Design improvement of automated gallon washing machine to minimize musculoskeletal disorders (MSDs) in CV Barokah Abadi using ergonomic function deployment (EFD) approach

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Abstract. In the production activity of Bottled Drinking Water (AMDK) in CV Barokah Abadi there is a gallon washing station. At the work station it involves three stages of activity such as washing and rinsing the outside of the gallon, spraying the inside of the gallon and rubbing the inside of the gallon which is done in a separate place. Distribution of Nordic Body Map (NBM) questionnaires showing employee complaints data at gallon washing stations where workers complained of pain in the right upper arm, right forearm and right wrist respectively 88% and workers also complained of pain in the waist and The right hand respectively by 81%. Ergonomic gallon washer is one way to minimize the risk of MSDs. The design begins with an ergonomic evaluation of the existing conditions and the concept of the initial design of the gallon washer. The evaluation is utilized for consideration of design improvements with the utilization of Ergonomic Function Deployment (EFD) in order for the product concept to conform to the ECSHE principle (Effective, Comfortable, Safe, Healthy and Efficient). The tool improvement design can minimize the risk of MSDs seen from the worker’s posture while using an ergonomic washer.

Keywords: Gallon Washing, Nordic Body Map, Ergonomic Function Deployment

1. Introduction
CV Barokah Abadi is one of AMDK supplier company whose activities focus on drinking water production process of gallon packaging. Production activities CV Barokah Abadi began with mobilization gallon gross of trucks at loading bay into the washing gallon, washing gallon exterior with a detergent solution, rinsing the outside of gallons of clean water, spraying gallons inside the hose pressurized medium, scrubbing gallons inside by using a special machine, filling gallons of drinking water from the spring, closing the mouth gallon by gallon lid, sealing cap on freight gallon to gallon that has been sealed onto trucks at the loading bay for a re-marketed as can be seen in figure Figure 1. in Development of this ergonomic product, the process focused on the process of washing gallons in CV Barokah Abadi. In the existing condition of the washing section consists of four stages, which 70% of the process is still done manually, such as washing the outside of gallons of water reservoirs in an area of 2.25 m² by using a liquid detergent and a scouring sponge and brush to clean the outside of gallons of dirt, further gallons already transferred to the clean water tank containing clean water without detergent of the same size to rinse the outside of gallons of residual foam detergent. The next process is to clean the inside of the gallon, by spraying by high pressure water using a special hose, if there are stains that are still attached, then the inside of the gallon will be cleaned by being rubbed with a special machine and then sprayed back by using a hose.
Based on the existing conditions, there are three body postures that need to be analyzed, such as body position while washing the outside of the gallon, spraying and brushing the inside of the gallon. The analysis was done by Rapid Upper Limb Assessment (RULA) method by using virtual environment based application on observation of mannequin Chinese population as can be seen in Table 1. Based on research of Anthropometry of the Singaporean and Indonesian that posture of Indonesian population have similarity with ethnic posture China with a 50% percentile rate [2].

Table 1. Rula score of existing process

| Activity                                | RULA | Action Analysis                                           |
|-----------------------------------------|------|----------------------------------------------------------|
| Washing and rinsing the exterior of Galon | 7    | High-risk posture, repairs should be made at this time   |
| Spraying the inside of Galon             | 5    | Medium-risk posture, repairs are done as soon as possible.|
| Rubbing the inside of the gallon         | 6    | Medium-risk posture, repairs are done as soon as possible.|
Based on the measurement of Rapid Upper Limb Assessment to the three washing activities, by looking at the score can be concluded that the process of gallon washing in CV Barokah Abadi tends to involve awkward posture that will result Musculoskeletal Disorders (MSDs) to the workers when the work is done repeatedly. Based on preliminary studies conducted on four workers by distributing Nordic Body Map (NBM) questionnaires related to the health complaints experienced during the washing work, it was found that 100% of respondents had Musculoskeletal Disorders (MSDs) after working with six of the largest complaint ratings Can be seen in Table 2. The pain experienced by the worker is supported by the conditions and the work load is quite heavy, such as conditions where workers have to hold the gallon with one hand while the other hand spray the inside of the gallon, the condition supports muscle fatigue of the upper, lower, hand and wrist as well as The mouth of the gallon should be in a downward position so that the worker must hold the gallon continuously over and over.

Table 2. NBM questionnaire result

| Fatigue                  | Percentage |
|--------------------------|------------|
| Back Pain                | 88%        |
| Right-Upper Arm Pain     | 88%        |
| Right-Forearm Pain       | 88%        |
| Right Wrist Pain         | 88%        |
| Waist Pain               | 81%        |

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![Figure 2. Initial Concept of Existing Gallon Washing Machine](image_url)

To assess whether or not a design results, there are three underlying elements, namely functional, aesthetic and economic [3]. The functional basis relates to the ability of the product designed to perform certain functions in accordance with the planned including the ergonomic elements therein. The aesthetic element is related to the physical form of the product to be pleasing to the eye. The basis of the economy relates to the purchasing power of the society when the product is marketed. Based on the case studies presented, a tool is needed that can not only operate in accordance with the planned function, but also
has an element of safety and comfort for workers [4]. For this purpose, an ergonomic evaluation of the existing proposed design is undertaken with the aim of ensuring that the proposed tool design simplifies leaching and reduces the risk of MSDs in workers compared to previous conditions in CV Barokah Abadi. Based on the importance of ergonomic evaluation on the product, the concept of galon washing machine development needs to be evaluated ergonomic test before the next concept is developed. In this approach, product design concepts developed based on user desires coupled with user comfort factor became the main focus in the development of product designed specifications. Based on the background that has been presented, Ergonomic Function Deployment (EFD) method can be used in solving problems in designing gallon washing tools in CV Barokah Abadi. Using the EFD approach is an approach that refers to the principle of user ergonomics so as to produce a product design that is ENASE (Effective, Comfortable, Safe, Healthy and Efficient) in order to reduce the risk of Musculoskeletal Disorders (MSDs) in the user.

2. Methods

![Conceptual model]

Figure 3. Conceptual model

Based on the conceptual model overview above, product development focuses on the initial concept of gallon washing tools proposed by previous researchers. This initial concept is a representation of the global voice of customer in terms of functional that has been processed by previous researchers. Existing working conditions are also examined as a reference in applying ergonomic aspects to the initial concept.
of gallon washer. Furthermore, further design is done by adding ergonomic aspects to the design concept by giving consideration of the comfort, safety and health of the workers. The addition of ergonomic aspects is done in the hope of reducing the risk of Musculoskeletal Disorders (MSDs) in workers. In adding ergonomic aspect, the first evaluation of initial draft concept is evaluated. The evaluation is an ergonomic evaluation that focuses on the evaluation aspect of Lifting Index (LI), Posture Evaluation Index (PEI) and anthropometric evaluation. The results of this evaluation are also used as a consideration in determining the specification of the concept of improvement of gallon washing machine design. The PEI score evaluation was performed to determine the magnitude of the risks that occur as a result of the worker's posture while performing the washing. The resulting PEI score determines the level of risk and the duration of the repair. Evaluation of manual removal is done to determine the risk of removal of gallons by workers. Anthropometric evaluation was conducted to determine the extent of the difference in the concept of the initial design dimension to the anthropometric data in question. Anthropometric evaluation will determine the dimensions of the product used to meet the aspect of ergonomics. After conducting an ergonomic evaluation of the initial draft concept, product development using the Ergonomic Function Deployment (EFD) approach is developed from Quality Function Deployment (QFD) to achieve the ergonomic proposal concept. In the EFD method, the design is based on the ergonomic aspect of the user in order that the product is designed in accordance with the principles of ENASE (Effective, Convenient, Safe, Healthy and Efficient). The applied ENASE principle is expected to help in reducing the risk of Musculoskeletal Disorders (MSDs) in gallon washing workers in CV Barokah Abadi. Proposed designs that have passed through the EFD flow will then be re-evaluated with ergonomics tools to compare aspects of ergonomics with the initial concept of the product. If the designed ergonomic aspect has been met, it is certain that the draft proposal concept is an ergonomic design concept or can be defined as an ergonomic design concept.

3. Result and Discussion

3.1. Work Process Identification of Initial Concept

To determine the evaluation of the proposed draft, it is necessary to first define the interaction that will occur between the workers and the draft concept. The definitions relate to the interaction of what happens between the worker and the parts of the tool for further observation. The following is the interaction of workers with tools can be seen in Table 3.

| Functional                | Interaction                                                                 | Parts of Worker-Related Tool          |
|---------------------------|----------------------------------------------------------------------------|---------------------------------------|
| Temporarily Engine Shut   | Workers pull the handle at the top of the door vertically.                 | • Lid Handle                         |
| Engine Down               |                                                                             | • Lid                                 |
|                           |                                                                             | • Limit Switch                        |
| Engine Run                | Workers pulled the door of the appliance until the wash chamber was closed. | • Lid                                 |
|                           |                                                                             | • Limit Switch                        |
| Engine Stop               | Workers pressed the emergency stop lever.                                  | • Emergency Stop                     |

3.2. Product Attributes

Research attributes were obtained by selecting and interpreting complaints and expectations of workers based on the results of observation and question and answer directly into a new concept for the gallon washer. Research attributes can also be obtained by studying the concept of similar products such as washing machines, baby taffles, block cake molding tools and gallon scrubbing machines that have been widely used by some refill drinking water companies. At this stage, the researcher can apply the concepts
of those products that are relevant to the research along with the concepts obtained based on observation into research attributes that refer to the concept of ECSHE (Effective, Comfortable, Safe, Healthy and Efficient) as can be seen in Table 4 as the attribute data required in the design of an ergonomic gallon washer.

3.3. House of Ergonomics (HoE)

In the Appendix can be seen the relationship between the matrix of attribute needs based on aspects of ergonomics with technical characteristics. Each relationship between the matrix has how big the relationship is and also there is also interaction relationship between technical characteristics that influence each other. HoE formation can be considered information to develop the product. Technical characteristics have priority which indicates higher priority, so if there is a trade-off in product development, the highest priority is not recommended to be modified in advance because it will affect product attributes and other technical characteristics.

3.4. Final Spesification

Based on the results of sorting the weight of product attributes, it was found that the 2nd alternative concept was chosen as the concept of design improvement on the gallon washing equipment in CV
Barokah Abadi. The following is the final specification of the selected ergonomic gallon washer (Table 5).

| No | Technical Characteristic                  | Unit      | Target Value |
|----|------------------------------------------|-----------|--------------|
| 1  | Washing machine length                   | Centimeter | 67.32        |
| 2  | Washing machine width                    | Centimeter | 84.56        |
| 3  | Washing machine height                   | Centimeter | 102.23       |
| 4  | Washing time duration                    | Second    | 15           |
| 5  | Display width                            | Centimeter | 30.00        |
| 6  | Display height                           | Centimeter | 1.25         |
| 7  | Display type                             | List      | -            |
| 8  | Handle width                             | Centimeter | 51.63        |
| 9  | Handle height from the ground            | Centimeter | 104.88       |
| 10 | Handle diameter                          | Centimeter | 3.00         |
| 11 | Handle type                              | List      | -            |
| 12 | Wash chamber length                      | Centimeter | 52.00        |
| 13 | Wash chamber width                       | Centimeter | 54.00        |
| 14 | Maximum lid angle                        | Degrees   | 110.85       |
| 15 | Emergency Stop type                      | List      | Emergency Button |
| 16 | Emergency Stop location                  | List      | Right Side   |
| 17 | Censor type                              | List      | Photoelectic |
| 18 | Switch type                              | List      | Limit Switch |
| 19 | Posture Evaluation Index (PEI) score     | Score     | 1.00         |
| 20 | Drainage type                            | List      | Convergent   |
| 21 | Recommended Weight Limit (RWL) score     | Kilogram  | < 3.72       |
| 22 | Lifting Index (LI) score                 | Score     | < 1.00       |
| 23 | Front and chamber lid material           | List      | Acrylic      |
| 24 | Washing way                              | List      | Handle Push  |
| 25 | Emergency Stop distance from worker      | Centimeter | 59.76        |

The result of the implementation of ergonomic gear washing machine design specification which is the improvement of the design of the proposed design concept. As for the physical shape of the improvement of ergonomic gallon wash design can be seen in Figure 4.

![Figure 4. Ergonomic Design](image)

4. Conclusion
Based on the results of data processing and analysis of food obtained some conclusions that refers to solve problems in this study. The conclusions are as follows:
1. Based on the purpose of research is to produce the concept of ergonomic tool improvement, the results of this study obtained the concept of ergonomic products based on product attributes that refers to the principle of ENASE (Effective, Safe, Healthy, Comfortable, Efficient)
2. This ergonomic concept of the ergonomic tea powder transporter is able to reduce the risk of MSDs by achieving some test parameters on the ergonomic evaluation performed.

5. References

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