E-ISSN 2503-1430
ISSN 2541- 3090

Journal of Industrial Engineering Management
(JIEM Special Edition Seminar Nasional Teknik Manajemen Industri (SENTRA))

ENGINEERING DESIGN OF AUTOMATIC SELENOID STOVE TO REDUCE MUSCULOSKELETAL DISORDERS COMPLAINTS USING NBM AND RULA APPROACH

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Article history:
Submit 17 Oktober 2020
Received in from 20 Oktober 2020
Acceted 20 November 2020
Avilable online 4 Maret 2021

ABSTRACT

UKM Kenanga is a home industry producing various cassava chips based in Kubu Raya district, West Kalimantan. Complaints regarding musculoskeletal were identified in the process of frying chips. The complaints were carpal tunnel syndrome, low back pain, neck pain, as well as on the forearm and upper arm. Non-ergonomic working position contributes to these complaints. Therefore, it is necessary to perform this analysis and suggest a tool that would be helpful to reduce the worker's complaints. Formerly, there haven't been any early studies that cover the design of an automatic stove for the frying process based on biomechanical considerations, particularly on musculoskeletal disorder complaints.

This study performs an analysis based on Nordic Body Map (NBM) and Rapid Upper Limb Assessment (RULA) concerning the process of frying the chips. Nordic Body Map analysis was used to identify body parts that were experiencing fatigue. Following the Nordic Body Map results, the automatic stove was designed to solve the employees' complaints. RULA approach was used to analyze the condition after the employees carried out the work using the stove. The outcomes of this study are an automatic solenoid stove and a stool for the process of chips frying. RULA approach on the frying process with the manual stove and with the automatic solenoid stove resulted in L4-LV compression level reduced by 71.05%, whereas for Flex/Ext Compression was 87.97%.

Keywords: ***Automatic Selenoid Stove, Biomechanics, Musculoskeletal disorders, NBM, RULA***

Published By:
Fakultas Teknologi Industri
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DOI :http://dx.doi.org/10.33536/jiem.specialedition.772

I. INTRODUCTION

The production process for various chips in UKM Kenanga is normally carried out by hand, from processing the raw material, the frying process to packing the chips. The repeated physical activities potentially inflict musculoskeletal disorders and fatigue. The initial observation showed that the female workers in UKM Kenanga had musculoskeletal disorders or fatigue in several body parts. Musculoskeletal disorders frequently appeared while the workers were chopping the ingredients and frying the chips, mostly on the wrist (*carpal tunnel syndrome)*, low back pain, neck, forearm, upper arm, and leg. Musculoskeletal disorders on the female employees indicate that work productivity in UKM Kenanga is low, either by the output produced or the work performance where they easily get tired. This condition is due to the working posture, which does not meet the principle of user convenience or ergonomics. Based on the initial observation findings, it is necessary to analyze and suggest a tool to reduce the employees' fatigue. In particular, on the existing frying process, the employee fries the chips while sitting in a small stool. The posture of the employee was slouching. UKM Kenanga does not have a frying station that considers the employee's proper posture to work yet. Accordingly, this study focuses to analyze a stove design that uses a gas aperture regulator (Selenoid) technology with consideration of the female employees' fatigue and posture in UKM Kenanga.

From the conditions explained above, this study formulates the problems as follows:

1. How are the complaints that the employees in UKM Kenanga had been tolerating, based on the Nordic Body Map?
2. How to reduce the complaints of the employees?
3. How is the analysis of the work posture based on Rapid Upper Limb Assessment (RULA)?

Whereas the objectives of this study are specifically:

1. Obtaining Nordic Body Map examination in regards of the complaints of the female employees in UKM Kenanga
2. Obtaining a design of an automatic solenoid stove and a work tool to reduce musculoskeletal disorder complaints.
3. Obtaining work posture analysis based on Rapid Upper Limb Assessment (RULA).

This study is useful to help UKM Kenanga to reduce the complaints of musculoskeletal disorders by the employees. The complaints would lower the overall productivity; therefore, proper treatment is necessary.

Various early studies regarding a stove design were conducted by Laksmi et al. (2010) about engineering design of a stove with Bioethanol fuel using user's needs identification method Quality Function Deployment (QFD) and Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ). The study results in the design of a user-friendly stove. Purnomo et al. (2014) has done a study to design and test a stove which uses biomass waste, specifically rice husk from agricultural waste, as fuel. Subiantoro and Wiwi (2015) conducted a study to design a coal-fueled stove to meet the domestic industry needs. The characteristic of this stove is its adjustable heat (the temperature can be set to high or low according to the user's needs). Djafar et al. (2018) conducted a study for designing and manufacturing a stove that uses biomass fuel from corn cobs. Those studies regarding the design or the redesign of the stove revolve around the fuel and the identification of the user's needs. There are no studies yet to cover the user's body posture.

This study considers work posture and fatigue to design an automatic stove that uses Selenoid. There are several methods to analyze fatigue in work, such as physiological measurement, biomechanical aspects using Rapid Upper Limb Assessment (RULA), Nordic Body Map, Rapid Body Entire Assessment (REBA), NIOSH, OWAS, and other considerations. The analysis using the RULA method has been quite an interesting topic to cover work fatigue studies. Research regarding RULA by Manghisi et al. (2017) developed the latest software, K2RULA, which is able to directly detect movements or postures out of ergonomics principles. Moreover, Manghisi et al. revised the existing grand RULA score. Valentim et al. (2017) combined biomechanical analysis using Rapid Upper Limb Assessment (RULA), and Strain Index (SI) approaches on physiological therapy. Bazazan et al. (2019) analyzed an improved work posture based on biofeedback intervention concerning musculoskeletal symptoms (MSS) and fatigue on petrochemical factory workers in Iran. These various studies prove that the RULA approach is still an interesting study to analyze fatigue in work.

RULA analysis may utilize aids such as RULA software or manual computing. This study uses a Computer-Aided Three-dimensional Interactive Application (CATIA). Using RULA in CATIA is fairly new for ergonomics study. There are several studies that apply RULA in CATIA, while CATIA has already provided a 3D mannequin that represents the proper work posture. An early study using CATIA to design a product was done by Kushwaha & Kane (2016) for redesigning a crane operation workstation at a steel industry in India. The redesign of this workstation was needed just after the company received complaints from 27 crane operators regarding their muscle pain and other pain on their several body parts after they were done working. By applying RULA in CATIA, the study discovered that the workstation could be improved for better and proper posture to achieve a comfortable working condition. Following the early studies, the analysis in this study is done using RULA in CATIA.

II. METHODOLOGY

This study consists of three main stages, which are problem identification, design, and result interpretation analysis. The flowchart is shown in Figure 1.

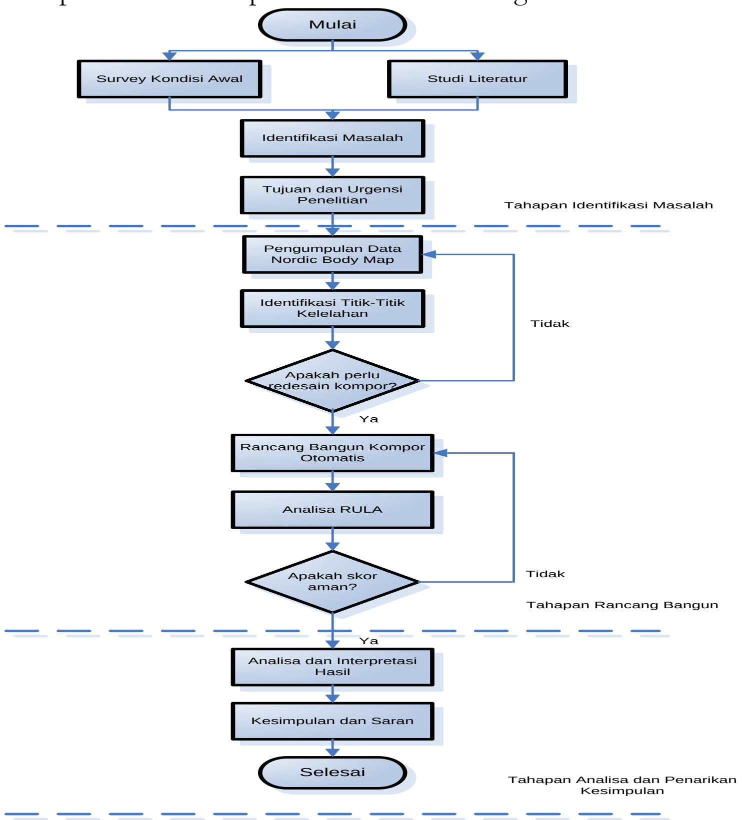


Figure 1 Flowchart of the study

From the flowchart, the three stages of this study are explained as follow:

1. Problem Identification
   The problem identification stage starts from the observation of the initial condition and literature review. The observation provides information regarding the existing condition in UKM Kenanga, which further the problem can be identified from this information. From the existing problem, then the objectives and urgencies of the study are determined.
2. Design
   The design stage is firstly collecting the data needed for the Nordic Body Map (NBM) of the female employees in UKM Kenanga as they were frying the chips using the manual stove. The NBM result shows where the body feels fatigued. This data becomes an input to design an automatic stove for the frying process. Afterward, the analysis regarding the automatic stove is run using Rapid Upper Limb Assessment (RULA). The analysis generates a score to determine whether the stove is proper or not to use. If the analysis gives out a poor score, then the design should be revised.
3. Analysis and Drawing Conclusion
   If a safe score is obtained from RULA analysis, the next step would be analyzing and interpreting the result of the automatic Selenoid stove, then benchmark the stove to the manual stove. Lastly, the study can be concluded and makes a suggestion for future studies.

III. RESULT AND DISCUSSION

The NBM questionnaires to observe the existing condition of the employees shows the area of fatigue comprises the foot, neck, shoulder, and arm. The frying process on the existing condition uses a gas stove and a plain small stool. The distance between the stove and the stool is close, consequently, this condition may harm the worker. The manual stove has the specification of a single-burner gas stove with 25 x 37 x 9 cm dimension. For solving the workers' complaints, the automatic solenoid stove was designed following the anthropometric data taken from the workers in UKM Kenanga. The anthropometric data used in the study are hip-width, popliteal rear, and popliteal height. The design of the stool and solenoid stove table using software CATIA can be seen in Figure 2.

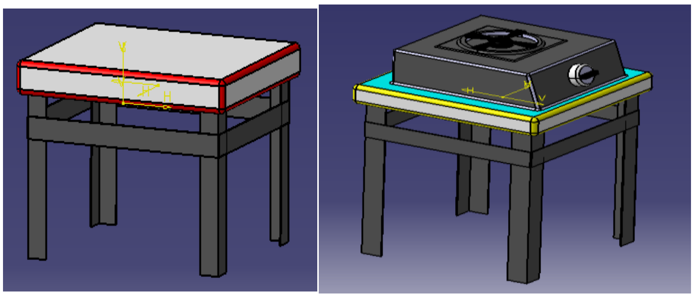


Figure 2 Design of the stool and stove table

Based on the design above, the stool and the automatic solenoid stove are built, as shown in Figure 3.

Figure 3 Stool and automatic solenoid stove

A. *RULA Analysis of Existing Work Posture Condition*

RULA analysis determines the final score on every posture of the worker while they were frying the chips using a manual temperature regulator stove. The posture position chosen for this measurement is when the worker is frying while holding the spatula. Figure 4 shows the RULA score for the existing condition.

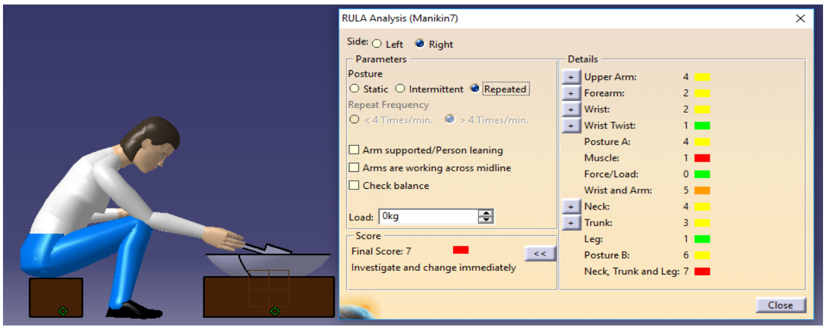
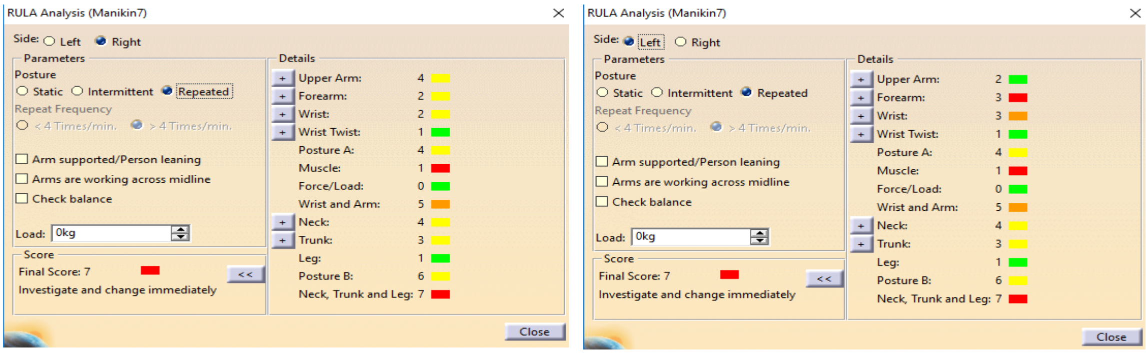


Figure 4 RULA analysis of the existing condition

Meanwhile, Figure 5 (a) and (b) show RULA results on the existing condition, consecutively for the right and left side of the body.



(a) (b)

Figure 5 (a) RULA analysis for existing condition, right side (b) RULA analysis for existing condition, left side

As seen in Figure 5, the final score result obtained from RULA analysis on the existing condition for both right and left sides is 7.

B. RULA Analysis of the Worker's Posture While Using Automatic Selenoid Stove

The difference between the automatic solenoid stove and the existing stove is on the setting or the regulator of its temperature. When the heat sensor dipped to the frying oil detects the optimum temperature that matches the setting, the solenoid valve will cut down the gas flow to the stove, and the stove automatically turns off. The result of RULA analysis on using the automatic solenoid stove is shown in Figure 6.

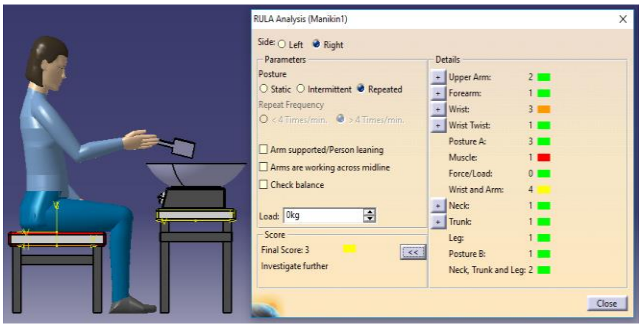
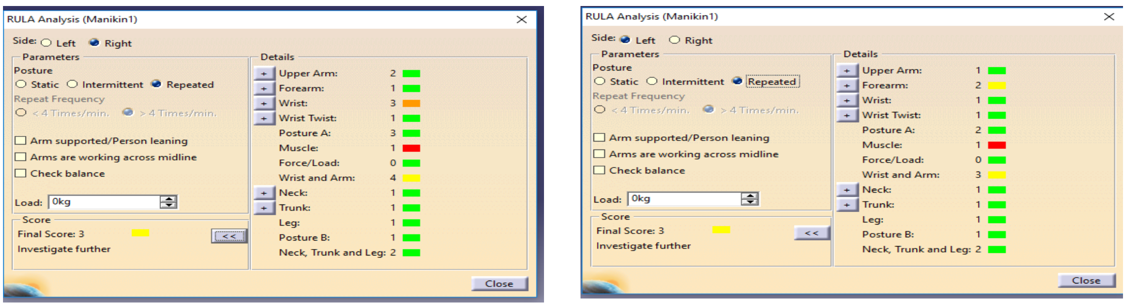


Figure 6 RULA analysis on a worker using automatic solenoid stove

Figure 7 (a) and (b) show the result of RULA analysis on consecutively the right side and left side of the worker using an automatic solenoid stove.



(a) (b)

Figure 7 (a) RULA analysis result on worker's the right side while using the automatic stove (b)RULA analysis result on worker's left side while using the automatic stove

Based on Figure 7 (a) and (b), the result of RULA analysis on the worker while using automatic solenoid stove on both right and left sides has the final score of 3.

C. Analysis of Compression Level of Using The Existing Stove and Using The Automatic Selenoid Stove

The comparison of the analysis result between the existing stove and the automatic solenoid stove can be seen in Table 1.

Table 1 Comparison of compression level between the manual stove and the automatic stove for frying process

		L4-L5 Compression (N)	Body Load Compression	Flex/Ext Compression
Frying process	Existing Stove	1755	209	1515
	Automatic Selenoid Stove	508	271	185

Based on the result of the torque measurement using the Biomechanics Single Action Analysis tool, the compression level on Lumbar 4 and Lumbar 5 decreased when using the automatic stove. Body load for L4-L5 on the posture that uses the existing stove is 91 kg, whereas a posture that uses the automatic solenoid stove for L4-L5 has an 11 kg loads. This result indicates that from the biomechanical aspect, there is a reduction of load which the body carried while frying.

IV. CONCLUSION

1. Based on the questionnaires for Nordic Body Map (NBM), the existing condition of the workers were showing several body parts suffering pain and fatigue, particularly on the leg, neck, shoulder and arm. Thus, the NBM after the employees worked using the automatic solenoid stove along with the redesigned stool showing a reduction of the NBM score.
2. The automatic solenoid stove, as an outcome of this study, is able to adjust the optimum temperature of the frying oil automatically. Apart from that, this frying facility has a convenient feature from both biomechanics and anthropometric aspects, specifically the stool that is adjustable to the worker's height and posture. Therefore, the worker will no longer slouch over while frying.
3. The result of RULA in CATIA to compare the process of frying chips using the existing stove and the automatic solenoid stove showing a significant reduction on L4-L5 Compression level by 71.05% while Flex/Ext Compression level reduced by 87.97%.

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