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Improvement of Wok Molding Station Increases Work Comfort and Productivity of the Workers

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***Abstract*---**Most small and medium-sized aluminum casting industries of wok products are still using simple work facilities. The work facilities such as the wok molder which is operated manually and some supporting facilities such as the water container, the temporary place for the end product, the wooden molder stamper, the brush, and the place for the diluted clay liquid are still placed irregularly and do not suit to the operators' body dimension. A work tool that does not suit the user will cause an unnatural work posture and can cause fatigue and uncomfortable feeling, and reduce work efficiency. Therefore, an experimental research needs to be conducted to improve the work comfort and productivity by using treatment by subject design. The research sample was 15 wok molders. There were two treatments given to the sample; molding wok using the former work facilities (P0) and molding wok using the new or improved work facilities (P1). The work comfort was measured using three questionnaires; fatigue in general questionnaire, musculoskeletal complaints questionnaire, and comfort in the general questionnaire. The work productivity was measured based on the total of the produced wok divided by the workload and the work time. The statistical analysis on significant difference results of the processed data before and after the work facilities improvement (P0 and P1) were calculated using Paired Sample t-Test on the significance level of α = 5%. The research results showed that there happened 32.71% decrease of fatigue, 25.71% decrease of musculoskeletal complaints, 34.91% increase of comfort in general, and 31.64% increase of work productivity.

***Keywords*---**work station, comfort, productivity.

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I. Introduction

The Aluminum casting industry experiences growth from time to time and spreads in some of Indonesia's regions. One of the quite-developed small aluminum casting industries is located in Yogyakarta province, in Kampung Nitikan, Umbulharjo. In this area, there are 37 small aluminum casting industries. There are 78 groups of workers that handle the wok molding section in various sizes, in which, each group consists of 3 persons.

Molding work requires high stamina and good precision in order to produce a qualified product because this work needs to be done fast, continuously, and repetitively in a long period of time. The workers have to be precise and careful in polishing the molder lid using liquid clay thoroughly and must be precise in placing the molder lid to its molder place in order to avoid creating a defected product. During the wok molding process, the workers do repetitive activities, and some bending work postures in one work cycle. A repetitive work type should use a special equipment which is suitable for the operation and safety so that it can speed up the operation and increase the productivity (Human Ergology Society, 2017).

The work facility in form of wok molder which is operated using physical strength and the irregular placement of other supporting facilities and has not considered the worker's anthropometry are the sources of unnatural work postures and musculoskeletal complaints. The supporting facilities are the water container, the temporary place for the end product, the wooden molder stamper, the brush, and the place for the diluted clay liquid. Tools or equipment which have not been adjusted to the user's dimension will cause unnatural work postures which can cause fatigue, uncomfortable feeling, and work efficiency decrease (Kroemer & Grandjean, 2009).

The workers' activities in the aluminum wok molding station have not yet met the ergonomic principles because the workers work using bending work posture for a couple of times, using hand reach which is more than maximum reach, irregular machine layout, tools and material which are located far from the worker's position, and many more. The average time to mold a wok is too short which is around 1.47 minutes. These conditions can give a direct impact on the operators such as back and shoulders pain, and wasting too much time in the searching activity because of the irregular layout. A repetitive work that is done in a long duration while using an unnatural work posture will give bad impacts on some muscle parts. Unnatural and uncomfortable work posture which is done in a long duration causes musculoskeletal complaints, and as a result, it will decrease the work productivity (Kohnavard et al., 2018)

The bending work posture is done for a couple of times in producing one product unit which can be seen on the activities of lifting and putting back the molder lid on the molder, wetting or dripping the wok after the casting, placing and lifting the molder wooden stampers, and putting the end-product on its place. These positions and movements are done for 7 work-hour per day which can cause musculoskeletal disorders and fatigue. Some works such as lifting, taking, pushing, and manipulating a heavy load is a physical work that requires strong power which can trigger the development of musculoskeletal disorders (Roman-Liu, 2013).

The initial observation showed the average work pulse frequency of 125.13 ± 1.30 beats/minute which was categorized in the high workload category (Kroemer & Grandjean, 2009), fatigue after work was 81.11 ± 3.44 and musculoskeletal complaints were 84.44 ± 6.78. The average fatigue after work of 51.27 and musculoskeletal complaints of 70.75 is the subjective complaints that cause various problems to the workers; thus, they need to be decreased (Sutapa et al., 2017). The room condition of wok molding station in the small aluminum casting industry was hot and not too bright with the average normal temperature of 320C- 350C, average of lighting intensity of 121 lux, and humidity of 51.3 %. This condition will influence the comfort and work spirit. These average temperature and lighting intensity have not met the applicable standard. The lighting intensity of a workroom needs to be adjusted to the type of work. A continuous-harsh-work requires minimally 200 lux, and a not-too-harsh work requires minimally 500 lux (Kroemer & Grandjean, 2009).

An uncomfortable environment condition can be met in an aluminum casting industry especially on the wok molding station such as a hot temperature room and a lighting intensity which is lower than the permitted regulation. If these kinds of environments happen continuously and there is no improvement, then, these can create potentials of decreasing work spirit, weakening work comfort, disturbing work health, and accumulatively causing a decrease in work productivity. The comfort of a workplace strongly influences the increase of the productivity, the comfort of the equipment or machine usage, and the comfort of the work environment (Budiyanto et al., 2019; Dul & Weerdmeester, 2008). The physical aspect of a work environment has a direct impact on the productivity, health and safety, comfort, concentration, work satisfaction, and morale of the society within it (Sarode and Shirsath, 2014).

In general, the small aluminum casting industries in Jogjakarta have not realized that a good work station design can contribute to increasing the worker's performance which then can contribute to increasing work comfort and productivity. One of the efforts which can contribute to increasing productivity can be done through ergonomic intervention. Designing ergonomic work stations and tools can give a meaningful contribution to the level of effectiveness, safety, and efficiency (Kamat et al., 2017), moreover, these can increase the work comfort (Jaishree, 2015).

Based on the above problems, an ergonomic-based improvement on wok molding station can be done by considering various aspects. The appropriate approach which can be applied to solve the problems thoroughly in the ergonomic sector is known as the total ergonomic approach. This approach consists of two concepts; Systemic, Holistic, Interdisciplinary, and Participatory (SHIP) by applying Proper Technology (TTG) which are conducted consequently and continuously (Manuaba, 2006). This research was conducted to increase the work comfort and productivity.

II. Research Method

The research was conducted experimentally by applying treatment by subject design (Pocock, 2013). The sample was 15 wok molders. The sample was treated using two treatments; molding wok using former work facilities (P0), and molding wok using the ergonomic-based work facilities

improvement (P1). The musculoskeletal complaints were measured using the Nordic Body Map questionnaire and the fatigue, in general, was measured based on the result of the 30 item Self Rating Questionnaire Industrial Fatigue Research Committee from Japan Association of Industrial Health. The work comfort was predicted based on the 5 Likert scale, musculoskeletal complaints questionnaire, and fatigue in general questionnaire. Work productivity was measured based on the total of the produced wok divided by the workload and work time. The statistical analysis on the significant difference results of the processed data before and after the work facilities improvement (P0 and P1) were calculated using Paired Sample t-Test on the significance level of α = 5%.

III. Results and Discussion

3.1 Subjects' Characteristics

All of the subjects were male a total of 15 persons. The measured subjects' characteristics covered age, height, weight, body mass index (BMI), and work experience. Detail of subjects' characteristics of the research can be seen in Table 1 below.

Table 1
Subjects' characteristics of the Research

Variables	Minimum	Maximum	Mean Score	Standard Deviation
Age (years old)	22	53	35.53	8.90
Body Height (cm)	155	173	164.67	6.31
Body Weight (kg)	54.30	70.40	61.97	4.70
Body Mass Index (kg/m^2)	21.08	23.99	22.84	0.95
Work Experience (years)	2	15	7.73	4.18

Table 1 shows that the mean score of age, weight, height, body mass index (BMI), and work experience of the research subjects were on the normal physical condition and productive to work. The mean score of work experience also shows that the subjects already had experience in handling the task.

The subjects' work experience was on the minimum range of 2 to 15 years with a mean score of 7.73 years. In general, the workers already had work experience based on the mean score of the work experience. A wok molder who has an average of 8 years of work experience can be categorized into an adequate-skilled worker. The levels of worker's skill, complaints on the musculoskeletal system, and productivity are also influenced by the work experience owned by the worker (Kroemer & Grandjean, 2009). A worker will increase his/her skill in handling the work in line with the increase or the length of the owned work experience. Worker's performance will gradually increase according to his or her experience, and after 20 years of experience, the performance will decrease (Kotur & Anbazhagan S, 2014).

3.2 Work Environment Condition

In The physical work environment, the wok molding station was measured on the initial condition (P0) and final condition (P1). The result is served in Table 2 below.

Table 2
Work Environment Condition

Variable	P0		P1		t	p
	Mean Score	SD	Mean Score	SD		
Temperature (^oC)	33.67	2.12	29.18	1.22	1.134	0.000
WBGT Index	30.15	0.95	27.54	0.97	2.173	0.000
Lighting Intensity (Lux)	104.51	7.43	225.93	15.42	1.314	0.000
Humidity (%)	58.74	1.83	68.17	2.71	0.931	0.002
Noise Intensity (dBA)	72.75	3.27	73.12	3.19	1.221	0.079

Table 2 shows that there was a significant difference between the initial condition (P0) and the environment condition after the improvement (P1) with the score of $p < 0.05$ on the temperature, WBGT index, and humidity, however, the noise intensity was insignificant. There was a decrease in room temperature from 33.67^0C to 29.18^0C, similarly happened to the Wet Bulb Globe Temperature (WBGT). There was an increase of lighting intensity from 104.51 Lux into 225.93 Lux, similarly happened to the air humidity, there was an increase from 58.74% into 68.17% which made the air condition become more comfortable. This lighting intensity increase had enabled the workers to see clearer on the work object, and the decrease of room temperature and the increase of humidity had made the workers feel more comfortable.

The maximum work temperature based on the medium-heavy work type is between $29\text{-}31^0C$ (Attwood et al., 2004). The average temperature in the molding room of the aluminum casting industry after the improvement could reach 29.18^0 C. It shows that the room temperature of the wok molding station was already within the permitted limit and resulted in the more comfortable room. The lighting intensity on P1 was 225.93 Lux. The lighting intensity for works such as simple assembling, working on carpenter's bench, turning, boring, milling, and key maker's work, require lighting intensity between 250 – 300 lux (Kroemer & Grandjean, 2009). The intensity after the improvement of the wok molding station reached 223.92 lux, it means that the lighting intensity had fulfilled the requirement of work comfort. Lighting improvement in the work environment can affect workers' performance. Researchers consider the lighting factor in the workplace as the main factor in determining workers' productivity (Katabaro and Yan, 2019). The air humidity on P0 was 58.74% while on P1 was 68.17%. the zone of comfort of air humidity is in the range of 65% to 95% (Helander, 2006). The lighting intensity threshold is 85 dB. Adjusting the physical work condition to the permitted threshold can contribute to giving work comfort. It can also create worker's satisfaction by adjusting the work environment and the worker's needs (Budie et al., 2019).

3.3 Work Comfort

The work comfort was predicted through three questionnaires; fatigue in general questionnaire, musculoskeletal complaints questionnaire, and work comfort questionnaire. These questionnaires used the five Likert scale. The significance analysis between P0 and P1 was done by using t-pair test. The analysis result is shown in Table 3 below.

Table 3
Analysis Result of Work Comfort Score

Variable	P0		P1		t	p
	Mean score	SD	Mean score	SD		
Fatigue in general	65.22	6.46	43.89	4.76	8.128	0.000
Musculoskeletal complaints	54.44	8.11	40.44	3.75	4.576	0.002
Comfort in general	37.56	3.84	50.67	8.19	-5.397	0.001

Table 3 shows that there was a significant difference ($p < 0.005$) between P0 and P1. It can be stated that the improvement in wok molding station had given effects on work comfort, decreased fatigue, decreased musculoskeletal complaints, and increased comfort in general. The mean score of fatigue in general on P0 was 65.22 while on P1 was 43.89 or decreased 32.71%. The musculoskeletal complaints score on P0 was 54.44 while on P1 was 40.44 or decreased 25.71%. The comfort in general score on P0 was 37.56 while on P1 was 50.67 or increased 34.91%.

The decrease in fatigue and musculoskeletal complaints, and the increase in work comfort were caused by the improvement of wok molding station which was adjusted to the worker's anthropometry, a good lay outplacement, sufficient lighting, and ventilation. The intervention was done through the improvement on the former wok molder and the supporting facilities and also the work facilities layout which formerly were using bending work posture were improved into the new work facilities layout which was designed by replacing the 2 wooden stampers on the lid molder with a hinge system using a standing work posture. The design of the new work and supporting facilities were adjusted to the worker's anthropometry and worker's needs by applying the proper technology which was as assessed using the total ergonomic approach. The improvement was also done on the work environment condition by installing 5 windows, 14 glass tiles, and 2 fans.

The aspects which should be determined in designing a work station are that they should be adjusted to the anthropometry and the needs of the users (Pheasant & Haslegrave, 2016). Thus, the work station can give comfort and benefits to the users. This intervention is categorized into a holistic intervention because it sees through many aspects. The covered aspects are wok making aspect, environment aspect (room comfort), and the use of proper technology aspects. This approach is called a holistic approach to problem-solving (Manuaba, 2006).

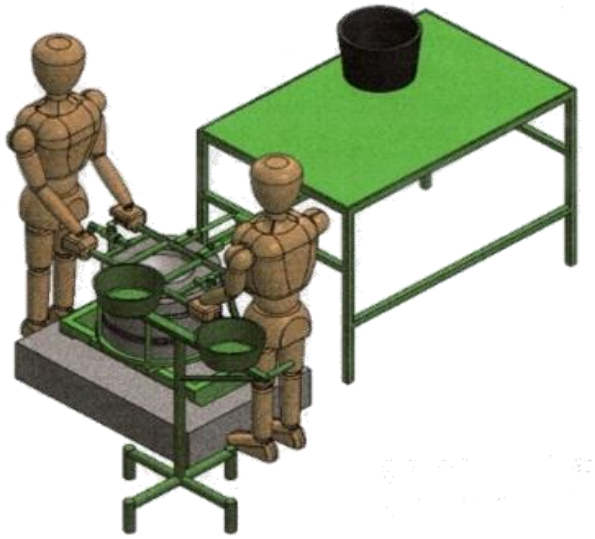

Figure 1 The design of the improved wok molding station

The improvement of the wok molding station covered the application of the new re-design of the wok molder, the work table, the water container, and the end-product temporary place using an ergonomic approach which were based on the worker's anthropometry data. The design of the work facilities is shown in Figure 1 above. Ergonomic hand tools can contribute to reducing uncomfortable feelings, biomechanical pressure, and risk factor of musculoskeletal symptoms and injury (Dianat et al., 2015).

The analysis results toward the work posture on molding wok after the ergonomic intervention showed a change from often doing bending work posture into a better movement which was more comfortable and ergonomic. It was able to decrease fatigue and musculoskeletal complaints of the wok molder, and also able to make the workers feel more comfortable. Moreover, it also gave an impact on the workers' health which became better because they did not have to work using bending work posture anymore, it also reduced fatigue and muscle pain. Intervention toward work posture improvement is one of the efforts in increasing work comfort and health (Yusuf, 2014)

3.4 Productivity

The productivity score was calculated based on the comparison of the achieved result or output and the input timed by the work time. The output was determined based on the total mean score of woks per day for 4 days, the input was calculated from the work pulse of the workers and the work time, in which, the work time was 7 work-hour. The analysis result of work productivity can be seen in Table 4 below.

Table 4
Analysis result of wok molding productivity

variable	P0		P1		t	p
	Mean score	SD	Mean score	SD		
Work Productivity	0.00390	0.00052	0.00513	0.00047	-3.190	0.013

Table 4 shows that there was a significant difference in the work productivity between P0 and P1 ($p < 0.05$). P1 showed a score of 0.00390 while P1 showed a score of 0.00513 or increased 31.62%. It proved that there was an increase in the work productivity between before and after the improvement of the wok molding station.

Work facilities, including sufficient equipment and a conducive work environment, have a very important influence in increasing workers productivity. A change of condition after an improvement in a work station design to achieve work comfort needs to be conducted especially in the industrial sector. In this research, the ergonomic-based improvement of the wok molding station by redesigning the work station which covered redesigning the wok molder and its supporting facilities and improving the physical environment could decrease the fatigue, musculoskeletal complaints, and could increase the comfort and work productivity, moreover, the increase of the productivity reached 31.62%. It happened because the work station was more anthropometric, the work environment was more comfortable, and the work posture was more natural. Work environment aspect has a direct implication on the human brain, worker's morale, and can slow down the change of interpersonal interaction (Edem et al., 2017), and it will give impact on the increase of productivity. Seen from the ergonomic aspect on the industrial center, there is a significant relationship between physical fatigue and work productivity (Man & Ling, 2014), The implementation of the study and ergonomic solution can give workers a better work, comfortable environment, and also can increase the productivity (Deouskar N, 2017).

IV. Conclusions

Based on the research results and the discussion, it can be concluded as follows.

1. The improvement on the wok molding station could decrease the fatigue for 32.71%, decrease the musculoskeletal complaints for 25.71%, and increase the comfort in general for 34.91%.
2. The ergonomic-based improvement on the wok molding station could increase the productivity of 31.64%.

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