Ergonomic Analysis of the Work Condition in Aluminum Crafts Industry

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Abstract. Indonesia has plenty of abundant natural wealth. This natural wealth produces natural materials that can be utilized as a craft product. The craft workers generally still work manually and the work is done repeatedly in one cycle so it is very susceptible to musculoskeletal disorders. Musculoskeletal disorders will cause decrease of worker's effectiveness and efficiency in completing the task. Thus, this fact has some adverse impact for the company. The purpose of this study is to analyze some task in manufacturing a traditional cooking tool (griddle) which encompasses mold of the griddle, refine of the griddle and the finishing touch by using the Occupational Repetitive Action Index (OCRA index) method. This method consists of high frequency movements, large forces, awkward postures, insufficient resting time and other factor such as vibration. Result of this study shows that in the molding operation, the worker has uncertain and medium risk on right hand in manufacturing small and large size of griddle with OCRA index is 2.5 and 5.3 respectively. In the refining operation the worker has light and medium risk on left hand in manufacturing small and large size with OCRA index is 3.6 and 5.8 using grinding machine and 5.8, 5.2, 6.3 and 5.0 using miser tool. In finishing operation, the worker has high risk on right hand in numbering of code griddle and has medium risk on right hand and medium on left hand in labeling with OCRA index is 9, 6.1 and 6.8 While in assembling operation the worker has no risk. Score that it indicates the risk level of the task in such job. Thus the following actions are to improve the work condition ergonomically in all operation in aluminum craft.

Keywords: Musculoskeletal disorder, OCRA Index, Aluminum crafts, Griddle

1. Introduction

Indonesia as a developing country has many kinds of handycraft. Commonly, the crafts are manufactured from a natural material such as soil. The process of manufacture is still done traditionally which no use an advanced equipment. This is frequently called the manual handling task. Manual handling task performed repeatedly or over long periods of time can lead to fatigue and injury to muscles, tendons, ligaments, nerves, and blood vessels. This condition is known as work-related musculoskeletal disorders (WMSDs)[1] [2].

WMSDs become the most significant problem in industrialized countries especially in manual activities[3]. Based on Data from the U.S. Bureau of Labor Statistics in 2015 showed that WMSDs can cause a one third loss of working time[4] and also adversely affect the society, especially in economics terms [5].
According to the European Occupational Disease Statistics (EODS), work-related musculoskeletal disorders (WMSDs) are the most common occupational diseases (accounting for nearly 40% of the total) and an increasing trend can be observed in many member countries. It can be proved that European workers have a risk of WMSDs where its 25% experience back pain and 23% experience upper muscle pain [6] [7].

The result of the Health Department study in the profile of health problems in Indonesia 2005 indicates that 40.5% of diseases suffered by workers are related to their manual work. As many as 9482 workers in 12 cities of Indonesia experience Musculoskeletal Disorder (16%), cardiovascular disease (8%), respiratory disorders (3%), and Ears-Nose-Throat disease (1.5%) [8].

According to preliminary study in traditional cooking tools industry was found that more than 50% of workers complain about their body health when molding, refining and finishing of the griddle. However, this condition has not been identified how much risk to the worker’s health. Therefore, it is very critical to know a risk level of the task that has been done so as the hazards associated with manufacturing a frying pan can be avoided.

Objective of this study is to analyze some task in manufacturing a traditional cooking tool (griddle) by using Occupational Repetitive Action Index (OCRA index).

2. Method

2.1 Occupational Repetitive Action (OCRA Index) Method

The Occupational Repetitive Actions (OCRA) is a method in ISO 11228 standard to identify the presence of upper limb work-related musculoskeletal disorders (UL-WMSD) for workers in high repeatability manual tasks. This method encompasses six variables. They are high frequency repetitiveness of actions, use of force, awkward postures, lack of recovery periods, movement of velocity and duration [2][10][11].

OCRA index is the ratio of the ratio between Actual Technical Action (ATA) and Reference Technical Action (RTA). Its procedure consists of three basic steps: (1) calculating the technical frequency of the action per minute and the total number of ATA performed in shifts and calculating the total number of RTA in the shift, (2) calculating the OCRA index, and (3) conducting a risk evaluation [11].

ATA is calculated based on several factors that are count the number of technical actions in one cycle (\(n_{TC}\)), then evaluate the frequency of technical action performed per minute (\(f\)), and taking into account cycle time (\(T_c\)). It can be formulated as below:

\[
f = n_{TC} \times \frac{60}{T_c}
\]

Next, calculate the total number of technical actions performed in one shift \((n_{ATA})\) by using Equation (2).\( \tau \) is the total operator working time expressed in minutes.

\[
n_{ATA} = f \times t
\]

After calculating the number of ATA \((n_{ATA})\), the next step is to calculate the amount of RTA \((n_{RTA})\) by using equation (3).

\[
n_{RTA} = \sum_{i=1}^{n}[k_f (F_m \times P_m \times R_m \times A_m) \times t] \times (R_c m \times t m)
\]

For calculating the number of RTA there are several factors to be considered. The first is the constant frequency \((k_f)\) which is the constant value for the constant frequency of the technical action, that is 30. The second is the force multiplier \((F_m)\) using Borg-10 scale, which is intended to assess how labored the worker is doing. The third is the postural multiplier \((P_m)\) obtained from the four upper body segments consisting of the shoulders, elbows, wrists, and type of grip. The fourth is the repetitiveness multiplier \((R_c m)\), where when the task requires the performance of the same technical
action for at least 50% of the cycle time, or when the cycle time is shorter than 15 seconds, \( R_{CM} = 0.7 \). If not, \( R_{CM} = 1 \). The fifth factor is the additional multiplier \( (A_M) \) obtained at least 1 additional factor that influences the work (using vibration tools, exposure temperature, light level and noise level).

### Table 1. Classification of OCRA Index

| Area            | OCRA Index values | Risk Classification       | Consequent possible actions                              |
|-----------------|-------------------|---------------------------|----------------------------------------------------------|
| Green           | \( \leq 1.5 \)    | Optimal                   | None                                                     |
| Green Yellow    | 1.6 – 2.2         | Acceptable                | None                                                     |
| Yellow – red    | 2.3 – 3.5         | Uncertain or very low     | Check again, if possible improve work conditions.        |
| Red – light     | 3.6 – 4.5         | Light                     | Improve work conditions, health surveillance, training   |
| Red – medium    | 4.6 – 9.0         | Medium                    | Improve work conditions, health surveillance, training   |
| Red – high      | \( \geq 9.1 \)    | High                      | Improve work conditions, health surveillance, training   |

The sixth is the duration of the repetitive task \( (t) \) which is the total operational time of the operator and expressed in minutes. The seventh is the recovery multiplier \( (R_{CM}) \) obtained from the total working hours at risk of overload. The last factor is the duration multiplier \( (t_M) \) obtained from the number of operators working hours.

After the calculation of the number of ATA and RTA, the next calculation of the value of OCRA index in accordance with the Press. 4 and evaluate the risk level according to table 1, which explains the risk level in accordance with the resulting OCRA index value [2].

\[
OCRA \text{ index} = \frac{n_{ATA}}{n_{RTA}}
\]  

\[ (4) \]

### 2.2 Subject and Object of Research

Focus of this study is a manufacturing process the traditional cooking tools (griddle) manually. It consists of three operations that are mold of the griddle, refine of the griddle and finishing. These operation is done by workers who have high skill for each task. Their age is about 23-60 years old and most of them are male. They works is in eight hours per day with one hour for rest and in standing position for molding and sitting position for refining and finishing.

### 2.3 Task

Task for manufacturing the traditional cooking tool is as follows:

1. Molding the griddles

Molding operation consists of pouring the aluminum fluid into the mold of wok then leave it in 87.04 seconds for small size and 135.4 seconds for large size while polishing the wok with lime water for keeping the pan not sticking in the mold. And last step is remove the griddle from the mold. (see Figure 1)
Figure 1. Manual Mold of The Griddle Activity: (a) Pouring the aluminum fluid into the mold of wok, (2) The griddle mold process, (3) Take a wok out of the griddle mold

2. Refine of the griddle
Refine operation consist of refine all edges of the griddle using a grinding machine 19.61 seconds for small size and 27.2 seconds for large size. Then refine the outside and inside an unreachable griddle ear using a miser tool for 17.5 seconds for a small size and 60.9 seconds for large size. (see Figure 2)

Figure 2. Refine of the griddle activity: (a) Using grinding machine and (b) misery

3. Finishing the griddle
Finishing operation consist of numbering of the griddle 3.1 seconds for small size and 7.24 seconds for large size, then label the company logo 6.3 seconds for small size and 8.58 seconds for large size, and also assemble the griddle 158.01 second for small size and 92.24 seconds for large size. (see Figure 3)

Figure 3. Final Finishing Activity: (a) Numbering, (b) labeling and (c) assembly of the griddle.

2.4 Analysis Method
Descriptive analysis of this study is conducted based on OCRA score to classify a risk level of each operation in a manufacture of the griddle. Futher analysis is also carry out to find a recommendation for improvement.
3. Result and Discussion

Table 2 shows scores of OCRA Index for each operation includes molding, refining and finishing. In the molding operation for manufacturing small size of griddle, score of OCRA index is 2.5 for the right hand and 1.1 for the left hand. It means this operation has uncertain and optimal risk. Uncertain risk on the right hand to make small size of griddle because of the force used is low as of not produce problem on arm but it is necessary to re-check the working conditions based on the analysis of movement posture on the left hand does not occur extreme movement during the time cycle of work but, on the elbow in the right hand is formed extreme flexion angle and palmar grip hand movement for 2/3 cycles, so it is necessary to re-check the tools used in molding operation to avoid muscle injury and upper body frame [13]. While for manufacturing large size of griddle, score of OCRA index is 5.3 for the right hand and 1.5 for the left hand. It means this operation has medium and acceptable risk. The medium risk occured on the right-hand is caused by use of the heavy force (at 4 level in BORG scale) and also the right hand is more dominant to take technical action on operation of mold for large size where molding tool has a weight more than 2 kg, so it can cause fatigue in the arm muscles and inflammation in the joints [14]. Thus it is required to improve the molding method done by both hands. This effort can avoid a load on hand [16].

In operation of refining the griddle for small size using grinding machine, score OCRA index is 2.9 for the right hand and 3.6 for the left hand. It means that this operation has uncertain and light risk. The uncertain risk on right hand is moderate (with level 3 on the Borg scale) with a factor multiplier of 0.35. It because use of a grinding machine in refining requires more power than the left hand that only holding, twisting and moving a small size of griddle. However, although the right hand exerts moderate effort but no high repetition. The light risk on a left hand due to an actual technical actions (ATA) larger than Reference Technical Action (RTA) which it describes a high repetitive motion so as causing musculoskeletal disorder for long period [14]. For refining large size of griddle, score of OCRA index is 1.0 for the right hand and 5.8 for the left hand. It means this operation has optimal and medium risk. The medium risk occured on the left hand is caused by the same technical action and involves a flexion of the elbow joint exceeding 50% of the cycle time so that it will result in harmful and injury on the upper limb [14]. Thus it needs to improve work place and method based on the ergonomic principle by providing an appropriate recovery time for muscles [10] [15].

As for refining the griddle by using miser tool for small size, score OCRA index is 5.2 for the right hand and 6.3 for the left hand. It shows this operation has medium risk. The medium risk on right and left hand is caused by frequency of repetition for every minute is large that is 20 action / minute for right hand and 34 action / min for left hand. It means the musculoskeletal disorders will be occurred due to develop the repetitive motion [14]. And also for large size of the griddle, score of OCRA index is 5.0 for the right hand and 4.7 for the left hand where it classify to medium risk. The medium risk occured on the right-hand and left hand is caused by use of the heavy force (at 3 and 4 level in BORG scale) at arms muscle so as fatigue and inflammation in joints [15]. Thus it is required to improve work place and method based on the ergonomic principle by providing an appropriate recovery time for muscles [10] [16].

In the finishing operation for numbering a code, score of OCRA index is 9.9 for the left hand and 0 for the right hand. It means that this operation has high and optimal. It happen because the repetitive activities are mostly done by the right hand, while the left hand is idle. For labeling of small and large size, score of OCRA index is 6.1 for the right hand and 6.8 for left hand and include risk area of medium risk. It happens because of the right hand often do pinch grip and there more opportunity there is for fatigue and inflammation to occur in the muscles and joints[14]. Thus this operation should be improved in method to avoid the excessive use of the hands. Improvements with rotating the worker in this is also done to fatigue[16]. While in assembling operation the worker has no risk.
Table 2. Determining risk level of the various jobs presented in manufacturing traditional cooking tool (griddle)

| Workstation          | Job type                          | Part of Hand | RTA   | ATA   | Score OCRA Index | Risk Area | Risk Classification |
|----------------------|-----------------------------------|--------------|-------|-------|------------------|-----------|---------------------|
| Mold of the griddle  | small size                        | Right hand   | 1806.95 | 4570.3 | 2.5              | Yellow-red | Uncertain           |
|                      |                                   | left hand    | 3011.58 | 2688.4 | 1.1              | Green     | Optimal             |
|                      | Large size                        | Right hand   | 555.984 | 2938   | 5.3              | Red-medium | Medium             |
|                      |                                   | left hand    | 1135.13 | 1728.2 | 1.5              | Green     | Optimal             |
| Refine of the griddle| grinding of small size            | Right hand   | 873.2   | 2520   | 2.9              | Yellow-red | Uncertain           |
|                      |                                   | left hand    | 2120.6  | 7710.4 | 3.6              | Red-light  | Light               |
|                      | grinding of large size            | Right hand   | 1621.6  | 1680   | 1.0              | Green     | Optimal             |
|                      |                                   | left hand    | 873.18  | 5040   | 5.8              | Red-medium | Medium             |
|                      | Refining use a miser tool for griddle of small size | Right hand   | 1621.6  | 8400   | 5.2              | Red-medium | Medium             |
|                      |                                   | left hand    | 2270.3  | 14400  | 6.3              | Red-medium | Medium             |
|                      | Refining use a miser tool for griddle of large size | Right hand   | 498.96  | 2482.8 | 5.0              | Red-medium | Medium             |
|                      |                                   | left hand    | 873.2   | 4137.9 | 4.7              | Red-medium | Medium             |
| Finishing the griddle| Numbering of code at small and large size griddle | Right hand   | 1868.61 | 13632.5 | 9.9              | Red-High  | High                |
|                      |                                   | left hand    | 0       | 4645.2 | 0                | Green     | Optimal             |
|                      | Labeling at small and large size  | Right hand   | 2324.08 | 14192.4 | 6.1              | Red-medium | Medium             |
| Workstation  | Job type         | Part of Hand | RTA   | ATA   | Score OCRA Index | Risk Area  | Risk Classification |
|-------------|------------------|--------------|-------|-------|------------------|------------|---------------------|
| griddle     |                  | left hand    | 1081.49 | 7324.3 | 6.8              | Red-medium | Medium              |
|            | Assembling at small and large size griddle | Right hand   | 2623.10 | 4884.25 | 1.9              | Green-Yellow | Acceptable          |
|            |                  | left hand    | 2623.10 | 4485.54 | 1.7              | Green-Yellow | Acceptable          |

4. **Conclusion**

Based on the analysis, it can concluded that:

1. In operation of molding the griddle is identified that the worker has uncertain risk on right hand in manufacturing small size and has medium risk on right hand in manufacturing large size with OCRA index is 2.5 and 5.3 respectively. So, it is necessary to Re-check and improve work conditions, health surveillance as well as training for worker in molding operation.

2. In operation of refining the griddle by using grinding machine is identified that the worker has light risk on left hand in manufacturing small size and has medium risk on left hand in manufacturing large size with OCRA index is 3.6 and 5.8 respectively. While by using miser tool is identified that the worker has medium risk on left and right hand in manufacturing all size with OCRA index is 5.8, 5.2, 6.3 and 5.0 respectively. So, it is necessary to Improve work conditions, health surveillance as well as training for worker in refining operation.

3. In operation of finishing the griddle is identified that the worker has high risk on right hand in numbering of griddle and has medium risk on right hand and left hand in labeling with OCRA index is 9.9, 6.1 and 6.8 respectively. So, it is necessary to improve work conditions, health surveillance as well as training for worker in finishing operation. While in assembling operation the worker has no risk.

5. **References**

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