Product Design Development of Ergonomic Mop: ANOMALI (An Ergonomic Mop for Healthy Life)

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Abstract

Increasing demand for housing causes higher demand for household equipment. To keep the house clean, tools that can help clean the house are needed. Based on the results of the questionnaire on 55 respondents in which the respondents were household cleaners, it can be seen that the product that needs to be redesigned is mop. ANOMALI (An Ergonomic Mop for Healthy Life) is a mop that can be squeezed by pulling, using the back-rolling principle so that the user does not need to bend the body and turn the wrist to squeeze the mop. In addition, you can remove soap only by pressing a button, using the Bernoulli principle so that it does not need electricity. Mops can be removed so they are easy to wash. Made with a good working mechanism, making the mop lighter, aesthetically and still comfortable to use. ANOMALI materials are made of plastic and stainless steel. For plastic, Polystyrene (PS) will be used which has strong, hard, and high resistance. Stainless steel is chosen because it is not easily bent, light and anti-rust. It is estimated that the maximum cost for one ANOMALI production is Rp. 233,000. ANOMALY is made using ergonomic methods such as the principles of hand tools design and anthropometric measurements, and also uses the Kano model as a method to identify customer needs.

Keywords
Anthropometry, Ergonomic, Kano, Mop, Redesign

1. Introduction

House is a place to rest, do activities and gather with family. Over time, the increase in the number of people led to the increasing need for homes. The General Ministry of PUPR said through Jurnal Asia writed by Anonim (2016) said that housing needs in Indonesia until 2025 are estimated to reach more than 30 million units, so that the needs of new homes are estimated to reach 1.2 million units per year.

The increasing number of houses built, leading to increased demand for household needs. To keep the house clean and healthy, tools are needed to clean the house. Based on the results of the questionnaire to 55 respondents, the most needed cleaning equipment for redesign is a mop. The current mop design makes people who using it has a potential to cause injury and fatigue. Poor work posture is indicated when the hand pressing the fabric of mop requires the user's body to bend and rotate his wrist firmly. It will certainly interfere health and safety especially in the lower back and wrist. Unusual work posture for a long time can cause discomfort and pain in one of the limbs (Mufti et al., 2013). Current condition of users while mopping the floor can be seen in Figure 1.

Figure 1. The condition of users while mopping the floor currently

Moreover, respondents also complained that it would be difficult to manually spray liquid soap while mopping because it wasted a lot of time to take a soap bottle, spray it, and then retain the soap bottle that was carried out during the mopping process. It causes the work of mopping become inefficient because it is wasting time and energy.

Among the respondents who were given questionnaires, 3 of them stated that they already had a mop that was able to squeeze without using hand. However, respondents complained that the load of the mop was very heavy due to the squeezer mechanism was poor so that it made the work of mopping the floor very tiring and they preferred to use manually squeezed mops because it was lighter.

By Looking at the existing problems in the design of the mop, it is necessary to improve the design of the product. The design and development of a product is an activity that is very important to do, because it is closely related to the functional aspects that consumers want the product (Roefiq, 2012). The research results are in the form of innovative and ergonomic mop product design proposals called ANOMALI (An Ergonomic Mop for Healty Life). ANOMALI is designed by using the principles of anthropometry and hand tools design to prevent potential injury and excessive fatigue. In conducting development of product, Researchers also use a method in designing product that able to integrate voice of customer into product design process to match consumer need and desire. Therefore, researchers use Kano method to identify customer needs appropriately. Kano method is a model that aims to categorize the attributes of products and services based on how well the product or service is acceptable and its influence in satisfying customer needs (Kano et al., 1984). This method can produce product specifications in accordance with the desired consumer by involving the current design.

2. Methods

2.1 Basic of Product Selection

To find out the tools that most need improvement in design, a questionnaire was conducted on 55 respondents, all of them were household workers who cleaned the house everyday. In the questionnaire given a choice regarding the items that need to be redesigned and what is the reason. The results of the questionnaire showed that 39 respondents chose mop (71%), the rest chose other products such as brooms, brushes, duster and sponges. Based on the most choices, researchers chose to redesign the mop.

The reasons of respondents chose a mop product to be redesigned because among them complaints of squeezing the mop that had to bend over the back and then twisting both wrists by pressing it firmly so that it often caused pain in the lower body and wrist. In addition, high frequency of taking liquid soap and then storing it again during mopping makes the work inefficient.

At this time, there is no mop that can spray liquid soap by just pressing button in the mop, however there is only mop that can be squeezed without using hands, but still has a bad mechanism proven by excessive weight so that the customer gets tired quickly, even based on the results of the questionnaire respondents prefer to use manually squeezed mop because it is lighter. It makes researchers want to redesign a mop product that can be squeezed without using hands with a good mechanism so that it is light and can increase efficiency.

2.2 Product Planning and Identifying Customer Needs

In fulfilling the conformity of products to be made with the customer needs, then done first identification of the needs and desires of consumers. This identification process is done by Kano method. Kano method is useful for determining customer satisfaction by determining attributes in the design and development of a mop design so that researchers can design mops appropriately. The method or technique used in data collection uses a questionnaire through several stages as follows.

- Phase 1 Questionnaire

To find out and identify customer requirements for the product that will be made, the initial questionnaire was distributed to 45 people who were the users of mop with different types of job, with a percentage of 20-30 years is 22.3%, 31-45 years is 44, 4%, and 46-60 years is 33.3%. The selected attribute becomes a modus and eliminates the percentage of consumers who are less than 50%.

- Adequacy Test

The attribute sample in this case is the population of mop users in the Yogyakarta area. In determining the number of samples used calculations with the Bernouli formula with a minimum sample size to test the adequacy of questionnaire data. The formula in Bernouli's calculation is as follows.

$$N \geq \frac{(Z_{\propto/2})^2 .p.q}{e^2} \tag{1}$$

Information:
N = Minimum sample number, Z = Normal distribution value, α = significant level,
p = The proportion of the number of questionnaires answered correctly, q = 1- p = the proportion of the number of questionnaires answered incorrectly, e = Tolerance error

This stage is the determination of the minimum sample number of the questionnaire with α = 0.05 which will be used in the next stage. From the first-phase questionnaires distributed there were two questionnaires that were not filled correctly, so there were 43 questionnaires that were considered correct and could be processed in the next stage.

$$N = \frac{(Z_{\propto/2})^2.(43/45).(2/45)}{0.05^2} = \frac{(1{,}96)^2.(0{,}95).(0{,}04)}{0{,}0025} \approx 60 \tag{2}$$

So, the minimum number of samples taken in this research is 60.

- Phase 2 Questionnaire & Kano Analysis

Based on several existing attributes from first questionnaire, a second questionnaire was made consisting of 14 questions, where each of the two questions consisted of 1 functional question and 1 dysfunctional question to represent each attribute. The purpose of this questionnaire is to be used as a data source in processing data using Kano method.

2.3 Concept Generation

To formulate the concept generation appropriately, researchers use five-step method shown in Figure 2.

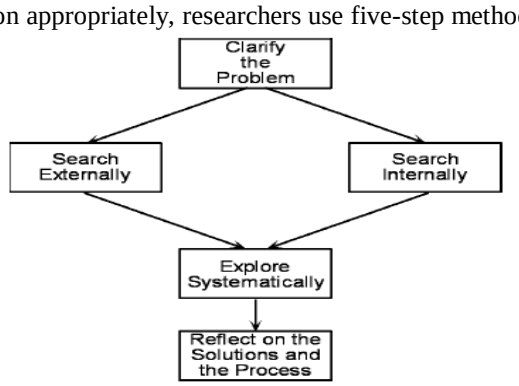

Figure 2. Flowchart of five-step method
(Ulrich & Eppinger, 2011)

1. Clarify the problem
   Problems that are too complex will be easier if divided into several subproblems. For mop design problems, it is divided into several subproblems, there are the mop is difficult to squeeze, the mop does not have a liquid soap shelter, the mop is heavy, and the mop design is not comfortable to use.
2. Search externally
   External searching has the function to find solutions that have been found for general or subproblem problems. In this research, an external searching was carried out by benchmarking. Banchmarking is the study of existing products that have functions similar to the product being developed. For the problem of mops that can be squeezed without using hands, there are already manufacturers that produce mops that can be squeezed by rotating, but this is not efficient because it requires a bucket to rotate. There are also manufacturers that produce mops without being squeezed by hand, namely by pulling the handle, but the mechanism is still bad, making the load of the mop very heavy. And there is no mop that can remove liquid soap by just pressing the button, as well as being integrated with a mop that can be squeezed without using hands.
3. Search internally
   Internal searching is utilization of team knowledge and creativity to produce solutions or concepts. In this research, internal searching was conducted by brainstorming, which consisted of 3 members, 1 as a designer, 1 as an analyst, and 1 as information seeker along with material selection. The results of this searching are the squeezer mechanism using the back-rolling principle and the sprayer mechanism using the Bernoulli principle.
4. Explore systematically
   Selection activities from internal and external searching results to be used as a basis for the concept of making products systematically.
5. Reflect on the solutions and the process
   Some things that were evaluated to formulate concept generation include: Maximum exploration has been carried out on possible solutions. There is no other way to do problem decomposition, external sources have been used comprehensively.

2.4 Product Spesification

This product spesification is based on the perceived problems of most users, as well as the needs and desires of consumers that have been identified and also concept generation that has been formulated. The specification of product details contained in ANOMALI are:

1. Product materials are made of plastic and stainless steel. For the plastic will be used type Polystyrene (PS) which has a strong, hard, and has a high resistance. Stainless steel is chosen because it is not easily broken, light and anti-rust.
2. Handgrip is equipped with rubber material, shape according to the shape of the fingers and measured based on anthropometric data. In the front of the handgrip there is a water spray button that can be used to release the liquid soap.
3. The squeezer mechanism uses the back-rolling principle and the sprayer mechanism uses the Bernoulli principle so that electricity is not needed.
4. There is a water tube as a container for liquid soap with a capacity of 600 ml. There is an indicator on the side so it can be seen whether liquid soap is empty or full and also can be refilled.
5. All wires and pipes as support mechanism are placed inside the trunk of and the working mechanism is closed using a cover so that it looks aesthetic.
6. The fabric of mop can be removed, making it easier to clean. Material uses microfiber so that it absorbs water well, does not make the floor damaged and easy to clean.

3. Results and Discussion

3.1 Kano Analysis

The sample data used were 60 people who were randomly divided in Yogyakarta area where all of them were people who often used mop products and those who rarely used mop products. As for the results of the second stage questionnaire, tabulation of consumer preferences and classification of categories are shown in Table 1.

Table 1. Tabulation of consumer preferences

								WORSE	BETTER
Attribute Code	**Product Requirement**	**A**	**M**	**O**	**I**	**Total**	**Category**	**- (O+M)** / **A+O+M+I**	**A+O** / **A+O+M+I**
A1	Mop can be squeezed without using hands	36	11	10	3	60	A	-0.350	0.767
A2	Mop can spray liquid soap	31	14	10	5	60	A	-0.400	0.683
A3	The mop can be removed from the mop trunk	23	16	13	8	60	A	-0.483	0.600
A4	Mop has a light load	15	13	27	5	60	O	-0.667	0.700
A5	Mop handle is comfortable to use	11	13	28	8	60	O	-0.683	0.650
A6	The mop has an attractive color	14	11	4	31	60	I	-0.250	0.300
A7	The fabric of mop can absorb water well	11	35	14	0	60	M	-0.817	0.417

Based on tabulation of consumer preferences, a scatter graph is made containing attributes placement based on coefficients of worse and better as shown in Figure 3.

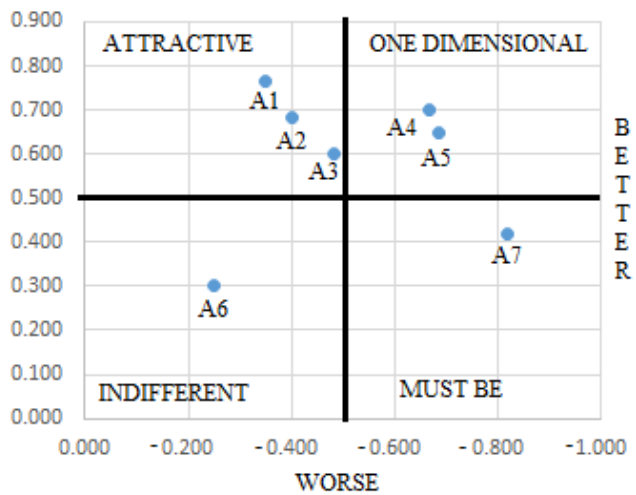

Figure 3. Kano diagram for mop product

Based on Kano diagram, guidelines in determining targets for Kano categories are trying to fulfill all the attributes must be, have better performance than competitors in one dimensional attributes, include attractive attributes that are different from competitors, and eliminate attributes that exist in the indifferent category.

3.2 Product Description of ANOMALI

To fulfill the voice of customers that have been identified using the Kano method, Figure 4 shows ANOMALI products to meet customer demand.

Figure 4. ANOMALI product

ANOMALI (An Ergonomic Mop For Healthy Life) is an ergonomic floor mopping device which does not need to be squeezed manually and can take out the cleaning fluid without having to be manually sprayed, designed with a good working mechanism so that the mop still has a light weight. ANOMALI can be squeezed using the principle of back-rolling work, the way is by pulling the puller of squeezer so that the mop will be squeezed directly because it is attracted by the wire inside the mop, and then it will return to the first position with the suspensions in the bottom of mop.

There is a tube to hold liquid soap that can be refilled, and on the side of the tube there is an indicator so that the user can see if the liquid soap has been full or empty. The liquid soap will enter through a pipe inside the mop trunk.The principle works using Bernoulli principle so that it does not need electricity, just by pressing the button on the mop handle, liquid soap will come out from the bottom hole of the mop with the direction of a straight spray so it is easily directed. The fabric of mop can be easily removed, making it easier for the user to wash the dirty fabric mop after using it. This mop has a handle that is adapted to the principle of hand tool design, anthropometry approach and also use comfortable materials.With the various advantages that exist in this product, it makes the activities of mopping the floor to be efficient, effective, and safe.

3.3 Product Architecture of ANOMALI

Design of ANOMALI is designed using Solidworks, shown in Figure 5.

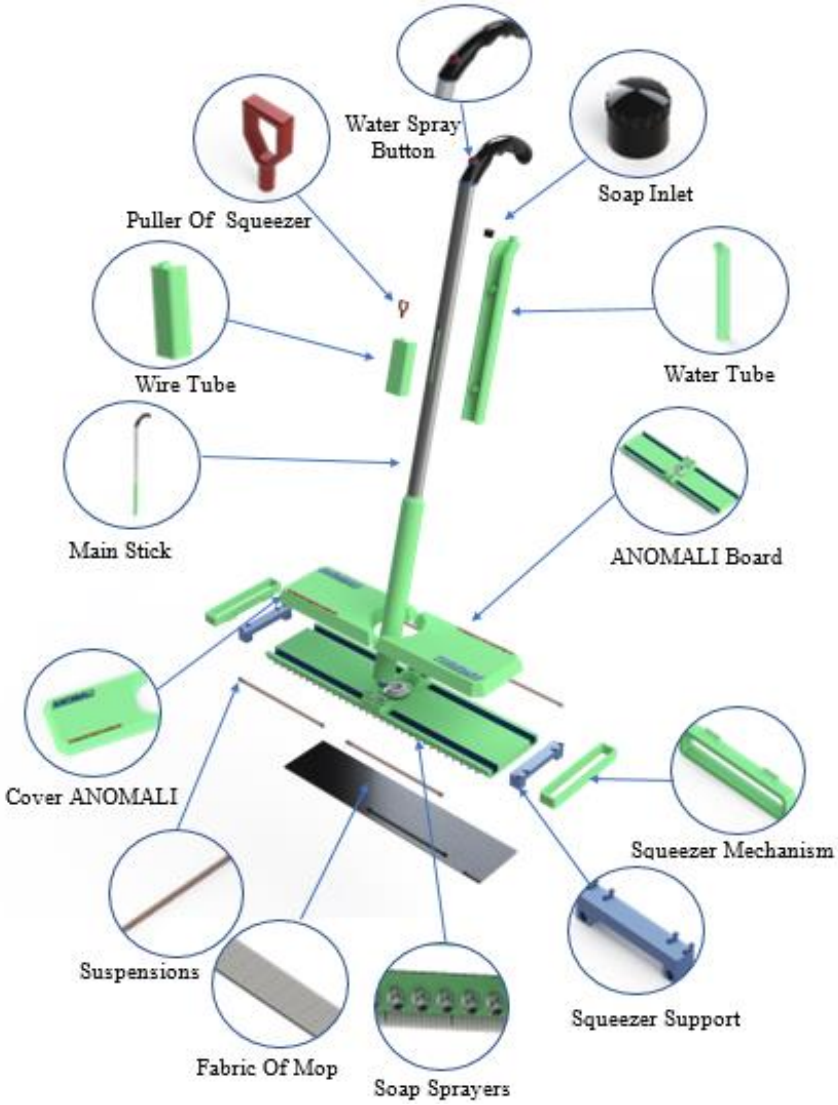

Figure 5. Exploded view of ANOMALI

For an explanation of each part, it can be seen in the Table 2.

Table 2. Explanation of product architecture

General Requirements	Part	Specific Requirements	Acceptable Performance
Sprayer System	Water Spray Button	The button to do the process of spraying liquid soap	Made from plastic which has a diameter of 1,9 cm and the distance has been calculated based on anthropometry
	Soap Inlet	Place out and enter liquid soap	Made from plastic and has been measured with the right tolerance so it is not easily separated

General Requirements	Part	Specific Requirements	Acceptable Performance
	Water Tube	A place to store liquid soap	Can accommodate 600 ml of liquid soap
	Soap Sprayers	The place for liquid soap comes out, designed taper so that the direction of the spray can be directed properly	There are 20 liquid sprayers
Body	Main Stick	The main handle of ANOMALI which has been adapted to the anthropometry of the human body so that it matches the height of the Indonesian people	Made of stainless steel so it is strong, lightweight and anti-rust, has a hole in it as a place of wire and pipe from the squeezer and sprayer mechanism
	Anomali Board	As the main tool to unite various attributes that exist in ANOMALI	Have Dimensions: Length: 50 cm, Width: 15 cm, Height: 5 cm
Squeezer System	Puller Of Squeezer	The handle that can run squeezer mechanism if it pulled	Made from plastic and designed with the hand tool principle
	Squeezer Mechanism	Squeezer who squeezes the fabric of mop	Made from stainless steel which is light and anti-rust
	Suspensions	Reversal mechanism of the Squeezer Mechanism so that it can return to its original position	Has a spring principle that is almost the same as shock breaker
	Wire Tube	Rolled wire container	Made from an iron plate that is adjusted in shape to the main stick contour
	Fabric Of Mop	Mop can be installed and removed	Made from microfiber so it absorbs water well, does not damage the floor and is easy to clean

3.4 Industrial Design Approach

Dreyfuss (1967) explained that there are five main objectives that can be supported by industrial designers when developing new products. The following applies to ANOMALI product.
1. Utility: product interaction with humans must be safe, easy to use, and intuitive. To achieve this goal, researchers take an anthropometric approach and the principle of hand tool design.
- Anthropometry Approach
Anthropometry can be expressed as a study relating to the measurement of the human's body dimensions so that the products made are in accordance with the dimensions of the human body. Anthropometric data were compiled from the anthropometry data banks that have been compiled by the Indonesian Anthropometry Association. The dimensions are used and the results of anthropometric calculations are shown in Table 3.

a. TSB (Height of Elbow Standing): To determine the height of the mop.
b. PIJ (Long thumb): To determine the maximum distance between the mop handle and the water spray button.
c. LIJ (Width of thumb): To determine the diameter of the water spray button.
d. TJT (Thick index finger): To determine the depth of the finger contour on the handle of the mop and puller of squeezer.
e. LTM (Metacarpal Palm Width): To determine the length of the handle of the mop & puller of squeezer.
f. DGMAX (Maximum Grip Diameter): To determine the maximum diameter of the mop handle and puller of squeezer.

Table 3. Calculation result

Anthropo metric Dimensions	Product Dimensions	Size Calculation			The Calculation Results (cm)
		Percentile	Percentile Value (cm)	Allowance	
TSB	Mop height	P_{50}	102,417	0,083	102,5
PIJ	The distance between the handle of mop with the button	P_5	3,881	0,019	3,9
LIJ	Water Spray Button	P_{50}	1,883	0,017	1,9
TJL	Handle of mop & puller of squeezer	P_{50}	1,091	0,009	1,1
LTM	Handle of mop & puller of squeezer	P_{95}	7,643	0,007	7,65
DGMAX	Handle of mop & puller of squeezer	P_{50}	4,012	0,088	4,1

- Principle of Hand Tool Design

ANOMALI is made using the principle of the hand tool design wherein the contour of the finger is made on the handle of the mop and the puller of squeezer so that it does not make the user's fingers hurt. Rubber material is used so that it is comfortable and not slippery. In addition, a tilt angle of 19° is also used on the handle of the mop which is the basis for designing hand-tools to keep the user's wrists straight (Emanuel et al, 1980).

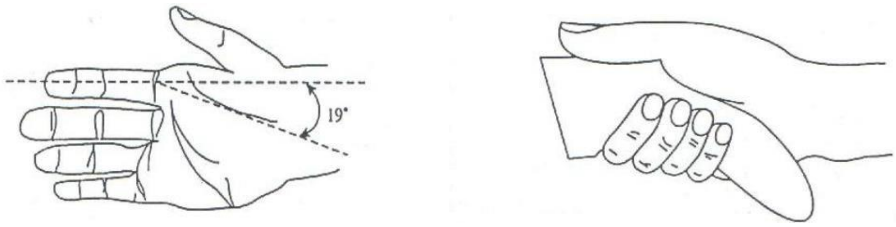

Figure 6. The 19° degree of tilt in the grip

2. **Appearance**: Forms and proportions are used so that the overall product becomes fun. To fulfill this goal, ANOMALI cover was made to cover the squeezer mechanism of the mop, and the trunk of mop was made perforated as a place of ANOMALI's wire and pipe so that it makes ANOMALI product look simple but still aesthetic and light in weight that can be seen in Figure 7.

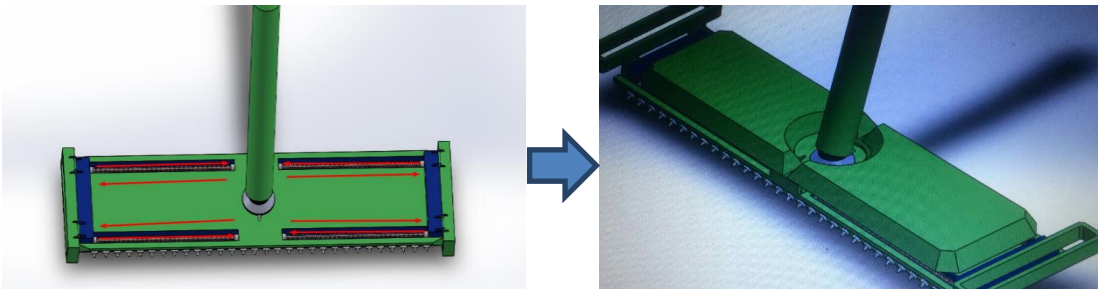

Figure 7. Cover closes ANOMALI mechanism

3. **Ease of maintenance**: The product must be designed so that it can communicate how to maintain and repair it. The fabric of ANOMALI can be removed from the board so it is easy to clean. Besides that, liquid soap containers can be refilled as needed.

4. **Low cost**: ANOMALI is made with good material quality so that it lasts longer. The production cost for 1 ANOMALI product is Rp 233,000, it can be said cheap because of using good material quality.

5. **Communication**: Product design must communicate the design philosophy and mission of the company through the visual quality of the product. ANOMALI is an abbreviation of An Ergonomic Mop For Healthy Life, which is suitable with the design that is made more ergonomic and more efficient.

3.5 Design for Manufacturing & Economic Analysis

The Figure 8 shows the ANOMALI's Bill of Material.

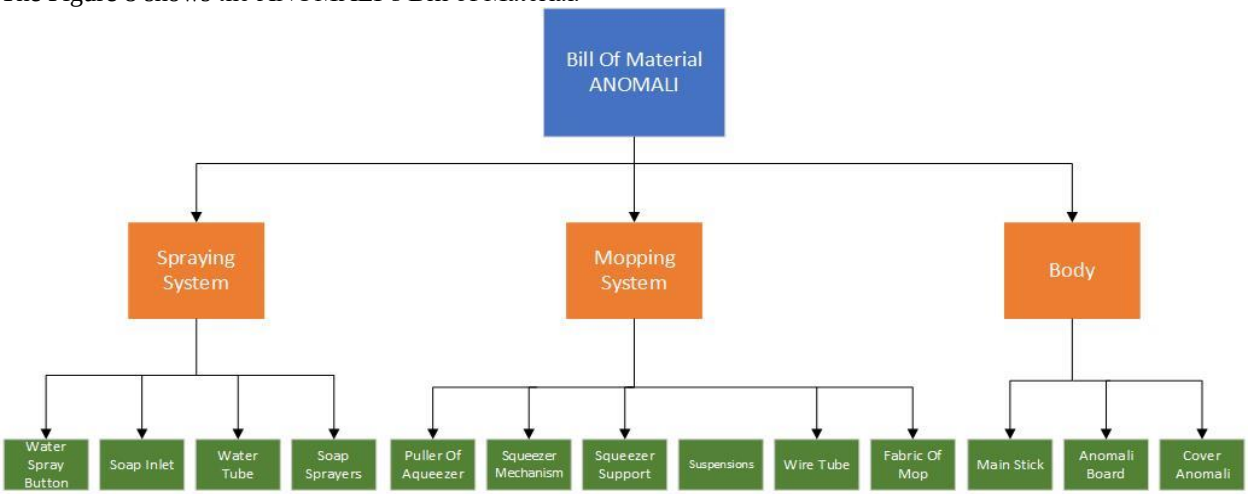

Figure 8. ANOMALI's bill of material

Estimated maximum price and total material requirements for the manufacturing of an ANOMALI product can be seen in the Table 4.

Table 4. Prices and number of components for 1 ANOMALI product

No.	Part	Unit	Quantity	Price	Total
1	Water Spray Button	Unit	1	Rp 2.500	Rp 2.500
2	Soap Inlet	Unit	1	Rp 2.500	Rp 2.500
3	Water Tube	Unit	1	Rp 10.000	Rp 10.000
4	Soap Sprayers	Unit	20	Rp 1.500	Rp 30.000
5	Main Stick	Unit	1	Rp 50.000	Rp 50.000
6	Anomali Board	Unit	1	Rp 20.000	Rp 20.000
7	Cover Anomali	Unit	2	Rp 15.000	Rp 15.000
8	Puller Of Aqueezer	Unit	1	Rp 5.000	Rp 5.000
9	Squeezer Mechanism	Unit	2	Rp 10.000	Rp 10.000
10	Squeezer Support	Unit	2	Rp 5.000	Rp 10.000
11	Suspensions	Unit	4	Rp 7.500	Rp 30.000
12	Wire Tube	Unit	1	Rp 5.000	Rp 5.000
13	Fabric Of Mop	Unit	1	Rp 30.000	Rp 30.000
14	Steel Wire	Meter	2	Rp 5.000	Rp 10.000
15	Liquid Soap Pipe	Meter	1	Rp 3.000	Rp 3.000
			Total Price		**Rp 233.000**

3.6 Creativity and Innovation Aspect

The main innovation in ANOMALI product is in the squeezing mechanism, which is able to squeeze the mop just by being easily pulled, using the back-rolling principle so that the puller of squeezer will return to the spot by itself if the puller is removed. The mop that can be squeezed without using hands already existed with the mechanism rotated and pressed, but requires a bucket as a rotating container so that without a bucket it cannot be used, this is not efficient because the user has to carry a bucket during mopping. In addition there is also mop which are squeezed by lifting handle, but based on survey from the users, the bad mechanism makes the mop very heavy even some respondents who have used the mop like that prefer to use ordinary mops because they are lighter. Therefore, the squeezer mechanism of ANOMALI is designed by being pulled and using a better mechanism so that the weight is light. For the working mechanism of squeezer can be seen in Figure 9 below.

- **Mechanism of squeezer**: Pull the puller of squeezer so that the squeezer mechanism and squeezer support move inside from the outside of the ANOMALI board.

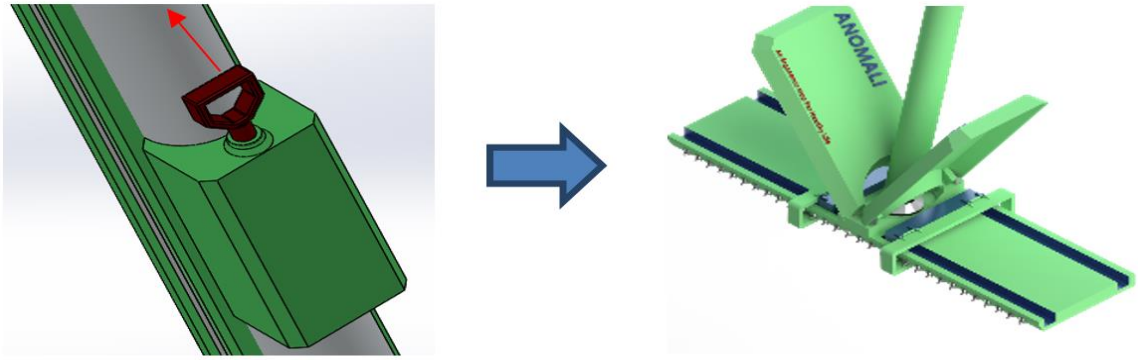

Figure 9. Mechanism of squeezer

In addition, the innovation is in soap sprayers. A water tube is provided on the trunk of mop. The liquid soap will come out if the user presses the button in front of the mop handle. Made using the Bernoulli principle so that it does not use electricity. For the working mechanism of sprayer system can be seen in Figure 10 below.

- **Mechanism of sprayer system**: Open the soap inlet, then fill the liquid soap into the water tube and close it again (to see whether the liquid soap is full or empty, the user can see the indicator on the side of the Water Tube). After filling, press the button in front of the handle so that the liquid soap comes out from the bottom of the mop.

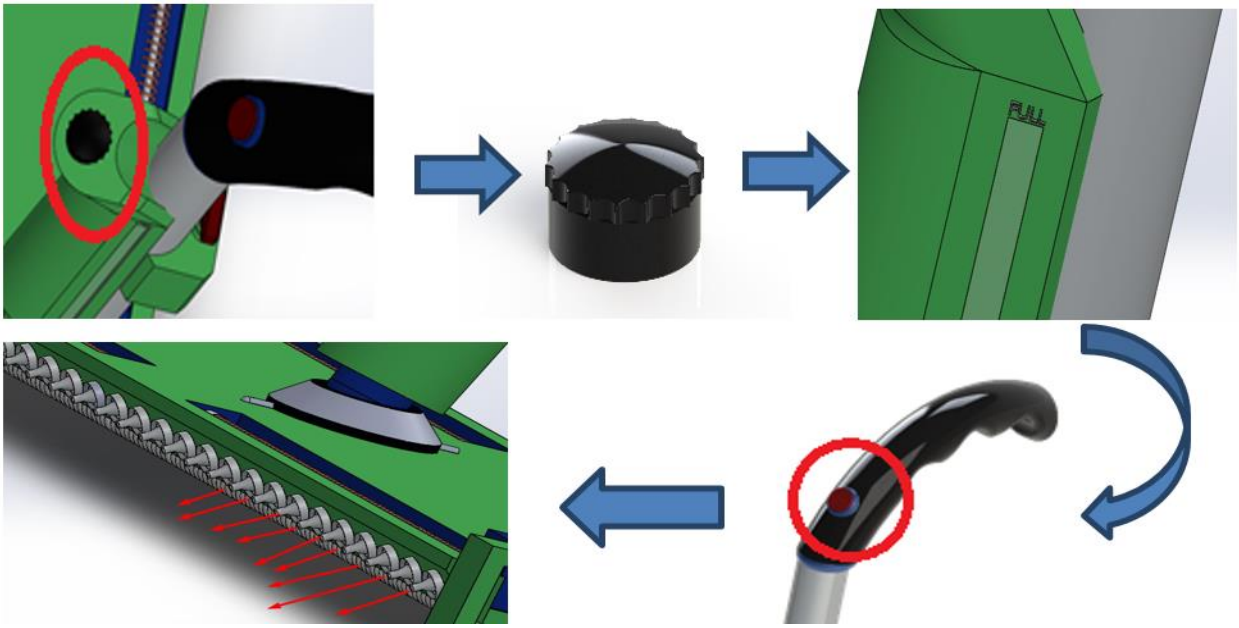

Figure 10. Mechanism of sprayer system

4. Conclusions

ANOMALI (An Ergonomic Mop For Healthy Life) is a mop that can be squeezed by being pulled using a back-rolling principle so the user will not bend the body and twist the wrist. In addition, it can remove soap just by pressing the button using the Bernoulli principle so that it doesn't require electricity. The fabric of mop can be removed from the trunk so that it is easy to wash. Made with a good working mechanism, so it makes the mop become light, aesthetic and comfortable to use. ANOMALI's materials are made of plastic and stainless steel. Polystyrene (PS) will be used as a material of ANOMALI which has a strong, hard, and high resistance. Stainless steel is chosen because it is not easily broken, light and anti-rust. It is estimated that the maximum cost for the production of one ANOMALI is Rp 233.000. ANOMALI is made by using ergonomics methods such as the principle of hand tool design and anthropometry measurement, using the five-step method to formulate concept generation appropriately and also using the Kano model as the method of identifying customer needs.

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Biography

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