Ergonomics Redesign of the Effective Chopping Tool for Harvesting the Eucalyptus Plant

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Abstract. Eucalyptus plant is a plant producing an essential oil. It is beneficial oil for fabricating the cosmetic and aroma therapy. In consequence, a quality of the oil is very substantial to ensure the quality of product. One of factor affecting it is the degree of purity of the oil. In the interest of producing the high purity, a good harvesting technique should be considered particularly with a design of the chopping tool. Preliminary study was found that the quality and number of the oil are still not able to reach the target by using the existing tool. Thus this is significant to improve the tool which is more effective and safer. The purpose of this study is to redesign the ergonomic and innovative chopping tool. TRIZ used to determine the inventive principles for producing the specific solutions or design on basis a contradiction between improving and worsening features. Fuzzy linguistic concept is implemented to specify the design attribute that is vague. Result of this study finds four specifications of a purposed design. They are sharp with specifications thickness of the tool at the tip is 0.2 cm and the base is 0.37 cm, then strong with specifications the gilding is done for 2.63 minutes with 1216ºC temperature, and for durable is the use of “Per” Steel as the material, and for comfortability is the size of the handle that corresponds to the dimensions of the human hand namely the diameter of the handle is 3.25 cm, the length of the handle is 12 cm, the width of each contour of the fingers is 2 cm using silicon rubber material. Signed-rank test results in that the proposed design is valid specifically it is more comfortable, more powerful, sharper, and more durable by using the existing design.

Keywords: Manual harvesting tool, Eucalyptus, TRIZ, Fuzzy Linguistic

1. INTRODUCTION

The eucalyptus plant (Melaluca leucadendron Linn.) is one of the plants that produces essential oils that are widely used and needed by the industry in Indonesia for manufacturing cosmetics and aromatherapy. This oil has a large opportunity to be developed as the high economic value of product by cultivating eucalyptus the plants [1]. According to [2], production capacity of eucalyptus leaf in Java is as much as 53.760 tons per year for producing 300 tons of the essential oil with a total land area of 24.255,56 ha [3]. There is company in East Java that has eucalyptus plantation land that uses “rimbas” method to harvest eucalyptus leaf and eucalyptus oil processing plant, having land area as big as 8.121 ha. In this area, harvesting process of eucalyptus leaves uses the “rimbas” method there are time and cost efficient. By this method eucalyptus plants grow until the stem reaches the age of 9 months, then the stems are cut to as high as 110 cm and new branches are harvested by the workers. This company currently has several problems related to the amount of eucalyptus leaf production and the purity degree of eucalyptus oil, which have not reached the target. Factors that are considered the most influential is chopping tools factor, because of this background, preliminary study is conducted using Nordic body maps questionnaire, collected data in Figure 1 as follows
In Figure 1, it is the result from 20 of the 30 workers who complained related to the use of existing chopping tools, with very sick levels in some parts of the body. One of the causes of high complaints of pain in the body parts of workers is caused by harvesting equipment that is currently used is not in accordance with the contour of the woody plant and is not comfortable to use. As many as 25 out of a total of 30 workers, want a change in chopping tool that is more comfortable to use and in accordance with the contours of eucalyptus plants.

With a background in the amount of production and yield that have not met the target with the main causes of workers' complaints about the tools used and workers who want chopping tools that are in accordance with the contour of eucalyptus plants, there is a need for innovations related to manual harvesting devices that can replace the sickle, to improve the quality of eucalyptus oil by using the TRIZ method. TRIZ is discovered by G.Altshuller from Russia through the study of the principle sources used to obtain ideas derived from patents contained in the TRIZ method [4]. In this study, the TRIZ Method is used as it provides a solution from the root cause of the problem objectively and responds to consumer desires from repairing manual chopping tools.

2. METHOD

2.1 Survey
A survey by interviewing the field supervisor, and field workers finds out the root of problems related to the use of existing harvesting equipment using the function analysis, and cause and effect chain analysis of TRIZ.

Further survey will be done by distributing consumer attribute questionnaires to the proposed manual chopping tools, that delivered to 30 workers in the field, and then the second questionnaire will contains weighting for each consumer attributes. After that the result will tested for validity and reliability.

2.2 Theory of Inventive Problem Solving (TRIZ)
TRIZ tools are employed as a knowledge-based and function-centered support for generating innovative product ideas [5]. In this study, TRIZ will be used in the process of finding root causes and resolving the contradictions that appear using the 40 inventive principles and 76 standard principles. Three TRIZ models general problems are physical contradiction, engineering contradiction, and the susceptibility of the field model. Selected inventive principles are chosen that can be most applied to solve problems, and determine the actions.
2.3 Fuzzy Linguistic
Fuzzy set theory is a method used to overcome uncertainty. Fuzzy logic provides a tool that is able to capture blurred information, generally explained in natural language, and convert it to a numeric format in the membership function. Linguistic variables are variables whose values are words or sentences in a natural or artificial language. In other words, they are variables with linguistic expression as their values [7]. Fuzzy linguistic mamdani will be used to determine the specifications of attributes that are still vague, ie sharp and strong. By using the steps as follows [8]:
1. Define variables that are vague or not specific and linguistic terms based on experts.
2. Build membership functions for each variable.
3. Make a rule base that will be used.
4. Convert input data into fuzzy using the fuzzification process into Matlab software.
5. Evaluate rules on membership functions.
6. Combine the results and each membership function, and get a specific value for each attribute that is still vague.

3. RESULT AND DISCUSSION
3.1 Collecting Consumer Attribute
After distributing questionnaires to the attributes of consumer desires on 30 workers, six attributes were tested for validity which was conducted to determine the level of accuracy of the instruments used in the study [9]. And reliability tests were used to see the stability and constancy of measuring instruments used in a study [10], the most consistent value is shown by the reliability value $\alpha \geq 0.8$ [11]. Obtained the valid and reliable attributes in table 1 as follows:

| No. | Attribute |
|-----|-----------|
| 1.  | Strong    |
| 2.  | Sharp     |
| 3.  | Comfortable |
| 4.  | Durable   |

3.2 Determine Product Specification Using TRIZ
Specific problems obtained from expert interviews are supervisor and workers in which the workers do not comfortable when using existing chopping tool. TRIZ general problem steps will use function analysis and cause and effect chain analysis tools to identify the potential root cause from the specific
problem. The two tools can be seen in Figure 3. And Figure 4. There will be a potential root cause that will be combined between potential root cause and consumer attribute. The next step is to enter into the TRIZ problem modeling seen in table 2, which contains the distribution of potential root causes based on the TRIZ problem model, before the completion of the TRIZ general solution.

![Diagram](Figure 3. Function Analysis)

![Diagram](Figure 4. Cause and Effect Chain Analysis)

| No. | Attribute    | Root of the Problem                                                                 | Identification   | Model of Problem        |
|-----|--------------|------------------------------------------------------------------------------------|------------------|-------------------------|
| 1.  | Strong & sharp | The blade used on the chopping tools is not sharp and strong                       | Inventive problem| Engineering Contradiction|
| 2.  | Comfortable  | Handle was slippery when exposed to sweat                                           | Inventive problem| Substance Field Model    |
Large Handle size

The blade that are not durable and easily damaged

Inventive problem

After knowing several options from TRIZ specific solutions given in table 40 inventive principles, the next step is to determine the inventive principles that can be applied to solve problems according to model of problem, which is physical contradiction, engineering contradiction, and substance field model. Thus, the following table 3 the action taken in this study will be presented for each potential root cause and consumer attribute.

| No. | Attribute | Root of the Problem | Identification | Model of Problem |
|-----|-----------|---------------------|----------------|------------------|
| 3.  | Durable   |                     |                |                  |

After knowing several options from TRIZ specific solutions given in table 40 inventive principles, the next step is to determine the inventive principles that can be applied to solve problems according to model of problem, which is physical contradiction, engineering contradiction, and substance field model. Thus, the following table 3 the action taken in this study will be presented for each potential root cause and consumer attribute.

| Attribute                | Inventive Principles       | Action                                                                 |
|--------------------------|---------------------------|------------------------------------------------------------------------|
| Sharp & Strong           | Principle 10              | change the gilding technique and thickness of the sickle eye so that it has a better level of sharpness and strength than before and the contour of the sickle eye that adapts to the branches of eucalyptus plants. |
| Comfortable (1) Slippery Handle | Principle 1.2.2 Increase Su – Field Effectiveness | Add silicon rubber to the sickle handle. By changing the physical state of the size of the sickle handle according to hand anthropometry, the use of the dimension of the width of the index finger (WIF), maximum grip (DGMAX), and the width of the palm to the thumb (WPT) so that it matches the size of the hand grip of the worker. |
| Comfortable (2) Handle Size | Principle 35 Parameter Changes | Change the metal components of the blade with better quality, namely “per” steel |

3.3 *Determine Fuzzy Attributes*

When determining the fuzzy attribute, an interview was conducted with an expert, namely a blacksmith related to the attributes of consumer desires that still have detailed specifications for the prototype making process [12]. The membership function process and rule making are based on the results of interviews with 2 steel experts. The study fuzzy mamdani will be used with fuzzy triangular number, linguistic variables are variables in which the value is in the form of words or sentences in nature or artificial. developing basic concepts and fuzzy integral theorems Fuzzy numbers are valuable in fuzzy sets. There are two fuzzy attributes that are strong and sharp with sharp and strong specifications as shown in Table 4, as follows:
Table 4. Fuzzy Attribute Identification

| No. | Attribute | Specific Attribute | Action | Description |
|-----|-----------|--------------------|--------|-------------|
| 1.  | Strong    | Blade Thickness    | Thick  | Fuzzy       |
| 2.  | Sharp     | Gilding technique  | Fair   | Fuzzy       |
| 3.  | Comfortable | Handle size and component | Size according to hand anthropometry and using silicon | Non-fuzzy |
| 4.  | Durable   | Blade component    | Using “per” steel as blade material | Non-fuzzy |

Strong attributes are determined by blade thickness, based on interviews with experts, the thickness of the blade will be divided into two parts, which are at the base and tip of the blade. After the membership function process, and the assessment rule by using Matlab R2013a software generate the optimum value for blade thickness is as follows:

Figure 5. Strong Attribute Membership Function

Table 5. Optimum Value for Strong Attribute

| Element     | Optimum Value (cm) | Selected Design (cm) |
|-------------|--------------------|----------------------|
| Blade’s base| 0,372              | 0,37                 |
| Blade’s tip | 0,259              | 0,2                  |

And for sharp attributes, it is influenced by the blade’s gilding technique, namely the time and temperature of sickle eye plating. With the optimum value as follows:

Figure 6. Sharp Attribute Membership Function
Table 6. Optimum Value for Sharp Attribute

| Element     | Optimum Value | Selected Design |
|-------------|---------------|-----------------|
| Time        | 2.63          | 2.63 minute     |
| Temperature | 1216          | 1216 ºC         |

3.4 Comfortable Attribute Specification
In the comfortable attributes, the executed action is to make a handle in accordance with the anthropometry of the human hand and use materials that can reduce the strength of the hand grip of the hand when the sweaty hands. The handle size will be modified using the three dimensions of the body and its application, as follows

Table 7. Handle Dimension

| Dimension / Percentile | Application | Size  | Allowance | Design Size |
|------------------------|-------------|-------|-----------|-------------|
| The width of the index finger | Finger Contour | 2.00 cm | -         | 2 cm        |
| The width of the palm until the thumb | Handle length | 11.13 cm | 1 cm     | 12.13 cm   |
| Maximum Grip Diameter | Handle Diameter | 2.95 cm | 0.3 cm    | 3.25 cm    |

In the handle length and maximum handle diameter, the workers will use the dimensions of the body width of the index finger and the width of the palm to the thumb [13]. While the use of allowances according to [14] large allowance for the length of the andle is 1-1.25 cm and the handle diameter is 0.1-1 cm. The prototyping process will be carried out using solidwork software to make prototypes in 3D and a real prototype will be made and will be used for the validity and signed-rank testing process.

Figure 7. 3D Mock-Up

3.5 Validating The Product
Validation test will be carried out using a marginal homogeneity test which is a test of two related samples to determine whether there are differences in responses between two interconnected groups of data [15] and Wilcoxon signed-rank will be conducted to find out whether the design is in accordance with the wishes of consumers and there are differences that are felt by workers when using old tools and proposals. This testing process will be carried out on 22 people harvesting the eucalyptus leaves results.
showing that the proposed chopping tool has greatly fulfilled the consumer's desire with indigo sig. 2 tailed in 4 attribute have value of ≥ 0.05 and in the signed-rank test it is known that there is a difference felt by workers when using the proposed chopping tool as evidenced by the sig.2 tailed value ≤ 0.05.

4. CONCLUSION

Based on the results of the processing and discussion carried out, it can be concluded as follows:

The study using TRIZ method to identify the potential root cause of the main problem of workers who feel uncomfortable when using the existing chopping tool. After determining the potential root cause, the completion of potential root cause is conducted using 40 inventive principles and the principles that is applied most to solve problems from the four attributes are strong, sharp, comfortable, and durable. In the comfortable attribute, a handle will be made that matches the dimensions of the human body, for the contour of the finger on the handle 2 cm wide, the handle length 1 cm, and the diameter of handle 3.25 cm. Lastly, the durable attribute will be indicated by a blade material that is "per" steel.

In strong and sharp attributes that still do not have specifications for the proposed chopping tool, it is identified using fuzzy linguistic, with the results on the strong attribute indicated by the blade thickness at the tip of 0.2 cm and at the base of 0.37 cm. As well as the sharp attributes indicated by the gilding technique which is 2.63 minutes with a temperature of 1216ºC. Validation and signed-rank tests performed indicate that the proposal design has fulfilled the consumer's desires and there is a difference felt by consumers when using existing tools and proposals.

The recommendation for this study is the possibility of using different methods to further review the statistical aspects. In addition, automatic harvesting or machine-powered tools can also be developed so that worker fatigue can be minimized.

Acknowledgement

This study was supported by Directorate of Student Development, also Industrial Engineering Department, Faculty of Industrial Technology, Universitas Islam Indonesia.

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