The Ergonomic Shooting Net Design for Pond Farmers

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Abstract. The application of ergonomics principle that all working activities can caused workers physical and mental stress. Ergonomics strive for this pressure is still within tolerable limits, satisfactory performance results, and the health and welfare of workers can be increased. If this excessive loads occurred, it will increase some errors and injury. This study aims to making the systematic design for conceptual design of a innovation product using Pahl & Beitz methods. The Variables in this research are hand length (HL), Grip diameter (GD), and length of index finger (LIF) along designing and making nets in accordance with the Anthropometry data. The results of the study recommend nets specification corresponding to the farmers. The length of the shooting net is between 75 cm to 64 cm (0.75 to 0.64 meters), The diameter of the PVC (pipe) is 7.5 cm (0.075 meters), The length of the shooting nets handle is between 5 cm (0.05 meters), The weight of product is 5.5 kg, The nets diameter size is 2.5 m, and The filling pressure of the wind at the automatic firing line is with a maximum limit of 80 psi (5.51 bar) and a minimum of 30 psi (2,068 bars). Its use is also very easy and practical because it is enough to fill the wind, then pressing the first lever that is already there to throw or fire the net and to pull it electrically just by pressing the second lever on this automatic firing net. For users, it is also very convenient because there is no need to carry and throw conventionally, because this mesh has been prepared a buffer that serves to support the mesh automatically. So, this automatic shooting net can reduce the burden, hand and hip injuries for its users.

Keywords: Systematic design, Anthropometry, Shooting nets, Pond farmers.

1. Introduction

The fisheries sector is one type of work that has a high risk for workers. They need not only the strength but also an optimum body condition. Their balance are very important since it have a direct impact on their health and performance. Fishing activity requires repetitive movement, thus the fishermen have potential to experience muscle fatigue. Ergonomic working behaviour will directly lead to fatigue and skeletal muscle system disorder, while require greater energy to perform repetitive activity [1]. Number of houses agriculture business ladder Fisheries Subsector Fishing activities as much as 0.86 million households, Fish Cultivation activities as many as 1.19 million households [2].

Indonesian Fisherman are still working in traditional way, that mostly relied on physical strength rather than using modern tools such as fishing technology. Most of Indonesian fisherman will choosing traditional way because its cost less. But they have to over work their muscles and perform continuous and repetitive movements in their activity. Such as net preparation, net stocking, throwing net in the pond, and then pulling net from pond using rope, net removing, stocking fish, and back from the beginning again, thus they can experience muscle fatigue. Exertion of excessive force while dragging net, repetitive hand and body movement in running pumps, might cause the MSD and associated disorders [3] The largest mesh size in the market is up to 150 mm. However, 130 mm can be applied for
coastal fisheries. All nets were the same number of meshes long resulting in net length proportional to mesh size. This gave a better representation of the larger fish, which were known to be less abundant [4].

Agricultural ergonomic problems like farming is acknowledged to be a high risk task including several kinds of occupational injuries, especially Musculoskeletal disorder (MSDs) [5]. Musculoskeletal disorder (MSDs) is the condition where the muscles suffered continuous load from repetitive activities for long period of time that accumulate muscle damage for joints, tendons and ligaments. This problem occurs as a result of unnatural working postures that influenced by unbalance ratio between the number of task demands, work tools, work stations and worker capabilities [1]. They are various work that related musculoskeletal disorder such as low job clarity, intensified workload, limited job control, and repetitive work [6]. Monotonous work at Farm work, can caused sprains and strains, quarter are back injuries and disability [7]. Work-related musculoskeletal disorders are so common among farm workers that many perceive them as no more than normal [8].

From the preliminary field study, fisherman often giving muscle work in their movement. For example when they throwing net in such a long distance, sometimes they just standing and let their arms reach the distance. And the way they lift up the net are also the same, like they have no concern about false movement that can be fatal injuries. Hard physical work, insufficient working methods and tools can cause non-essential fatigue and accidents but also leads to low productivity [9]. Slippages of tool from hand because of sweat on handle, faulty handle diameter and length of handle, faulty texture and material of handle, bad clearance for hand in handles and mismatch of anthropometric dimension and tool handles [10]. Based on that problems, design of systematic and conceptual work tools was carried out in the fisheries sector, especially in the area of aquaculture that can reduce the unnecessary and repetitive movement, and other activities which cause pain and musculoskeletal disorder. In this study, the priority is the ergonomic factor of the tool so that it can minimize the occurrence of hand and hip pain of the pond farmers.

The subjective aspects of product development process are mostly associated to human qualities such as the wills and expectations. The subjectivity is inevitable since people manage every decision thus it will affect the whole process [11]. Dealing the subjective aspects is important to attempt the transposition of information rather than information interpretation. It able to guaranty the product qualities for users [12]. On the other hand, macro-classification of information is able to organize the desired qualities such as technical, ergonomic and aesthetic attributes [13]. In order to improve the performance and safety aspect for farmers, it is necessary to adjust the machine design with anthropometry of the farmers [14] and [15].

Kalanganyar village is one of the villages in the Sedati sub-district located in Sidoarjo regency, East Java province with the majority of its livelihoods being fishermen and pond farmers. Pond farmers in this village are still use conventional (traditional) methods to work on their ponds, such as trapping fish with a throwing net that weighs ± 4 kg with a diameter of 4 meters that is carried out by one fisherman.

2. Methods

A systematic approach to design has been developed and proposed by Pahl and Beitz, The way to design the Pahl and Beitz consists of 4 activities or phases, each of which consists of several steps. The four phases are; Start off with product planning and the task clarification such as drafting a product proposal, and collecting a requirement list. Then the second is the conceptual design phase which involves preliminary form design, material selection, technical evaluation and economic criteria. The third phase is embodiment design in which errors checking, disturbing influences, and minimizing the costs are become the main concern. The last phase is carry out the detailed design such as production completion, assembling, transporting and operating the instructions [16] and [17].

Ergonomic consideration are required to produce a great balance between machines and tasks. It assures the safety and comfort to leverage productivity [18]. Anthropometry is a branch of Ergonomics that focus on the measurement and description of human body dimension. It affect in tools design that influence the performance improvement and efficiency, while still able to assure the safety and comfort.
It also prevent work related injuries or accident [19]. Two primary fitting methods are used such as selecting two percentile points to cut out ranges from the whole data set and using just one cut off percentile [20].

This study aims to design and create an ergonomic shooting net using Pahl & Beitz method. The object of the study was carried out by collecting anthropometric data as many as 32 selected samples, along with designing and making nets in accordance with the data. Located at the fisheries village, the Kalanganyar village, Sedati district, Sidoarjo regency. The time of this research was conducted in February 2018 until the study was completed. In this study there are two kinds of variables, the dependent variable of this study measures the length of the hand to reach the net, measured from the position of the fingertip to the arm, measuring the diameter of the hand grip, and measuring the length of the index finger for the automatic button, measured from the tip of the index finger to the hand, while the independent variable is to design and create an ergonomic automatic firing line and implementation stage.

3. Results

3.1. Anthropometry Measurement

The dimension of the automatic shooting nets was taken from the user's anthropometry data, namely the body dimensions of farmers in the Kalanganyar village with a minimum height is 150 cm and 20 years old as a minimum respondent age. Based on data sampling of 32 farmers using the Bernoulli equation with control chart, the anthropometry data for hand length (HL), grip diameter (GD) and length of index finger (LIF) dimension can be seen in Table 1. It shows that all the data of hand length measurement, hand grip dimension measurement, and length of the index finger for the pulling range of the button on the automatic firing line are uniform.

| Body Dimension         | UCL  | LCL  | $\sum X$ | $\overline{X}$ | Data Min. | Data Max. |
|------------------------|------|------|----------|---------------|-----------|-----------|
| Hand Length (HL)       | 75.97| 62.85| 2.221    | 69.41         | 66        | 73        |
| Grip Dimension (GD)    | 11.97| 6.85 | 301      | 9.41          | 8         | 11        |
| Length of Index Finger (LIF) | 8.35 | 5.95 | 229      | 7.15          | 6         | 8         |

*Measurement are in cm
b UCL = Upper Centre Limit, LCL = Lower Centre Limit

For the data adequacy test, the accuracy level is 5% and the feasibility level is 95%, the data adequacy test equation is using the formula:

$$N' = \left(\frac{k}{s\sqrt{N}} \sum x^2 - (\sum x)^2}{\sum x}\right)^2$$

(1)

The value of $k = 2$ and the value of $s = 0.05$

If, $N' \leq N$ then the data is sufficient to do the design

If, $N' < N$, then the data is insufficient to do the design.

The test is used to analyze the number of measurements to prove that the sample data can represent the population. From the formula, the results can be seen in Table 2.
Table 2. Adequacy Test

| Body Dimension                  | \( \sum x \) | \( \sum x^2 \) | \( N' \) |  
|---------------------------------|--------------|----------------|-------|---|
| Hand Length (HL)                | 2.221        | 154.253        | 27.64 | N' \( \leq N \), Sufficient |
| Grip Dimension (GD)             | 301          | 2871           | 22.37 | N' \( \leq N \), Sufficient |
| Length of Index Finger (LIF)    | 229          | 1657.5         | 18.23 | N' \( \leq N \), Sufficient |

Table 3. Percentile of farmer’s anthropometry data

| Body Dimension                  | \( \bar{X} \) | SD  | 95\(^{th}\) pct | 5\(^{th}\) pct |
|---------------------------------|---------------|-----|----------------|---------------|
| Hand Length (HL)                | 69.41         | 3.28| 74.80 \( \approx \) 75 | 64.02 \( \approx \) 64 |
| Grip Dimension (GD)             | 9.41          | 1.28| -              | 7.31 \( \approx \) 7 |
| Length of Index Finger (LIF)    | 7.15          | 0.60| 8.13 \( \approx \) 8 | 6.16 \( \approx \) 6 |

\(^a\) Measurement are in cm  
\(^b\) SD = Standard Deviation

Determining the percentile based on the data of the farmer body dimensions that have been obtained can be determined by the size of the product by adjusting the percentile. The length of the automatic firing line is used for the length of the hand length with 95\(^{th}\) percentile value, which is the largest percentile of the farmers population measured with intention to use this automatic shooting net comfortably, and also used the 5th percentile value, which is the smallest percentile of the farmer’s population measured with intention to comfortably use this automatic shooting net. As the results from the table 3, the length of automatic shooting range suggested between 75 cm to 64 cm, the diameter size in PVC (pipe) automatic shooting net is 7.5 cm, and the shoot length of the automatic mesh for firing suggested between 8 cm to 6 cm.

3.2. Designing product

Based on comfort, traditional nets that are still thrown according to one of the respondents said that the comfort side is still very lacking because at the time of inappropriate throwing can result in muscle and bone injuries, especially in the hand and spine muscles and frequent deterioration of the rope nets at the time of throwing and that made the farm farmers take it in the pond and that was very influential on the work of the pond farmers.

Whereas the shooting net whose use has been ergonomic according to the respondents said that the comfort side was comfortable because of the easier and faster way of using it than traditional net and when the net was fired there was no deterioration of the rope or falling into the pool, therefore reducing the occurrence of injured the hand muscles and backbone of the farmer while doing his work. Besides that, its use is also very easy and practical because it is enough to fill the wind, then pressing the first lever that is already there to throw or fire the net and to pull it electrically just by pressing the second lever on this automatic firing net.

According to Pahl & Beitz Method, First step is prepare all materials and tools that have been explained at the design stage of the project above, after that, do the cutting phase of PVC (pipe) to make this automatic shooting frame, check and mark all prepared materials and tools that aim to simplify and facilitate the assembly process, the assembly process can be started after checking and marking all the materials and tools that have been prepared to become automatic shooting nets. Based on the results of the calculation of the size of the automatic shooting net according to the body dimension data above, are the length of the shooting net is between 75 cm to 64 cm, the diameter of the PVC (pipe) is 7.5 cm, the length of the shooting nets handle is between 5 cm (0.05 meters), the weight of product is 5.5 kg, and the nets diameter size is 2.5 m, the filling pressure of the wind at the automatic firing line is with a maximum limit of 80 psi (5.51 bar) and a minimum of 30 psi (2.068 bars).
So, the final product design that we can see in Figure 1, it is also very convenient because there is no need to carry and throw conventionally, because the net has been prepared a buffer that serves to support the mesh automatically.

![Diagram of Shooting nets](image)

**Figure 1.** Final design of Shooting nets

**Conclusion**

Based on its superiority, this automatic shooting net has been ergonomic because for its manufacture it has been calculated with user anthropometric data from the dimensions of the hand length (HL) which aims to reach the reach of the tool when using, then the dimensions of the hand (GD) which aims to hold and hold the tool and the length of the index finger (LIF) which aims to press the button on the tool.

Besides that, its use is also very easy and practical because it is enough to fill the wind, then pressing the first lever that is already there to throw or fire the net and to pull it electrically just by pressing the second lever on this automatic firing net. For users, it is also very convenient because there is no need to carry and throw conventionally, because this mesh has been prepared a buffer that serves to support the mesh automatically. So, this automatic shooting net can reduce the burden, hand and hip injuries for its users.

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