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***Key words:*** *ergonomics risk assessment, rapid upper limb assessment (RULA), analytic hierarchy process (AHP)*

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# ERGONOMIC RISK ASSESSMENT OF THE PRESS MACHINE FOR CASAVA CHIPS IN SMES-KARYA LESTARI JAYA: A CASE STUDY

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*This article discusses about the press machine posture movement effectiveness for cassava chips mold. This research was conducted at Karya Lestari Jaya which is one of the SMES in Tulungagung, East Java, Indonesia. The industry is in trouble with new manual press machine that is too rigid and heavy to handle. The operator complain of pain the arm and forearm. this means the activity has deficient posture when the operator works. This study aims to know the ergonomics risk factors for press machine and determine the best recommendation by the operator and owner SMEs Karya Lestari Jaya suggestion. We conduct a case study by collect the data from observation. We analyze the observation data by RULA (Rapid Upper Limb Assessment). Then, we do interview of eight resource person to get the attribute that required to upgrade the machine. Besides that, we analyze the best recommendation by AHP (Analytic Hierarchy Process). This research result a value of RULA 6 which means the attitude in pressing the dough or working facilities need to repair immediately. There are five phases to determine design there are information phase, creative phase, analyze phase, development phase and recommendation phase and the result of AHP show that the best recommendation is the addition of a pneumatic system in machine press to lighten the lever. In the end, this research can be useful to the company by knowing body posture and evaluating the upgrade machine.*

*Key words: ergonomics risk assessment, rapid upper limb assessment (RULA), analytic hierarchy process (AHP)*

## INTRODUCTION

Humans have limitations in the usage of body dimensions. If their movement in conducting activities has an angle that exceeds normal limits, they may feel pain and injury while working. According to Dewangan et al. (2010), in achieving good performance, suiting the workplace, and eliminating musculoskeletalpain, it is requisite to consider the worker's ability and body limitation. The risk of injury needs to be minimized to gain better work performance (Jadhav et al., 2014; Heydaryan, Suaza Bedolla and Belingardi, 2018).

In designing the tools or devices that fit the human body, the integration between the human factor and the dimension of work facilities should be considered (Liu, 2008). Since the hazard could be emerged due to human errors and/ or machine errors, the posture of workers should be fit with the machine to avoid ergonomic risk factors. The risk factors of Ergonomic comprise the awkward postures, forceful exertion, static motion, pressure point, and repetition posture(Rossi et al., 2013; Mgbemena et al., 2018; Karimi et al., 2020). It can reduce the productivity of workers due to the injuries and pain influence their health. It can indirectly increase health and insurance costs. Therefore, it is required to identify the risk, analyzed it, and prevent it (Crescencio and Ortiz, 2016).

Many SMEs are still using the manual machine and neglect the ergonomic risk factors (Dianat and Salimi, 2014). It is maybe, they do not know occupational hazards and health programs. Also, they do not have enough finance to be allocated as healthy and insurance costs. It has also occurred at SME's Karya Lestari Jaya as the cassava chips-SMEs in Tulungagung, East Java, Indonesia. They have manual molding chips machines that utilize upper and lower arms to pull the lever's handle of the molding machine. This activity can be upsetting upper and lower arms because of musculoskeletal pain at the arms. Also, the repetitive certain motion for a long time and the stiff lever of pressing machine can cause pain and fatigue.

Many previous studies investigate the design of their tools based on the ergonomics perspective (Dianat and Salimi, 2014; Li, Gül and Al-Hussein, 2019; González et al., 2020). Also, the previous studies investigate the risk of inappropriate posture(Crescencio and Ortiz, 2016; Mgbemena et al., 2018; Enez and Nalbantoğlu, 2019)and working procedure (Houshyar and Kim, 2018); as well as minimizing the ergonomic risk by training. In addition, there are less supportive previous studies that investigate the best priority of recommendation for reducing the pain inappropriate posture. Therefore, this study aims to identify the level of posture by using RULA and determine the best recommendation to improve the posture by utilizing AHP. Then, this research aims to identify the work posture using and to evaluate the current work posture.

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### *PRESSING MACHINE*

The pressing process is the mechanism to set the level of the metal piece in either empty form or coil form into an imprinting press by using a tool (Kalpakjian, Schmid and Musa, 2009). In this study, we employ a pressing machine to mold the dough to be the raw of cassava crackers. Figure 1 depicts the pressing machine that we use to mold the dough.

In a pressing process, some studies such as Arezes and Carvalho (2016); Pavlovic-Veselinovic, Hedge and Veselinovic (2016) elucidated the requirement to be skilled and considered ergonomics factor which was identified as "after-reach". This means that operators should be aware of the maximum reach of the press machine, shear, and the other regarding their position and posture. According to Pavlovic-Veselinovic, Hedge and Veselinovic (2016), this risk could be evaluated by utilizing an ergonomic expert system, i.e. SONEX. This software can simulate can evaluate the possible WRMSDs (work-related musculoskeletal disorders).

*Figure 1: Pressing machine to mold the cassava dough*

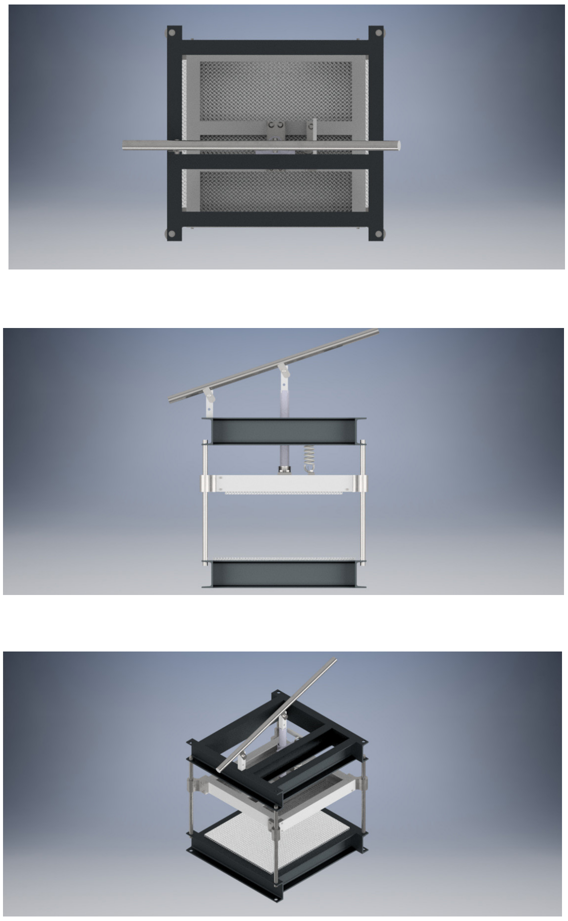

*Figure 2: The design of pressing machine*

### *RULA (RAPID UPPER LIMB ASSESSMENT) MEASUREMENT*

RULA was developed by Lynn McAtamney and E Nigel Corlett to investigate the ergonomics evaluation regarding the suitable posture of operators to the workplace or tools (Lynn and Corlett, 1993). It analyzes posture, strength, and muscle activities that can cause injury due to repetitive motion. The mechanism in undertaking RULA is presented as follows.

1. Divide the observation of the operator's body into 2 groups, namely A consisting of the neck of the upper arm (lower arm), lower arm (lower arm),
2. Wrist (wrist), group B which consists of the neck (neck), legs (leg), and back (trunk), additional load activity score.
3. Assess each operator's work posture using RULA into score A and score B.
4. Determine the RULA score from the combination of the A and B. score calculations.

In this case, Ergonomics can be implemented in evaluating the results of the form that illustrates the risk score. The total risk score can be between one to seven. Seven is the highest score which means the greatest risk or the most dangerous work posture. This does not guarantee that the lowest score will be exempt from the ergonomic hazard (Akshinta, P. Y. dan Susanty, 2017).

### *AHP (ANALYTIC HIERARCHY PROCESS)*

The Analytical Hierarchy Process (AHP) was developed by Thomas L. Saaty in the 1970s. AHP is a multi-criteria decision-making tool that can choose many alternatives and criteria based on the weight of prioritizing (Saaty, 1990; Saaty and Vargas, 2001). Many study implement this method in various field such as Information technology (P, Wardhani and Putri, 2020); knowledge managemen (Lee, 2010); operation management (Subramanian and Ramanathan, 2012); and ergonomics (Unnikrishnan et al., 2015; Heydaryan, Suaza Bedolla and Belingardi, 2018).

According to Saaty (1990); Saaty and Vargas (2001); Heydaryan, Suaza Bedolla, and Belingardi (2018), the AHP method can be presented as the following steps.

1. Defining the problem and the goals.
2. Creating a hierarchical structure. After defining the problem and the goal, the next step is composing the hierarchical structure (Figure 3) based on the top level which represents the goal. Then, it is followed by the middle level which is arranged as the criteria and subcriteria. The lowest level shows decision alternatives or solutions.

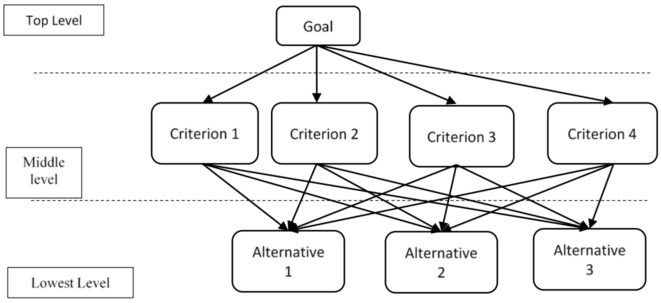


*Figure 3: The hierarchical structure*

*Table 1: Saaty's importance scale*

| Important level | Scale |
|---|---|
| Equally important | 1 |
| Weakly more important | 3 |
| Moderately more important | 5 |
| Strongly more important | 7 |
| Extremely important | 9 |
| In between | 2, 4, 6, 8 |

1. Implementing the pair-wise evaluation scale for AHP by comparing each criterion or alternative. According to (Saaty, 1990), the range of the scale is from 1–9 (the level importance) as elucidated in Table 1.
2. Creating the comparison of pair-wise each criterion. For each criterion and alternative, we must make a pairwise comparison, which compares each element with other elements at each level of the hierarchy in pairs so as to obtain the value of the element's importance in the form of qualitative opinions.The evaluation ratio results from the AHP scale are presented in the matrix form. Then, it is normalized to get the eigenvalue.
3. Composing the comparison of the pair-wise matrix which evaluates each alternative and criterion.
4. Assessing the consistency ratio for the comparison of alternatives and criteria. To validate the consistency logic of value, we need to assess the consistency ratio of importance scale. The consistency ratio could be analyzed after determining the Consistency Index (CI) which is a mathematical calculation for each pairwise comparison. This CI expresses consistency deviation. Then a Random Index (RI), as a result of an absolute random response is divided by CI. It results in a consistency ratio (CR). The higher the CR, the lower the consistency, and vice versa. Table 2 shows RI for each number of alternatives or criteria.

The formula of Consistency Index (CI) can be shown as follow.

$$CI=\frac{\lambda_{Maks}-n}{n-1} \qquad (1)$$

Where:

$CI$=Consistency Index

$\lambda_{Maks}$=the biggest eigenvalue

$n$=the number of criteria

AHP measures all consistency assessments using the Consistency Ratio (CR), which is formulated as follows.

$$CR=\frac{CI}{RI} \qquad (2)$$

A comparison matrix is consistent if the CR value is above 10%. The CR value below 10% means the assessment needs to be revised.

5. Creating the priority matrix for the alternatives (solutions) and choosing the best alternative which has the highest weighted.

### METHODOLOGY

The type of data collection was the operator's work posture data in molding cassava chips. We take a photograph of the operator when using the pressing machine in the Karya Lestari Jaya company. Then, we measure the degree of posture by using the APECS mobile application. Further, we processing the work posture data by using the RULA worksheet method to measure body posture (Agustina and Maulana, 2019). In this case, we use the excel template from http://ergo.human.cornell.edu/. Afterward, we interview five operators; two mechanics; and the owner to investigate the recommendation to improve the pressing machine. Some recommendations are analyzed to find the best recommendation by using AHP. The flowchart is shown in the following figure.

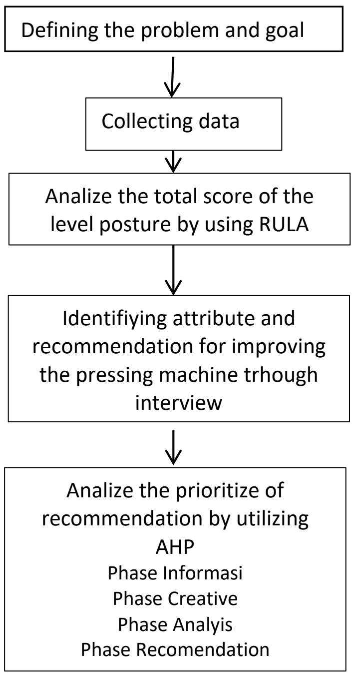


*Figure 4: The research method's flowchart*

*Table 2: Random Index (RI)*

| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0,00 | 0,00 | 0,58 | 0,90 | 1,12 | 1,24 | 1,32 | 1,41 | 1,45 | 1,49 |

## RESULT AND DISCUSSION

In assessing the operator's work posture, we take one of the operators' pictures and analyze it by using APECS mobile application. Then, we evaluate the posture level via the RULA spreadsheet template for excel. The result of RULA showed that the risks at the point of score level which was 6. It means that the immediate change of work posture should be taken. The posture in using a pressing machine can be shown in Figure 5. In addition, the analysis of the ergonomic risk level is depicted in Figure 6 and Figure 7.

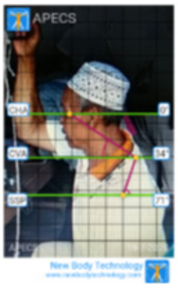


*Figure 5: Head – Neck – Shoulder analysis*

Based on the results of the RULA assessment (Figure 7), the recommendation to improve the pressing machine is analyzed by conducting interviews. The interview was undertaken to five operators (interviewees no. 1 to 5); two mechanics (interviewees no. 6 and 7); and the owner (interviewees 8). This data collection aims to gather the attribute and recommendation of work posture in an operating press machine. The result of the interview can be shown as follow.

Based on Table 3, we can summarize the required at-

*Table 3: Head – Neck – Shoulder Angel*

| Section | Angel |
|---|---|
| Tragus – Canthus line | 0.0 0 B. |
| Craniovertebal angel | 34.0 0 B. |
| Shoulder angel | 71.0 0 F. |

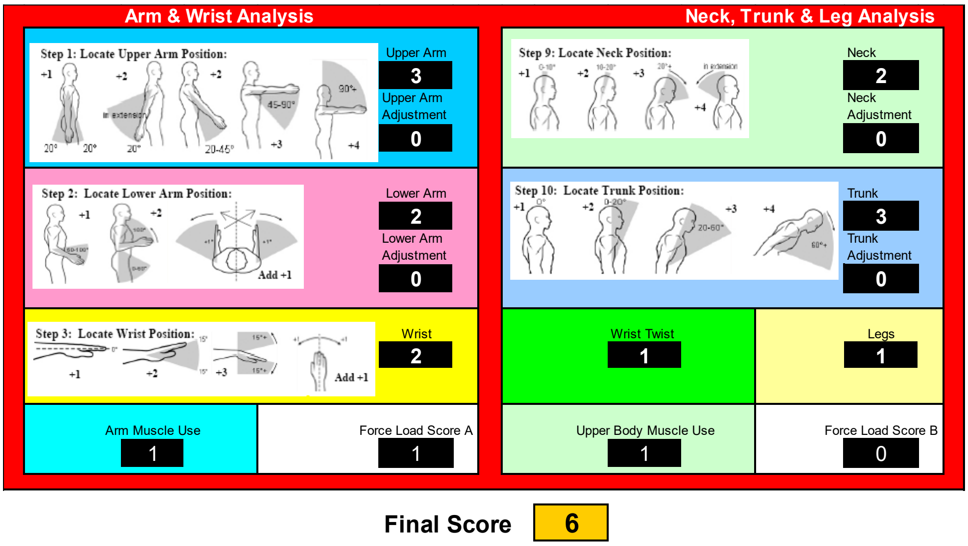


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*Figure 6: The posture and the degree of posture*

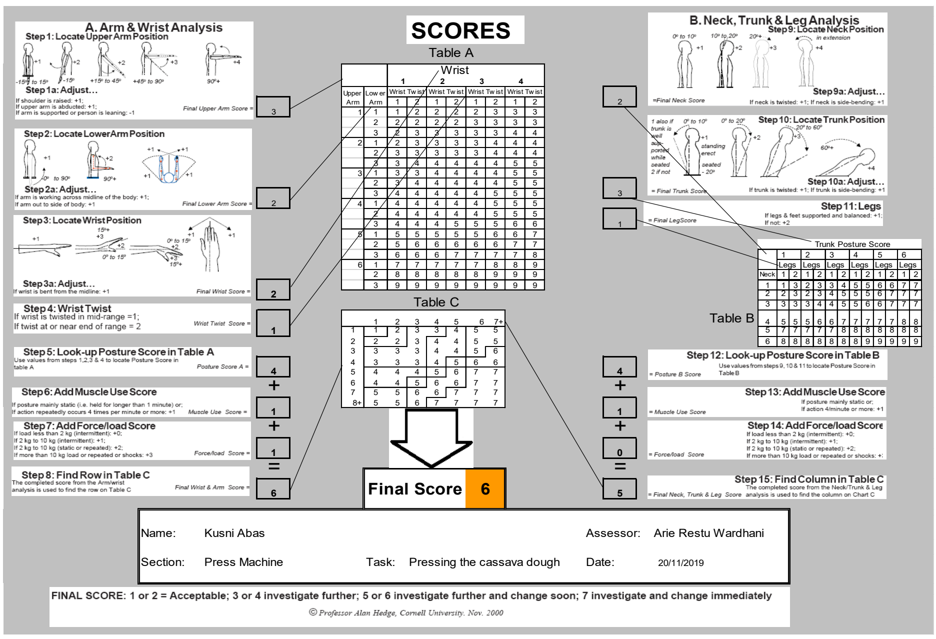


*Figure 7: The calculation of final score of Rula*

*Table 4: The result of the interview*

| No | Interviewee's name | How do you feel in operating press machine? | What are the consequences | Recommendation? |
|---|---|---|---|---|
| 1 | Kusniabas | "It was ok for the first ten minutes. But then, I feel pain right at the upper arm because the lever is too heavy." | "I need to take a rest for about three minutes after pressing. I realize, it can waste the production time." | We need machine improvement, maybe by automating it or adding the other system such as a hydraulic system to support the lever. So, it will a bit lighter than before." |
| 2 | Pujirahayu | " Both the upper and lower arms are stiff." | "I often get some rest." | "Since the lever is too hard to be pulled, it will be better to support a press machine with something to make the machine becoming easy to use." |
| 3 | Putrimalta sari | "I feel ache at the upper arm." | "I could not reach the minimum production which should reach 2 kg each person." | "Maybe the position of the machine which is on the table does not fit with my height. So I need to tiptoe whenever I pull the press machine lever." |
| 4 | Cepto | "I usually work with the plastic chair, so I did not feel exhaustive. But, I still feel the arm's pain." | "I need to bend my body to reach the lever." | "I need the adjustable chair." |
| 5 | Wutekno | "My right arm always feels in pain when I pull the lever." | "I always stopworking after 10 minutes to relax my arm." | "I think the lever of the press machine is too stiff and heavy. We need something to make it lighter." |
| 6 | Sujito | "My upper and lower arm were in pain after a while, then it was ok, after I take a rest." | "The output number and the standard working time could not reach the target." | "We can add hydraulic to support the lever of the press machine. However, it maybe not a better choice because it contains oil. If it leaks, it can affect the dough. " |
| 7 | Tormudi | "I use both hands to pull the lever. Then, my upper arms are aches." | "It can influence time. It can take a long time to make one production cycle" | Hydraulic and pneumatic systems can help the lever to be lighter than before. However, pneumatic maybe better because it utilizes the air support. If it is leaked, it does not affect the dough. In other words, the pneumatic system is more hygienic rather than hydraulic." |
| 8 | Nanda budiartasabela | "I feel exhaustive and in pain, especially at the whole arm." | "The production's number cannot reach the target." | "The pressing machine and working desk require to be improved" |

tribute and the alternative decision. Figure 8 illustrates the hierarchical structure of the AHP model to decide the best recommendation for improving the work system at the pressing machine.

Based on the interview result, we summarize the point of attributes which are the criteria and the point of recommendations as to the alternatives. There are five criteria (Time reduction, output size, hygienic, productivity, and the shape of the lever's handle). Also, there is four recommendation, i.e. adding pneumatic system, adding the hydraulic system, creating an adjustable desk and chair. The AHP analysis is presented as follows. The important

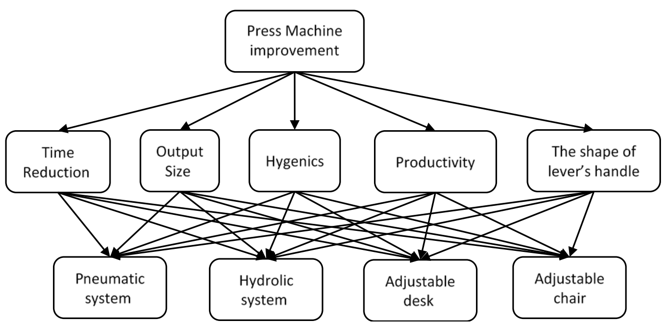


*Figure 8: The hierarchical structure*

*Figure 9: FGD*

scale is filled by FGD (Focus Group discussion) as illustrated in Figure 9.

From the result of the FGD (Focus Group discussion) then made a design for cassava chips mold as desired by the producer, based on Five Phase Work Plan in value engineering (Five Phase Job Plan) as follows:

1. Information phase

Information phase will take as much information and data as possible that needed for redesign the conventional cassava chips mold (as the initial object that will redesign)

After doing calculations to know the priority order of the requirement attribute from the initial design then conclude and sort the requirement attribute to know the ideal conventional cassava chips mold. See table 5.

*Figure 10: The conventional cassava chips mold (initial design)*

*Table 5: Initial Design Requirement Attributes*

| No | Conclusion Requirement Attributes of Initial Design | Δ | Rank |
|---|---|---|---|
| 1 | Time efficiency | 22.88 | 7 |
| 2 | Output quantity | 8.42 | 6 |
| 3 | Construction strength tool | 5.54 | 5 |
| 4 | Hygiens | 0.83 | 4 |
| 5 | Dimension design tool | 0.69 | 3 |
| 6 | Operational tool | -12.23 | 1 |
| 7 | Result measure | -11.06 | 2 |

2. Creative phase

Creative phase is the second phase in value engineering where at this phase can be developed a number of design alternatives based on the ideas obtained.

3. Analysis phase

The alternatives obtained in the creative phase are evaluate and analyze at this phase. The evaluation and analysis process done based on technical and economic factors to determine the advantages and disadvantages of each design alternative in order to obtain the chosen design alternative. From the matrix calculation can be seen in table 6

4. Development phase

After evaluate with the evaluation matrix and produce the best tool design alternative, will continue with the development phase.In this phase the best design alternative will be developed and implemented. Then presented the best alternative development record that contain the materials used and other details, design and value calculations and the best alternative designs discussion.

5. Recommendation phase

After evaluate with the evaluation matrix and produce the best tool design alternative, will continue with the development phase.In this phase the best design alternative will be developed and implemented. Then presented the best alternative development record that contain the materials used and other details, design and value calculations and the best alternative designs discussion.

The best design alternative, B as the selected alternative which has the following criteria:

1. The pressing plate of cassava chips mold is a thick plain plate form, and the pressing type uses the peneumatic type / model
2. The mechanism of cassava chips mold use a pneumatic press makes it very easy for operators to print and produce cassava chips on a large scale in a shorter time and more efficiently. Usage of this cas-

*Table 6: Evaluation Matrix*

| Alternatif | Attributes | | | | | | | Total | Rank |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | |
| Weight | 31.2 | 10.4 | 6.65 | 5.81 | 2.97 | 15.67 | 27.33 | | |
| A | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 | 0.3 | 0.2 | 22.774 | 3 |
| | 6.24 | 2.08 | 1.995 | 1,743 | 0.594 | 4.701 | 5.466 | | |
| B | 0.3 | 0.3 | 0.3 | 0.2 | 0.4 | 0.2 | 0.3 | 28.158 | 1 |
| | 9.36 | 3.12 | 1.995 | 1.162 | 1.188 | 3.134 | 8.199 | | |
| C | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 0.2 | 0 | 16.458 | 4 |
| | 6.24 | 3.12 | 1.33 | 1.743 | 0.891 | 3.134 | 0 | | |
| D | 0.3 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.3 | 23.995 | 2 |
| | 9.36 | 2.08 | 1.33 | 1.162 | 0.297 | 1.567 | 8.199 | | |
| E | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.2 | 11.333 | 5 |

*Figure 11: The selected tool design*

sava chips mold tool is enough to put the cassava chips dough into an aluminum pan and put it in the emphasis space, then the operator press the power button which will automatically fill compressor by air with a pressure capacity of up to 1 bar. When the air in the compressor has reached the desired pressure, then the pneumatic piston that connect to the pressure plate will move towards the base plate of the press which has been filled with cassava chips dough until it is flat according to the desired thickness.

## CONCLUSION

This study aims to know the work posture when use a press machine. Besides that, this study aims to find the best recommendations with use AHP. And from the results of the AHP evaluation produce the best recommendations that is the addition of a pneumatic system to the pressing machine which can lighten the lever. The data cannot be generalize because it is specifically for Karya Lestari Jaya company. In the future, it is need to explore whether the results can be applied in other companies or not. Besides that, we also need to test the other alternatives, such as training on how to properly use a press machine.

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