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ERGONOMIC ANALYSIS ON REDESIGNING RICE HARVESTING MACHINES

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Abstract

Purposes of Study: Research was conducted with the aim of redesigning and analyzing rice harvesting machines that are in accordance with Indonesian anthropometry, machines that have designs to minimize injuries to the working position of farmers in harvesting rice.

Methodology: The approach used to complete this research is by method Rapid Upper Limb Assessment (RULA) and Nordic Body Map, RULA considering anthropometric data, energy consumptions. The next step is to implement the calculation of data in the form of rice harvesting machine product design using the product design stages.

Main Findings: The results of this study indicate that improved rice harvesting machines have better performance than the previous machines. Modification is done by adding two wheels on the front of the rice harvesting machine which can reduce energy expenditure by 2.73 Kcal/minute from 3.82 Kcal/minute to 1.09 Kcal/minute. In terms of productivity, it increased by 22.2% from 9 m^2/hour to 11 m^2/hour. Other ergonomic parameters using the Nordic Body Map have a significant decrease in pain complaints at 10 points of the limb.

Implications: Products produced have valuable benefits that can be felt directly by the community with significant results in the process of completing their work.

Novelty/Originality: The design carried out can provide benefits for traditional farmers who turn to harvest machine technology which can also minimize injury to machine users; this has not been done much research before.

Keywords: *Rapid Upper Limb Assessment (RULA), Ergonomics, Nordic Body Map, Product Design, Rice Harvester, Rice Machine.*

INTRODUCTION

The process of harvesting rice is a work activity of a human-machine system that is done manually and depends on the operator, both in the use of energy and control of work activities. Rice harvesting activities are carried out using rice harvesting machines whose operation is determined by operator performance (Ichikawa, Sugiyama, & Manaka, 1985; Otto, 2003; Setyono, 2010; Veerangouda, Sushilendra, Prakash, & Anantachar, 2010). Rice harvesting machine is placed on the back of the operator and the rice cutter is given a handle and held by the operator's hand. Problems faced by the operator are back pain due to receiving a machine load, the arms of the hand accept the burden of the cutting knife handle, and leg pain. In every activity carried out by humans, both daily activities and production activities definitely require methods, time and place. In order for activities to achieve the best goals, the best method, the best place and the best time are needed (Cross & Roy, 1989; Kahn, Castellion, & Griffin, 2005; Kurniasih, 2018; Prasnowo, Nurdin, & Ahlan, 2019; Richey & Klein, 2014). Similarly, the use of a work aid in the form of a rice harvesting machine(Nurdin, Lestari, Hidayat, & Prasnowo, 2018). Therefore, this study aims to redesign and analyze ergonomic rice harvesting machines according to Indonesian anthropometry. Ergonomic measurements are carried out to ensure that the operator's work environment is ergonomically designed to minimize the risk of injury and to increase productivity (Paoletti, 2014; Prasnowo & Hidayat, 2017; Sajiyo & Prasnowo, 2017). Complaints in the musculoskeletal system are complaints to parts of the skeletal muscles that are felt by a person ranging from very mild complaints to very sick. If the muscle receives a static load repeatedly and for a long time, it can cause complaints in the form of damage to joints, ligaments or tendons (Grandjean & Kroemer, 1997). One method of measuring ergonomics to measure musculoskeletal risk is Rapid Upper Limb Assessment (RULA). RULA provide an easily calculated assessment of musculoskeletal burden in activities where the operator has a risk of injury, the research presented by previous researchers shows that there are injuries experienced by the operator in the use of related equipment. as in the ceramic production machine operator, the use of computers and the use of other machines. so that the RULA approach is able to minimize accidents and injuries(Dockrell et al., 2012; Golchha, Sharma, Wadhwa, Yadav, & Paul, 2014; McAtamney & Corlett, 1993; Rahman, 2014; Stanton, Hedge, Brookhuis, Salas, & Hendrick, 2004).

The objective of this research is to farmers who use rice harvesting machines in Malang. In this research, a rice harvesting machine has been redesigned with results that can minimize injury to users (farmers) with an ergonomic approach based on Rapid Upper Limb Assessment (RULA) rules.

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LITERATURE REVIEW

The term "ergonomics" comes from the Latin of *Ergon* (work) and *Nomos* (the Law of nature) and can be defined as a study of human aspects in an environment that is reviewed anatomically, physiology, psychology, engineering, management. and Design (Nurmianto, 2008). Ergonomic is a systematic branch of science to utilize information about the nature, ability, and limitation of human beings to design a working system so that people can live and work on that system well, that is to achieve the desired purpose through the work effectively, securely, and comfortably. The main objectives of the ergonomics are four, namely: [1] Maximizing employee efficiency, [2] improving occupational health and safety, [3] advocating working safely, comfortably and vigorously, [4] maximizing the shape of work.

Working posture is the determining point in analyzing the effectiveness of a job. If the work posture performed by the operator is good and ergonomic, it can be ensured that the results obtained by the operator will be good, but if the operator's work posture is wrong or not ergonomic then the operator is easy Fatigue and abnormalities occur in the form of bones. If the operator is easily experienced the fatigue of the work performed by the operator also decreased and not as expected. Skeletal muscle complaints, in general, occur due to excessive muscle contraction due to heavy overloading of workloads with prolonged loading duration. Conversely, muscle complaints may not occur when muscle contraction only ranges from 15-20% of maximum muscle strength. However, when the muscle contraction exceeds 20%, the blood circulation to the muscles decreases according to the level of contraction influenced by the amount of energy required. The supply of oxygen to the muscles decreases, the process of carbohydrate metabolism is hindered and as a result, there is a filling of lactic acid that causes muscle pain.

The RULA (Rapid Upper Limb Assessment) is a method of a survey developed for use in ergonomics investigations in the workplace and its analysis (Dockrell et al., 2012). RULA was developed by Dr. Lynn McAtamney and Dr. Nigel Corlett who are ergonomics of the university in Nottingham (University of Nottingham's Institute of Occupational Ergonomics)(Kadikon, Shafek, & Bahurdin, 2015). It was first described in the Ergonomics Journal application form in 1993. RULA is a method developed in the field of ergonomics that investigates and assesses the working position done by the upper body. This method does not require a special device to provide assessments in the posture of the neck, back and upper body.

In line with the function of muscles and external loads supported by the body. The ergonomic technology evaluates posture, strength, and muscle activity that inflict injury due to repetitive activity. The RULA was developed to detect risky working posture and make repairs as soon as possible (Dockrell et al., 2012). The RULA has been identified as a technique for assessing and studying the relationship between occupational risk factors and complaints in work(Moor & Garg, 1995). RULA analysis can be used in recording information such as worker posture scores and the burden carried by a worker(Massaccesi et al., 2003). RULA is a method to assess the individual operator's exposure to risk factors of fatigue in doing work, so that excess workload causes fatigue and needs to be reduced (Boenzi, Digiesi, Facchini, Mossa, & Mummolo, 2017).

The RULA method uses the target posture to estimate the risk of muscle impairment, especially in upper limbs, such as repetitive motion, a job required strength exertion, muscle static activity in muscles Skeletal, etc. The assessment is systematic and fast against the risk of interference by pointing to the part of the worker's body that is experiencing the disorder. Analysis can be done before and after the intervention, to demonstrate that the intervention given will be able to lower the risk of injury. Inside the application, the RULA method can be used to determine the priorities of the work based on the risk factor of the injury and seek the most effective action for the work of relatively high risk(Yazdanirad et al., 2018)

METHOD

This research method is carried out starting with problem identification, data collection, and processing, data analysis with conditions in the field. This research was conducted in Malang Regency with the object of research being farmers who use rice harvesting machines. Data were obtained through direct observation when farmers used rice harvesting machines, measured the body dimensions (anthropometry) of farmers, calculated energy consumption by measuring the pulse/heart rate, and conducted interviews about complaints experienced by farmers when using the machine. Then the researchers observed and analyzed the body posture using the RULA (Rapid Upper Limb Assessment) method(McAtamney & Corlett, 1993; Stanton et al., 2004). Furthermore, the researchers measured the anthropometry of the farmer's body and modified the design of the rice harvesting machine ergonomically based on the design steps, which consisted of planning and explanation of tasks, designing product concepts, designing product shapes and designing details (Boothroyd, Dewhurst, & Knight, 2001; Cross & Roy, 1989; Kahn et al., 2005; Otto, 2003; Richey & Klein, 2014; Wiraghani & Prasnowo, 2017).

RESULTS AND DISCUSSION

Interview with 30 operators of rice harvesting machines, there were complaints in the use of rice harvesting machines. The complaint resulted in 10 parts of the body feeling uncomfortable, including body parts; back, wrists, fingers, neck, waist, shoulders, thighs, legs, ankles and elbows. Based on these data, it is necessary to design rice harvesting machines. Then measured anthropometric data on 30 farmers in Malang Regency. This anthropometric data is used to calculate the

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measurements that will be used in the design of rice harvesting machines. The following are the results of anthropometric data:

Table 1: Design Size and Percentile

No	Dimension	Percentile	Size (cm)
1	Machine grip height	5^{th}	55,54
2	Handrail distance	5^{th}	40,75
3	Length of the cutter handle	5^{th}	110,18

After obtaining anthropometric data, the next step is to design improvements to rice harvesting machines. Design (design) is an activity or engineering design that starts from the ideas of design innovation, or the ability to produce works and inventions that really can describe market demand because of the existence of research and technology development. The following is a design picture of the improvement of rice harvesting machines.

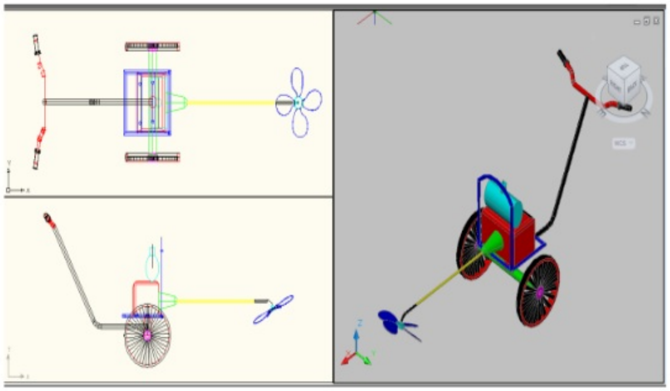

Figure 1: Design of Rice Harvesting Machine Repair

Figure 2: Testing of Rice Harvesting Machine After Repair

After repairs to work facilities, data collection and processing are carried out related to the comfort of limbs by using questionnaires to operators of rice harvesting machines. The results of data processing showed that there was a decrease in pain complaints after using the new rice harvesting machine, as shown in the following table.

Table 2: Discomfort Questionnaire Results

No	Parts of body	Initial Machine	New Machine
1	Back	10	3
2	Wrist	8	2
3	Fingers	6	4
4	Neck	8	5
5	Waist	10	4
6	Shoulder	9	4
7	Thigh	8	3
8	Feet	8	4
9	Ankle	8	3
10	Elbow	10	3

After redesigning the rice harvesting machine, the rice harvesting process time was measured for time comparison before design and after design. The results of the measurement process time after design increased by 22.2% from 9 m^2/minute to 11 m^2/minute.

Energy needed to operate a rice harvesting machine before repairs is carried out as follows; before operating a rice harvesting machine of 0.68 liters/minute which is equivalent to energy consumption of 3.45 Kcal/minute, and oxygen consumption after operating a rice harvesting machine of 1.51 liters/minute which is equivalent to energy consumption of 7.27 Kcal/minute. So that energy consumption needs before repairs of 0.79 liters/minute are equivalent to the energy consumption of 3.82 Kcal/minute. The energy needed to operate rice harvesting machines after repairs is as follows; before operating a rice harvesting machine of 0.65 liters/minute which is equivalent to energy consumption of 3.11 Kcal/minute, and oxygen consumption after operating a rice harvesting machine of 0.88 liters/minute which is equivalent to energy consumption of 4.19 Kcal/minute. So that energy consumption needs before repairs of 0.23 liters/minute are equivalent to the energy consumption of 1.09 Kcal/minute. Modification is done by adding two wheels on the front of the rice harvesting machine which can reduce energy expenditure by 2.73 Kcal/minute from 3.82 Kcal/minute to 1.09 Kcal/minute overall there are improvements that occur after the engine redesign process with an average repair value of 20%. Furthermore, there was also a decrease in the number of complaints about the use of machines from the questionnaire results that had been distributed.

This result in line with the research below : (Das & Gangopadhyay, 2011; Mishra & Satapathy, 2019; Singh & FMP, n.d.; Swangnetr et al., 2012; Syuaib, 2018).

CONCLUSION

The conclusion of this study is that improved rice harvesting machines have better performance than the previous machine. Modification is done by adding two wheels on the front of the rice harvesting machine which can reduce energy expenditure by 2.73 Kcal/minute from 3.82 Kcal/minute to 1.09 Kcal/minute. In terms of productivity, it increased by 22.2% from 9 m^2/minute to 11 m^2/minute. Other ergonomic parameters using Nordic Body Map have a significant decrease in pain complaints at 10 limb points, among others; back, wrists, fingers, neck, waist, shoulders, thighs, legs, ankles and elbows. This study indeed still provides a description of the 10 measurement points that cause injury. The results of engine design that have been implemented still do not take into account the level of vibration caused so there is still the potential for muscle fatigue in the user in the process of harvesting rice with a large area. The condition of the agricultural land used is also a factor in the design of the engine so it needs to be adjusted to the drive model (wheels).

LIMITATION AND STUDY FORWARD

The product design implemented has limitations in its implementation which may subsequently be continued in other studies. The limitations of this study include:

1. Product design does not discuss the strength of the machine frame structure after the redesign.
2. Product design still uses human labor as the operator who operates the machine.
3. Agricultural land applied in the form of small plots.
4. In the product design process, the design is arranged according to the Focus Group Discussion agreement.

IMPLICATION

Based on the results of the study the following theoretical and practical implications can be stated:

1. Theoretical Implications
   a. RULA (Rapid Upper Limb Assessment) method and Nordic Body Map which are used as a product design approach combined with a product design process approach can reduce the energy consumption needed by farmers to harvest rice.
   b. It provides an illustration of the addition of a new approach in product design that is the occupational safety and health approach so that the resulting product is really comfortable and ergonomic to use.
2. The results of this study can be used as an input or an overview of the design of modifications to the rice harvester for farmers because the design is easily applied by farmers. So that the work of harvesting rice becomes more effective and efficient.

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