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Application of Forging Hammer to Increases Productivity of Balinesse Blacksmith

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***Abstract*—Bali consists of nine districts where aside from working in the tourism industries, the citizen also works as an artist and craftsman. The craftsman produces several kinds of handicrafts such as sculptures, souvenirs, metal crafts, and others. Generally, the craftsmen in Bali are categorized as micro, small and medium enterprises (MSMEs), therefore, their equipment used in the production process is still conventional. One of the MSMEs referred to the blacksmith in the village of Gubug Tabanan. A blacksmith is a person who produces items made of wrought steel or iron by forging the metal, using tools to repeatedly bend, hammer, cut, and shaped as desired. The process of repeatedly hitting the material is deemed ineffective, requires a relatively long time and exhausting, which makes the production is not optimal. From the results of preliminary observations, it was known that the average age of the subjects in this study was 36.15 years, the average body weight of the subjects was 62.15 kg, while the average height of the subjects was 165.95 cm, and the average work experience of 13,85 years. From age, weight and height are included in the normal category. First, the anthropometry subjects for the 5th percentile were: palm length of 18.68 cm, palm width of 10.09 cm, and elbow height of 103.95. Second, for the 50th percentile, they had a palm length of 19.00 cm, a palm width of 10.80 cm, and an elbow height of 106.00 cm. Last, people categorized in the 95th percentile had palm length of 19.30 cm, palm width of 10.91 cm, and elbow height standing of 108.05 cm. The initial workload measurement showed that the results were not significantly different ($p > 0.05$) with $t = -0.09$ and $p = 0.93$. It illustrated that the resting pulse rates of group I and group II in the first experiment period were similar. By designing this hammer forging machine, it is hoped that it could speed up forging time, have a more precise size, and produce a smoother surface, therefore, the blacksmiths in the village of Gubug Tabanan are expected to increase their income and welfare. The observation results of 20 craftsmen before and after using the machine showed a decrease in workload based on their work pulse, from 100.95 bpm to 87.81 bpm ($p < 0.05$). The decrease in subjective complaints according to the fatigue score was 43.21 to 34.01 ($p < 0.05$). Then, based on musculoskeletal complaints after worked with conventional tools it was 43.85 while with new tools it decreased to 32.94 ($p < 0.05$). Finally, the productivity also increased significantly (23.88%) from 0.0289 by using conventional tools and improved to 0.0358 by using new tools ($p < 0.05$).**

Keywords—Hammer, forging hammer, and work productivity

I. Introduction

Apart from tourism industries, Balinese people also work in arts and crafts in nine districts. The crafts referred to are jewelry, clothes (such as songket, endek and others), sculpture, souvenirs, metal crafts, and others. In general, the Balinese craftsmen are categorized as micro, small and medium enterprises (MSMEs) so that the production equipment used by these people is still conventional. One of the MSMEs referred to the blacksmiths in the village of Gubug Tabanan. A blacksmith is a person that works to create a tool or craft that is made from metal/iron. The process includes heating the iron until it has a bright red color, after that it will be forged and shaped as desired. The finishing process is where the iron that is formed according to the request, soak by water, then continue to quality control to make it presentable. Making metal handicrafts is nothing new for Balinese people. Since a long time ago, when there was still a kingdom, metal crafts had developed in many parts of the world. Some of the metal handicraft items that have existed since the days of the kingdom are various weapons (ranging from knives, keris, swords, machetes, spears, etc.), jewelry, gamelan, and others. In Bali, people who make tools from iron or steel are called blacksmiths in English or Pande Besi in Bali. They produce a lot of equipment such as farming equipment (for example sickles, axes, hoes, and others), household tools (for example knives, machetes, and others), weapons (for example keris, swords, spears, machetes and others) and gamelan. In order to forge the metal and change into various equipment or weapons, it must pass through several stages of the process starting from heating the metal in a furnace to form it through a hammering/hitting process. Currently, the forging/hitting process still uses hands as a method, but this method is still classified as less effective because it is exhausting and requires a lot of time. To overcome these problems, we need a working mechanism with the help of a hammer forging machine to speed up the process of forging/hitting [1,2]. The hammer forging machine mechanism can work continuously with the same pressure, resulting in a more uniform and presentable product. The power of the engine comes from the rotation of the electric motor which is transmitted to the V-belt which then moves the hammers vertically. With the hammer forging machine, it is hoped that it can make it easier for blacksmiths to process forging with a better result than using the previous method (conventional). Intervention is also needed to increase work productivity [3,4].

II. Methods

This research is a *one short case study* that includes a pre and post-test design group which is carried out by observing the work process by using a hammer forging machine. The chart can be described as follows:

R ⟶ *P0* ⟶ *PI*

Fig. 1. Research design.

Information:

R = Random sample.

P0= the result of the pretest experimental unit

PI = the result of the posttest experimental unit.

The of this research includes the design of ergonomic forging tools. The hammer forging machine model is designed using an electric motor to drive the V-belt and swingarm through an ergonomic approach.

III. Results and Discussion

A. Discussion

From the results of pulse measurements, while working, craftsmen from both villages obtained an average of ± 92 beats per minute, which is categorized as medium workload category [4] which means there is an increase in workload from light to moderate workload. In addition, the low income earned by craftsmen, which is around Rp. 50,000 per day, causes them not to be able to improve their standard of living. This is possible because the level of their education and skillsare low.

The results of forging iron using a hammer or conventional tools have not been maximal. The accuracy of size and uniformity are common problems when they used conventional tools such as the iron hammer. Therefore, the blacksmith had to spend a lot of energy and need to concentrate in order to get the specified size.

To overcome this condition, the blacksmith's work process needs to be adjusted. In addition, the wrong way of working can cause various complaints after work and reduce work productivity. In order to solve this problem, the application of the principles of ergonomics is mandatory [5,6]. By developing a hammer forging machines, the crafters can work naturally, effectively, safely, and comfortably. Based on the result of the observations of 20 blacksmiths in the village of Gubug Tabanan, it was found that the percentage of complaints of skeletal muscles and fatigue in general after working is shown in Table 1 and Table2 below:

TABLE I. Top Five Skeletal Muscle Complaints Percentage of the Blacksmith

Type of Complaint	Before Work (%)	After Work (%)
Back pain	0,00	85,71
Pain in the right arm	0,00	57,14
Pain in the left arm	0,00	48,30
Pain in the waist	10,29	71,43
Pain in the right leg	9,29	57,14

TABLE II. Top Five General Fatigue Percentage of the Blacksmith

Type of Complaint	Before Work (%)	Type of Complaint (%)
Feel heavy on the head	14,29	71,43
Feeling tired whole body	0,00	85,71
The feeling of wanting to lie down	14,29	100,00
Feel awkward moving	14,29	57,14
Feel stiff in the shoulder	0,00	71,43

Fig. 2. Forging an iron with conventional tools.

B. Ergonomic Principles

The application of ergonomic principles is an intervention that aims to obtain a humanism, competitive, and sustainable work system [7]. Ergonomics applications in general have several objectives to be achieved. The main goal is to create a healthy physical and psychological condition for workers, by harmonizing human capabilities and limitations with the task or job to be carried out. In addition, to create a humanism work system, ergonomics has also proven to be economically beneficial. *Good ergonomics is good economics* [8], which means that the appropriate application of ergonomics will provide higher economic benefits and has been proven by the application of ergonomics in the forestry industry, transportation, material handling systems, product design, repair workstations, and others which can improve productivity significantly.

In particular, ergonomics also brings several benefits, [9,10]: (a) improve the efficiency of muscle and energy; (b) improve the time effectiveness; (c) reduced fatigue; (d) reduced work accidents; (e) decreased occupational diseases; (f) increased job comfort and satisfaction; (g) improved work efficiency; (h) increased product quality and work productivity; (i) minimized work errors and difficulties, and; (j) reduced the expenses or costs for dealing with occupational accidents and diseases, also consequently operational costs can be lower. Thus, a forginghammer can be made according to the needs of the workers.

Forging machines that are driven by an electric motor to rotate the V-belt and swingarm. it converts the movement from the rotation to up and down movement which able to swing an iron hammer. This machine is very easy to operate and speeds up the forging process, both for preliminary work and finishing work because it provides the same power of pressure in every hitting process. The forging hammer machine design is as shown in figure 3:

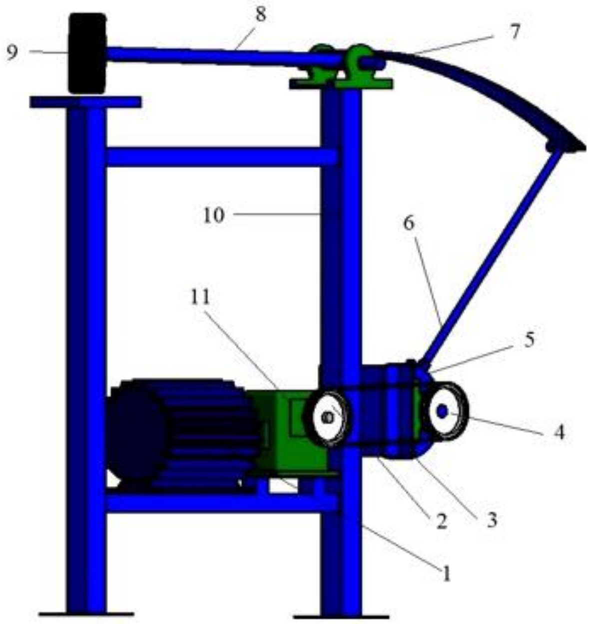

Fig. 3. The hammer forging design.

Image caption 2:

1. Electric motor
2. The drive pulley
3. Belt V
4. Pulley that is driven
5. Crankshaft
6. Connecting rod
7. Hammer shaft
8. Hammer shank
9. Hammer
10. Frame
11. Gearbox

This tool is made to be used easily and safely. In addition, this tool has never been found in any blacksmith, especially in the Tabanan district of Bali. This hammer forging machine is expected to speed up the forging time, the results of the forging are even and more uniform. Therefore, it speeds up the product-making process and increases the productivity of the blacksmith.

C. *Workload Calculation*

The workload is calculated by measuring the resting pulse rate, in order to control these subjects to have a similar condition and get a robust calculation result. The resting pulse rate of the blacksmiths of 20 people measured can be shown in Table 3 (pulse before work) as follows.

TABLE III. THE DIFFERENCE IN RESTING PULSE RATES BETWEEN BEFORE AND AFTER USING A FORGING HAMMER (N = 20)

Group	Average Resting Pulse (dpm)	SD	*t*	P
Use of conventional tools	75,18	4,19	126,91	0,529
Use of hammer forgingmachines	76,19	4,81		

Note: SD = standard deviation

Table 3 shows that the average resting pulse rate of blacksmith before using conventional tools and after using the hammer forging machine which obtained a value of $p > 0.05$. It means that the average resting pulse rate before and after using the forging machine can be considered the same or the two groups are comparable.

After using the hammer forging machine, the average work pulse rate was also measured after work. The measurement results are as follows table 4.

TABLE IV. THE DIFFERENCE IN THE AVERAGE WORK PULSE BETWEEN BEFORE AND AFTER USING THE HAMMER FORGING MACHINE (N = 20)

Group	Average Pulse Work (dpm)	SD	*t*	p
Use of conventional tools	100,95	2,71	15,58	0,001
Use of Hammer Forging Machines	87,81	3,39		

Note: SD = standard deviation

1) Calculation of musculoskeletal complaints: Based on the normality test with Shapiro-Wilk, the resultsare as shown in Table 5.

TABLE V. MUSCULOSKELETAL COMPLAINTS DATA BETWEEN THE CONTROL GROUPS AND TREATMENT GROUP BEFORE WORK (N = 20)

Description	Use of tools conventional			Use of Hammer forging machines			P*
	Mean	*SD*	*p*	*Mean*	*SD*	*p*	
Musculoskeletal complaints pre	29,88	1,60	0,212	30,24	1,71	0,419	0,154

Information: p = Significance for normality, p * = Significancefor comparability.

From Table 5, it can be seen that the p-value of musculoskeletal complaints before work for blacksmith craftsmen who still use conventional tools is 0.212 and craftsmen who use a forging hammer machine are 0.419 (p> 0.05) so it can be concluded that the data for musculoskeletal complaints before work is distributed normally. Because the musculoskeletal complaint data before work is normally distributed, the mean difference test can be continued using the Independent-Samples t-Test. Analysis of the effect of using a hammer forging machine was tested based on the average of musculoskeletal complaints between before using the forging hammer machine and musculoskeletal complaintsafter using the forging hammer machine. The analysis results are presented in Table 6.

TABLE VI. MUSCULOSKELETAL COMPLAINT DATA AFTER WORK BETWEEN BEFORE AND AFTER USING THE HAMMER FORGING MACHINE (N = 20)

Description	**Use of Conventional Tools**			**Use of Hammer forging machines**			**P***
	Mean	***SD***	***p***	***Mean***	***SD***	***p***	
Musculoskeletal complaints Post	43,85	3,59	0,145	32,94	4,17	0,092	0,001

Note: p = Significance for normality, p * = Significance for comparability.

Table 6 shows that the data from musculoskeletal complaints after work are normally distributed. Analysis of significance using the Independent-Samples T-Test showed that the value of p * = 0.001. This means that the mean score of musculoskeletal complaints after using a forging hammer machine is significantly different (p * <0.05) or indicates that there is an effect of using a forging hammer machine on reducing musculoskeletal complaints.

2) Fatigue calculation: The results of the normality test for the mean fatiguescore are presented in Table 7.

TABLE VII. DATA FOR BLACKSMITHS FATIGUE BEFORE WORK (N = 20)

Description	**Use of tools conventional Tools**			**Use of Hammer forging machines**			**P***
	Mean	***SD***	***p***	***Mean***	***SD***	***p***	
Fatigue (pre-test)	32,89	1,47	0,113	32,71	1,91	0,513	0,501

Information: p = Significance for normality, p * = Significancefor comparability

From Table 7, it can be seen that the p-value of fatigue before working on the blacksmiths before using the hammer forging machine and after using the hammer forging machine has a p-value > 0.05, so it can be concluded that the data is normally distributed. Since the fatigue data before work is normally distributed, the mean difference test uses the Independent-Samples t-Test. The treatment effect analysis was tested based on the average fatigue score between the groups of blacksmiths before using the hammer forging machine and after using the forging machine. The analysis results are presented in Table 8.

TABLE VIII. DATA FOR BLACKSMITHS FATIGUE AFTER WORK (N = 20)

Description	**Before using the hammer forging Machine tool**			**After Using Hammer forging machines**			**P***
	Mean	***SD***	***p***	***Mean***	***SD***	***p***	
Fatigue (post-test)	43,21	2,19	0,178	34,01	3,32	0,334	0,001

Information: SD = Standard Deviation, p = Normality Test, p*= Comparability Test

Table 8 shows that the average score of fatigue for blacksmiths who worked before using the hammer forging machine was 43.91 ± 2.19 and for crafters who worked after using the hammer forging machine was 34.99 ± 3.32.

3) Calculation of work productivity physiologically: For one work process, the average production yield reaches 10 ±0.31 pieces with an average working time of 4 ± 0.18 hours.

TABLE IX. WORK PRODUCTIVITY DATA OF BLACKSMITH (N = 20)

Description	**Use of Tools Conventional**			**Use of Machines Forging Hammer**			**P***
	Mean	***SD***	***p***	***Mean***	***SD***	***p***	
Work productivity from a physiological aspect (pieces/hour bpm)	0,0289	0,0031	0,621	0,0358	0,0089	0,415	0,001

Note: p = Significance for normality, p* = Significance for comparability

From Table 9 it can be seen that the value (p) of work productivity in the group using conventional tools and hammer forging machines p value > 0.05 so that it can be stated that the two data are normally distributed. Because the data is normally distributed, the mean difference test uses the Independent - Samples T-Test. The results of the analysis showed that the productivity of blacksmith before and after using the hammer forging machine was significantly different or the productivity increased by an average of 49.70%.

4) Calculation of work productivity from the forging results: The production data of the beating using a hammer forging machine per hour obtained in this study were tested for normality by the One sample KoImogorov –Smirnov Test. The results show that the data are normally distributed (p> 0.05). The significance analysis using the paired t-test is presented in Table 10.

TABLE X. DIFFERENCE TEST (T-PAIRED) AVERAGE PRODUCTION USAGE HAMMER FORGING MACHINE

Subject Group	**n**	**Production Average (pieces/hour)**	**Standard Intersection**	**Different Averages (Pieces/hour)**	**t-paired**	**n**
Control	20	3,60	4,63	-163,40	-50,63	0,00
Treatment	20	10,31	15,25			

From Table 10 above, the significance analysis using the t-paired test shows that the results are significantlydifferent ($p < 0.05$) with $t = -50.63$ and $p = 0.00$. This means the use of hammer forging machines increases production.

Based on the results and discussion above, interventions can reduce fatigue, skeletal muscle complaints, and increase work productivity. Ergonomic interventions are able to provide solutions to work problems and able to increase work productivity [11,12].

IV. Conclusion

From the results of the discussion, several conclusions from the usage of hammer forging machine are described as follows:

- A significant reduction in workload based on the pulse rate ($p < 0.005$), namely the rate before using the hammer forging machine reach 100.95 ± 2.71 bpm, while the pulse rate with the usage of hammer forging machine only 87.81 ± 3, 39 bpm.
- There was a significant decrease in subjective complaints of fatigue score after working from 43.21 ± 2.19 into 34.01 ± 3.32 by switching from using conventional tools to forging hammer machine ($p<0.05$). Based on the complaints of skeletal muscle after work, it was 43.85 ± 3.59 with conventional tools, while the complaint from the use of forging hammer machine decreased to 32.94 ± 4.17 ($p <0.05$).
- Increasing work productivity where before using hammer forging machine work productivity of blacksmith was 0.0289 ± 0.0031, then rise into 0.0458 ± 0.0089 ($p <0.05$).
- Compared to the use of conventional tools, switching to hammer forging machines could increase work productivity significantly by 49.7%, which means that the iron forging process using a hammer forging machine is much better and faster.

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