, namely redesigning the height of the work field to 60-65 cm from the floor so that the worker's work posture becomes natural and the top of the smelting furnace is equipped with a canopy to remove dust and heat from the workplace.

Keywords : work posture, subjective disorders, and work productivity.

1. Introduction

The process of *gamelan* making in Tihingan Village consists of: the first phase; the process inside *perapen* (hearth furnace) and the second phase; the process outside the *perapen.* The processes inside *perapen* include smelting process (*nglebur*) of raw materials, and formation process (*nguwad*), meanwhile the processes outside the *perapen* are final settlement processes; i.e. the processes of shape refinement and sound alignment until the desired quality of *gamelan* is achieved.

The working process inside the *perapen* is accompanied by heat exposure of open flames and the workers' non-ergonomic work posture due to the use of non-ergonomic work stations. Hot ambient temperature and dust exposure result in an increase in the workload of the craftsmen as well as an increase in subjective complaints of fatigue and skeletal muscle complaints, therefore the craftsmen's work productivity gets lower and the dust exposure causes an increase in air pollution. The open flames cause more and more burning fuel. In the processes outside the *perapen,* the refinement process (*manggur*) and the alignment process of *gamelan* sound are carried out in non-ergonomic work posture due to the use of work tools and work places that do not consider the crafters' anthropometry.

Related to this case, workers need working procedure, posture, tools, environment, and organization that are according to their abilities and limits, so that they can work safely, comfortably, and healthily. This will result in the increase of work quality and productivity. One way to make this out is by implementing green technology in the production process. This is in line with the presidential decree number 28 year 2008 about the policy of industrial development. The purposes of industrial development are maintaining the balance of ecosystem, maintaining sustainable resources, health improvement and environmental conservation. The efforts in applying green technology in the process of *gamelan* production is really needed considering that Bali is one of the provinces that contribute to the main emission of waste (reaching 87%) and Bali is one of the ten provinces with the highest emission [1]. The implementation of alternative solution of green technology in form of green productivity model in the leather tanning industry in PT.PQR, Malang can reduce the volume of sludge waste up to 70% so that it gives increase to the index of EPI (Environmental Performance Indicator) from 34,89 to 37,33 [2]. It is the same for the application of clean technology in brass industry, it can increase the production, reduce defective products as well as pollution, so that production costs can be saved up to 85% [3].

The main problems of this research include: green technology model design and the making process of *gamelan* that is environmentally friendly. Solving these problems are very important because the process of *gamelan* production in Tihingan village is not ergonomic yet because there is increase of work load, environmental pollution, and the work productivity is low, meanwhile the requests of *gamelan* products are increasing every year. The special specification of the output of this research is green technology model which is a superior applied products in ergonomic production process; safe, comfortable, healthy, and productive.

2. METHODS

2.1 Framework

The production process of Balinese *gamelan* consists of smelting, formation, and finishing process. In the smelting process, bronze material is needed, in which bronze is a combination between copper (*Cu*) and white tin (*Sn*). To obtain good quality, it is needed right proportion of copper and white tin. From the result of phase diagram, it is obtained good composition of 80% Cu – 20% Sn. The next process is formation process by heating/ burning the raw material (copper) which has been molded to be particular form of *gamelan.* The last process is *manggur,* i.e. smoothen the shape of *gamelan* until it produces particular sound. Considering that many factors are involved in the production process if *gamelan,* it is needed efforts toward the management of environmental condition so that the production can be sustainable through the concept of green technology or clean production. Cleaner production concept was proposed by United Nation Environmental Program (UNEP) in May 1989. UNEP stated that Cleaner Production was an environment management strategy which is preventive, integrated, and implemented continuously in the process of economy and production benefit, products and services increase eco-efficiency, reduce the risk of human and environment health [4].

Green technology concept – which is also named as clean technology/ environmental technology – is a concept emerged from human awareness toward the needs of sustainable natural resources. Therefore, the initial design of green technology process can save the needs of raw materials and the process, so that overall it can save the costs in manufacture industry [5]. In the process of *gamelan* production, the craftsmen workloads can be from the activities done and the influence of environment condition. Workloads are generally divided into two groups namely [6]:

1) External workloads (stressor) are workloads from the works done. External loads include task, organization, and environment.
2) Internal workloads are workloads emerged from the craftsmen individual factors which are somatic (gender, age, body size, health condition and nutrition status) and psychic (motivation, perception, desire, and others)

The increased body activities cause body metabolism to increase which makes the needs of O_2 and heart pulse increasing. Physiological complaint is body adaptation mechanism to remain in homeostatic state [7]. Workloads are very affected by work postures during work activities. Human work postures are affected by four factors: (1) physical characteristics, such as age, gender, anthropometry size, body weight, physical health, joint movement ability, musculoskeletal system, vision sharpness, overweight problem, disease history, and so on; (2) kinds of work requirements, such as work that requires accuracy, hand strength, task turn, break time, and so on; (3) work station design, such as seat size, work foundation height, condition of work fields or surfaces, and work environment factors; and (4) environment: lighting intensity, environment temperature, air humidity, air speed, noise, dust and vibration [8]. These workloads will be able to affect work productivity. The increasing workloads along with work duration cause a decrease in productivity. In order to increase the productivity, it is needed efforts to harmonize various factors such as: work tools, procedures, and environment with the abilities, skills, and limits of workers. One of the efforts is by implementing green technology through the approach of SHIP (systemic, holistic, interdisciplinary, and participative [9].

2.2 Research Method

This research is a one short case study research with the design of pre and post test design group which is carried out observationally toward the craftsmen during the smelting process of bronze as the raw materials of the *gamelan* [10]. This can be illustrated through the following chart:

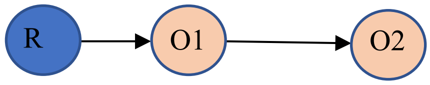

Figure 1 Research Design

Description:
R = Random sample.
O1 = result from pretest of the experiment units measured
O2 = result from posttest of the experiment units measured.

The research stages in redesigning smelting furnace are examining the current use of the furnace (open furnace) to the work productivity of craftsmen and examining the current use of the furnace to the work posture of craftsmen so that ergonomic furnace design in accordance to the more natural craftsmen's posture is obtained.

3. RESULT AND DISCUSSION

3.1 The Condition of Smelting Furnace of *Gamelan* Raw Material

Based on the observation result of smelting process of *gamelan* raw materials in Tihingan village toward 4 craftsmen who work using the furnace, smelting furnace which is too low makes the craftsmen bow. Besides, the metal-smelting furnace that is still opened makes the craftsmen exposed to heat radiation from the burning process of the fuel during the smelting process. Work posture and condition of the craftsmen are presented in figure 2.

Figure 2. Smelting Furnace with the Craftsmen's Work posture

3.2 Subject Characteristic

Subjects in this research are totally 4 men. All subjects followed the research in accordance with the provisions of the research protocol, so that no subject was declared dropped out. The average of subject ages are 43,36 ± 3,41 years and the age range was 28 – 53 years. This age range is still included in the working age group. This age range is still included in the labor force according to the Central Statistics Agency (BPS). The age limit of the labor force in Indonesia is from 15 to 64 years. The average age of the subjects of this research viewed from muscle strength has decreased because the optimum muscle strength for working that is recommended is between 20 to 30 years (Reenen, *et al.*, 2009).

3.3 Work Environment Conditions

The average air temperature was 32,06 ± 0,32 ^{0}C, the average temperature of the ball was 31,34 ± 0,53^{0}C, the average relative humidity was 64,21 ± 0,38%, the average WBGT index was 29,84 ± 0,49 ^{0}C. The threshold value for the category of heavy work with a WBGT of 30,5^{0}C is that the working time per hour is only allowed to reach 25%, while the threshold value for the medium workload with the WBGT reaching 29^{0}C is allowed for the working time setting of 50% - 75% per hour. The intensity of lighting 332,21 ± 6,23 lux, the value of this intensity is in the safe category based on the decision of the Minister of Health Republic of Indonesia number 405 year 2002 concerning the requirements and procedures for the implementation of industrial work environment health, where for rough work requires a minimum light intensity of 100 lux. Inadequate lighting of lighting which is below the required threshold will cause work fatigue as Tarwaka (2010) states that the lack of light intensity in the workplace results in the decreased eye sight and work fatigue. The average noise intensity reached 85,75 ± 2,21 dBA. Suma'mur (1982) stated that work place noise was still at normal limit when it was below 85 dBA. The air velocity was 0,75 ± 0,63 m/sec. Grandjean (1993) and Manuaba (2003b) stated that the movement of air in the room is recommended not more than 0,2 m/ sec, so that air movement does not cause adverse effects on workers, while for work environments exposed by heat requires higher wind velocity.

Table 1. The Work Environment Condition of *Gamelan* Craftsmen

Description	n	Minimum	Maximum	Mean	Std. Deviation
Air Temperature (^{0}C)	4	32.10	32.90	32.06	0.32
Ball Temperature (^{0}C)	4	30.80	33.00	31.34	0.54
Humidity ($^{\%}$)	4	61.90	66.60	64.21	0.38
WBGT (^{0}C)	4	28.16	30.01	29.21	0.49
Lighting Intensity (lux)	4	331.20	341.40	332.21	6.23
Noise Intensity (dBA)	4	84.31	86.32	85.75	2.21
Air Velocity (m/sec)	4	0.70	1.14	0.75	0.64

The value of air velocity in this research is at a comfortable working conditions to work based on the statement of Grandjean and Manuaba stating that it is recommended that the movement of air in the room is no more than 0.2 m/s so that air movement does not cause adverse effects on workers, while for the work environment exposed by heat, it is required higher wind velocity [11], [9]. The results of Listiani Nurul Huda & Kristoffel Colbert Pandiangan's research through the improvement of work environment exposed by heat by redesigning ventilation can increase wind velocity up to 0,7 m/sec [12].

3.4 Workload Condition, Percentage of CVL, ECPT, ECPM, and Skin Surface Temperature

Subject workloads in the smelting process are recorded with work pulse (DNK) and resting pulse (DNI) before work. The resting pulse rate is measured by the 15-second palpation method while the working pulse is measured by the 10-pulse palpation method. The measurement results obtained an average resting pulse rate of 74,21±0,57 per minute and increased after work to 132,42±4,41 per minute or an increase of 58.21 beats per minute. This workload classification is included in the category of "heavy" workloads because they are in the range of 125-150 per minute [13]. The increase in pulse causes the ECPT to 18.00±1,23 per minute and ECPM by 16.21±2,07 per minute. The average cardiovascular load (%CVL) also increased to 56.34 and the average surface temperature of the skin increased to 38.05^{o}C. The increase of CVL percentage which reached 56.34 with WBGT of 29.21 resulted in craftsmen being only allowed to take 50% work and 50% rest. Adiputra states that the higher activity of the body causes the body's metabolism to increase impact on the need for greater O_2 and the frequency of pulse will increase [6]. Increased metabolism causes increased body temperature. ECPT values that are higher than ECPM indicate a higher workload due to environmental factors, so there needs to be improved environmental conditions.

Table 2 Resting Pulse, Work Pulse, %CVL, ECPT, ECPM, and Skin Surface Temperature

Description	N	Minimum	Maximum	Mean	Std. Deviation
Resting Pulse (/minute)	4	64.00	78.00	74.21	0.57
Work Pulse (/minute)	4	130.05	134.33	0.58	5.89
ECPT (/minute)	4	15.67	22.24	18.00	1.22
ECPM (/minute)	4	15.67	23.33	16.23	3.77
%CVL	4	49.93	66.32	56.34	5.25
Skin temperature (^{0}C)	4	37.90	39.50	38.05	0.61

The workload in this research is in accordance with the Sitepu's research that simultaneous workload has a significant effect on employee performance [14]. This improved performance is also influenced by changes in the body metabolism, as Adiputra argues that the higher activity of the body causes the body metabolism to increase the impact on the need for greater amount of O_2 and the pulse rate will increase [6]. The percentage of change in workload in this research is consistent with other similar researches such as the research conducted by Artayasa, et al. which reported that the total ergonomics approach can reduce workload by 10.61% [15], while the results of Muliarta's research to improve working conditions, it is obtained workload reduction of 8,24% [16]. Likewise, the percentage of decrease in workload of research result reported by Purnomo; repairing work system through a total ergonomic approach; it is reported a decrease in workload by 21.69% [17], as well as the result of Setiawan's research in making improvements to work station design reported a reduction in workload by 24.39% [18]. This difference in change percentage is due to differences in the characteristics of the task, work organization, and work environment, as well as the choices of intervention given to subjects that are characteristic of work improvement in each research.

3.5 Subjective Complaint Condition

The results of the average musculoskeletal complaints score before work were 29,60±0,69 and after work increased to 49,30±4,98. The average score of complaints of fatigue before work by 31.59±1,21 increased to 50,12±1,23. The increase in the average score of musculoskeletal complaints and complaints of fatigue is due to the bowing posture of the craftsmen and environmental heat exposure due to radiation from the smelting furnace. The posture of bowing repeatedly for a long time is a non-physiological work posture. Non-physiological work postures can be caused by characteristics of task demands, work tools, work stations, and work postures that are not in accordance with the abilities and limitations of workers [13], [9]. Non-physiological work posture carried out for years can cause bone abnormalities for the workers [13], and couse subjective disorder of workers [19,20].

Table 3 Scores of Musculoskeletal and Fatigue Complaints

Description	N	Minimum	Maximum	Mean	Std. Deviation
Scores of musculoskeletal complaints before work	4	29.00	32.00	31.5900	1.2192
Scores of musculoskeletal complaints after work	4	42.00	58.00	48.2000	2.3421
Fatigue before work	4	31.00	32.00	31.3000	0.4830
Fatigue after work	4	43.00	55.00	49.2000	3.3214

3.6 Design of Green Technology Furnace Model

Based on figure 1, the current condition of furnace is 18 cm in height from the floor where the craftsman stands. Very low work area causes the work posture of the craftsman to bow with the bowing angle of more than 30 degrees. An unnatural work posture for a long time is a non-physiological work posture. Non-physiological work postures can be caused by characteristics of task demands, work tools, work stations, and work postures that are not in accordance with the abilities and limitations of workers [9]. Non-physiological work postures carried out for years can cause bone abnormalities for workers [13]. The worker's posture to the smelting process needs to be improved towards a physiological work posture so as to reduce the complaints of the craftsman's skeletal muscles. The work posture of the craftsman should be sought in a physiological position as when standing, so as not to cause a forced posture that exceeds the physiological ability of the body [13].

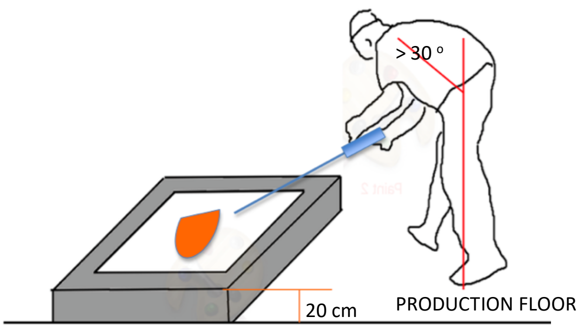

Figure 3 Sketch of Craftsman's Work posture (Before Improvement)

Panjang alat culik ini sekitar 60 cm, sehingga ketinggian bidang permukaan tungku dirancang dengan tinggi 65-70 cm di atas lantai tempat perajin berdiri. Hasil rancangan disajikan Gambar 4.

Considering the data of craftsmen's anthropometry, the average height of the craftsmen's elbows is 105.82 cm. To design a more natural work posture, the height of the work field is obtained 20 cm below the height of the standing elbow which is 85.82 cm. In the smelting process, the craftsman uses a tool to clamp the mass, and a tool to stir or arrange the position of charcoal with a tool called *culik* (Balinese language), which is a kind of straight iron rod used to stir or remove impurities on raw materials that have been smelted. The length of *culik* is about 60 cm, so that the height of the furnace surface area is designed with a height of 65-70 cm above the floor where the craftsman stands. The results of the design are presented in Figure 4.

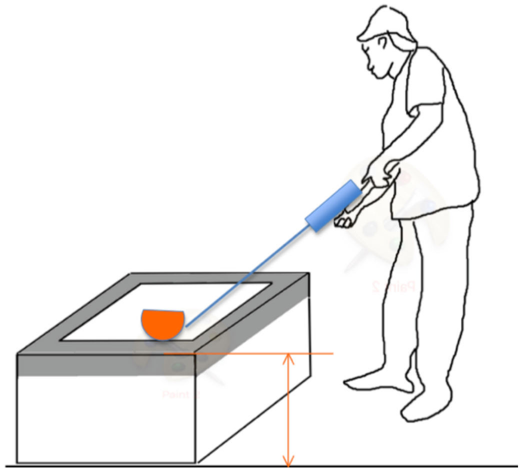

Figure 4 Improvement Sketch of Furnace Height and Craftsman's Work posture

3.7 Green Technology Canopy System Models

The combustion air produced in the smelting process is wasted around the workplace and resulting in an increase of the furnace dust content. In addition, the exposure of heat resulted from the combustion causes the skin surface temperature of the craftsman to increase; therefore it is necessary to design a canopy model to remove dust and heat from the combustion out of the workplace. The design result is presented as follows.

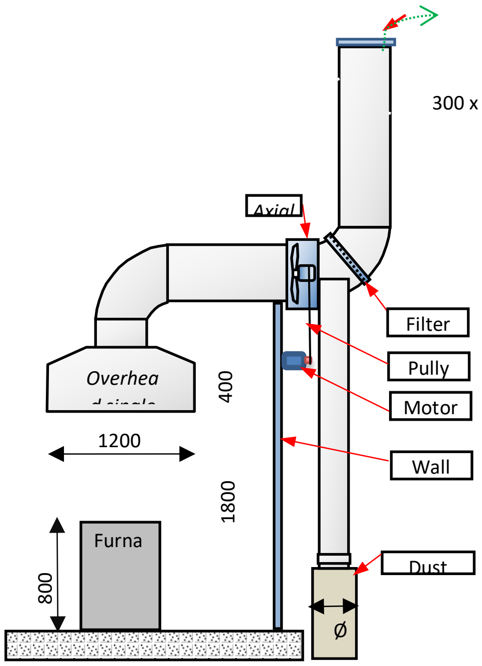

Figure 5 Design of Hot Gas and *Perapen* Dust Exhaust System

4. Conclusion and Suggestion

4.1 Conclusion

Based on the result of the research and the analysis of the obtained data, it can be drawn conclusion as follows:

1. Craftsmen's workload increases by 58.21 pulses per minute. This workload classification is included in the category of "heavy" workload because it is in the range of 125-150 per minute.
2. Pulse increase causes ECPT to become 18,00±1,23 per minute and ECPM is as much as 16,21±2,07/ minute. The average of cardiovascular load (%CVL) increases as well to be 56,34 and the average of skin surface temperature increases to be 38,05°C. The increase of %CVL reaches 56,34% with the WBGT of 29,21 that makes the craftsmen are merely allowed to take 50% work and 50% rest.
3. Designs of bronze smelting furnace model result with green technology concept are such as: a. Improvement of

the height of combustion field in the furnace to 60-65 cm above the height of the floor where the craftsman stands. b. Improvement of craftsmen's work posture into a natural standing work posture. c. Repair the furnace by giving the top canopy for channels of the hot air from combustion and dust.

4.2 Suggestion

Berdasarkan atas hasil simpulan maka dapat disarankan kepada perajin gamelan di Desa Tihingan untuk melakukan perbaikan desain tungku sehingga sikap kerja perajin lebih alamiah, proses pembakaran bahan bakar pada tungku dapat berlangsung sempurna dan udara panas serta debu tidak lagi memapar perajin.

Based on the conclusion, it can be advised to *gamelan* craftsmen in Tihingan village to repair of village furnace so that the work posture of the workers. The process of burning fuel can take place perfectly and the hot air and dust cannot expose the craftsmen.

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