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Reverse Engineering Design of Ceiling Lamp Changer to Increase Product Value By Using DFMA Methode

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ABSTRACT
The prevalent manual method of replacing ceiling lamps, which often involves climbing on unstable furniture, poses significant safety risks, including potential falls, electrocution, and other severe injuries. This common practice underscores an urgent need for safer and more efficient lamp maintenance solutions in both domestic and commercial settings. This research aims to mitigate these inherent dangers by developing and upgrading conventional ceiling lamp changers into a semi-automatic system. The primary objectives are to enhance the safety, speed, and overall ease of the lamp replacement process, thereby effectively minimizing the risk of user injury. The proposed methodology involves designing a semi-automatic ceiling lamp changer by integrating a control switch mechanism that enables remote rotation of the lamp holder. This innovative approach will facilitate the safe removal and installation of lamps without direct manual contact or the necessity of climbing. Concurrently, comprehensive product cost planning and market-driven pricing strategies will be conducted to ensure the device's affordability and widespread community acceptance. The successful development of this semi-automatic ceiling lamp changer is anticipated to provide a significantly safer, faster, and more convenient alternative for lamp replacement. This remote-operated design is expected to substantially reduce injury incidents associated with current manual methods. By ensuring affordability and market compatibility, this innovation aims to achieve broad community adoption, ultimately contributing to safer environments for lamp maintenance.

Keyword: Ceiling Lamp Changer, Reverse Engineering, Automatic Motion, Ergonomic

INTRODUCTION

As technology and creative ideas advance to minimize injuries when replacing ceiling lights, there is now a simple tool for replacing ceiling lights. This tool resembles a long rod with a maximum length of about 2.5–3 meters, the end of which is designed in such a way that it can firmly grip the ceiling light (Comunian et al., 2015; Kačerauskas, 2015; Kumpulainen et al., 2014; Marques & Borba, 2017; Weingarten et al., 2020). The use of this tool is also quite simple, which is simply by rotating it clockwise or counterclockwise, depending on whether you want to remove or install the ceiling light, as shown in Figure 1. This tool is quite easy to use by the general public because its shape and how it works are very simple. However, upon closer inspection, it turns out that this tool has a slight weakness in terms of its use or how it works. Using it by rotating the wrist poses a risk of arm injury because even a slight mistake can cause the muscles and joints of the arm to slip, resulting in significant pain and discomfort.

Based on this problem, it is necessary to plan a ceiling lamp replacement tool that is easy to use, requires a short time to replace ceiling lamps, and minimizes the risk of injury for the operator or person using the tool. The tool planning in this discussion is a development of the ceiling lamp changer that already exists in society, which will later be upgraded from manual to semi-automatic. *Semi-automatic* here refers to the use of a control switch to rotate the lamp holder, so that the process of replacing (removing and installing) the lamp becomes faster, safer, and easier.

Customer needs and product specifications are very useful in guiding the direction of concept development (*conceptual advance*) (Timoshenko & Hauser, 2019; Urlich & Eppinger, 2016). This is the basis for many design and manufacturing teams to practice the *design for X* (*DFX*) method for a variable, let's say "X," where "X" can be interpreted as manufacturing capability. The most common elaboration of this method is called *Design for Manufacturing* (*DFM*), which can also inform manufacturing costs (Arifin et al., 2022; Luqyana et al., 2019; Nasution et al., 2022; Putri et al., 2020).

Manufacturing cost is an indicator of the economic success of a product. Economic success depends on the profit margin on each product sale and how many products the company can sell. The profit margin itself is defined as the difference between the selling price and the product manufacturing cost. Therefore, one way to increase profits is to reduce product manufacturing costs, but it is also necessary to note that the selling price is closely related to the overall quality of the product itself (Aulia et al., 2018; Firdhaus & Santoso, 2022; Ichsan & Hafizh, 2021; Muchlis et al., 2021).

Figure 1. Existing Product

DFMA consists of a team that is interconnected and functionally integrated. Therefore, it requires several types of information delivery to enable effective collaboration. Some of these types of information are:

a. Detailed understanding related to the production process and assembly.
b. Sketches of product design drawings, product specifications, and several alternative design proposals.
c. Product volume estimated manufacturing costs, and product sales or release agenda.

For the delivery of information not to be incorrect or deviate from the initial goal, a *DFM* requires experts such as mechanical or manufacturing engineers, production personnel, product

design experts, and financial accountants who handle matters relating to production costs. The *DFM* method is carried out during the concept development process, when product functions and specifications are determined. In product concept selection, one of the most important criteria in decision-making is the cost factor, although this cost estimate is very subjective and is an approximation. When the product concept is selected in the final evaluation, the team makes choices among several desired performance characteristics, for example, reducing product weight by selecting lighter but more expensive materials.

Given the urgent need to mitigate safety hazards associated with manual ceiling lamp replacement, and identifying a research gap where previous research on lamp changers has often overlooked optimizing product value through robust *design for manufacturing and assembly* (*DfMA*) principles, this study presents a novel approach by utilizing reverse engineering to systematically apply the *DfMA* method to existing designs, with the primary objective of significantly enhancing the product's safety, ease of use, and operational efficiency. This, in turn, provides the crucial benefit of a more valuable and widely adoptable solution for consumers.

RESEARCH METHODS

Commonly, a product is designed and made to fulfill a specific function. A product can be considered successful if it can be used or works according to its intended function. If a product is less than optimal or cannot perform its function properly, it is considered a defective product. In product design planning, it is necessary to have a list of needs or functions that the product must be able to perform. This list of needs is then created in a requirements list table, which becomes the guideline or foundation for designing a product,he requirements list table is the initial step in the *Design for Manufacturing and Assembly* (*DFMA*) method.

Table 1. List of Requirements

Revision	(S / H)	Description of Needs	Person In Charge
S	S	**1. Function**: a. Can replace lamps easily and safely. b. Automatic, just by pressing a button to replace the damaged ceiling light with a new one.	Design and Manufacturing Team
S	H	2. **Strong and Safe**: a. Hard to break or damage (durable). b. Not slippery when held or used.	Design Team
S	S	3.**Dimension and Geometry**: a. The lamp holder is made of elastic material with a diameter between 40 to 50 mm, and a length of 250 mm. b. Total length: 3000 mm.	Design Team
S	S	4. **Weight**: a. Maximum weight 3 kg b. Easy to lift.	Manufacturing Team
S	H	5.**Manufacturing and Assembling**: a. Can be made. b. Easy to disassemble.	Manufacturing Team

Revision	(S / H)	Description of Needs	Person In Charge
		c. Components are easy to make.	
S	H	6. **Maintenance**: a. Easy to store. b. Easy to clean. c. Easy to repair. d. Spare parts are easy to get.	Design and Manufacturing Team
H	H	7. **Cost**: a. Low manufacturing costs. b. Affordable price.	All Team

Table 1 outlines the functions that a product, in this case a ceiling lamp replacement tool with an easily adjustable arm, will achieve, with its main function being to simplify the process of replacing ceiling lamps. There are seven requirement descriptions to be achieved, including function, strength and safety, dimensions and geometry, weight, manufacturing and assembly, maintenance or care, and cost or price. Each of these requirement descriptions has sub-requirement descriptions, which are marked with "S" (Should Have) or "H" (High Priority). "Should Have" means that the sub-requirement description must or is mandatory to be fulfilled, while "High Priority" means that the sub-requirement description may or may not be fulfilled as it is an added value that supports the function of the lamp changer. The rightmost column of Table 1 explains the implementing team that will carry out or realize the specific requirement descriptions that have been made.

Reference Concept

The design of the lamp changer in this paper is a development of a similar product that existed previously or is called a reference concept. The reference concept is presented in Figure 2. The existing ceiling lamp replacement tool or product model on the market is shown in Figure 3. As briefly reviewed in the Introduction chapter, the ceiling lamp replacement tool consists of a long pole with a lamp holder made of polyester material at its end, equipped with springs to strengthen the grip on the lamp, preventing it from slipping when removed or reinstalled into its lamp socket.

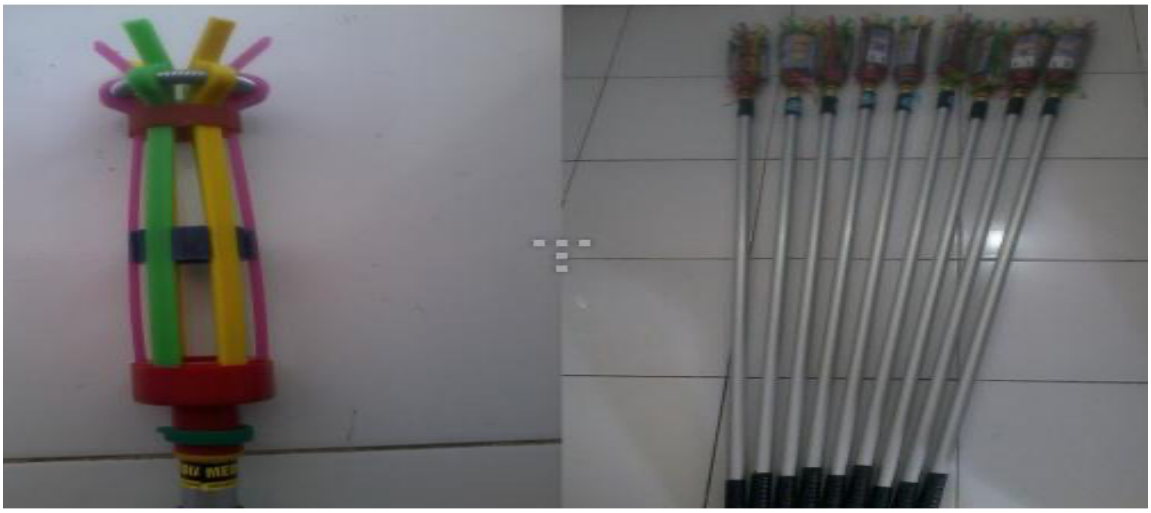
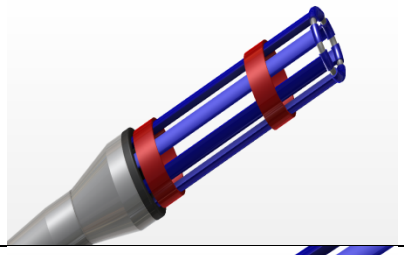
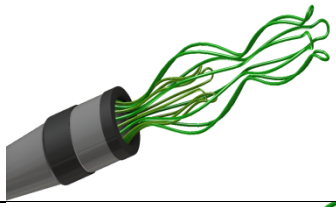
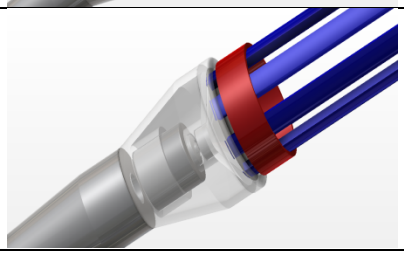
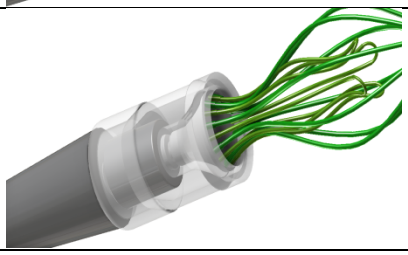


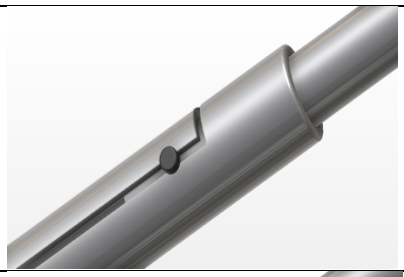
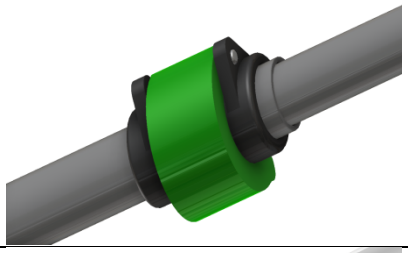
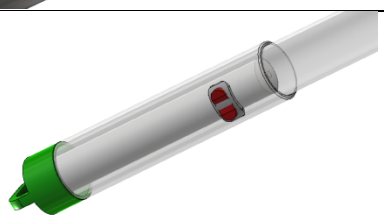
Figure 2. Common lamp charger

Alternative Concept

The development of the previously described reference concept will be explained in more depth in the form of an explanation of several alternative concepts as shown as Table 2. The alternative concepts are solutions or innovations from the reference concept, where these alternative concepts will form the basis for modeling the new product design. In this new idea, there are several parts of the ceiling lamp replacement tool model that will be developed. Some of them are the lamp holder, the driver motor system, the adjustable arm lock, and the control switch model. In option A, the resources used are 8 batteries, each with a voltage of 1.5 volts. For option B, a battery specifically made for this alternative concept is used, with an output power of 12 volts and rechargeable.

Table 2. Optional Concept Design

Sub-sections with functions	**Options**	
	A	B
Lamp *Holder*		
Clamping Model		

Arm Lock		
Control Switch		

Screening and/or Scoring

The next step after obtaining two alternative concept options, option A and option B, is to conduct concept evaluation and selection. The existing concepts, both the reference concept and the alternative concepts, are compared with each other on several specific criteria as shown in Table 3. The weighting given to each selection criterion is adjusted to the planned concept to be achieved, where some selection criteria are primary and others are supporting. The Rate is the point given to each concept for each specific selection criterion. The reference concept is given a value of "3" for all selection criteria because this reference concept serves as a basic comparison to determine whether a proposed alternative concept is better, the same, or worse in quality than the reference concept. The ratings are: "1" = much worse than the reference concept, "2" = worse than the reference concept, "3" = as good as the reference concept, "4" = better than the reference concept, and "5" = much better than the reference concept. The Weighted Score is the result of multiplying "Weight" x "Rate". The Absolute Value is the total sum of the "Weighted Score" from all the given selection criteria. The Relative Value is the percentage comparison of the "Absolute Value" of a concept with the "Total Absolute Value" of all proposed options or concepts.

Table 3. Concept Evaluation

Selection Criteria	**Percentage**	**Concept A**	**Concept B**	**Reference Concept**
		Rate	**Score**	**Rate**
Automatic, easy to use	20%	4	0.8	4
Strong and safe	20%	3	0.6	4
Futuristic design	5%	3	0.15	4
Easy to lift	10%	3	0.3	3
Easy to manufacture and disassemble	5%	3	0.15	3
Easy to maintain (stored, cleaned, repaired)	20%	4	0.8	4
Priced	15%	4	0.6	4
Absolute Score		3.4		3.65

Selection Criteria	Percentage Concept A	Concept B	Reference Concept
Relative Score	33.34%	36.87%	

Selected Concepts

Based on the concept evaluation process, it was found that alternative concept option B has the highest value compared to alternative concept A and the reference concept, with an absolute value of 3.65 and a relative value of 36.87. This result forms the basis for choosing option B as the selected concept, as shown in Figure 3. The working principle is very easy and simple. First, prepare a ceiling lamp that is still functioning (lit). Second, adjust the length of the adjustable arm to reach the lamp to be replaced. Once a certain length is obtained, pull the locking lever so that the arm length can be maintained. The next step is to insert the lamp holder onto the ceiling lamp to be replaced, making sure the position is correct and the lamp is properly and firmly attached to the lamp holder. Remember that the position of the lamp holder should be perpendicular to the ceiling lamp. Press the button to rotate the lamp holder counterclockwise so that the ceiling lamp can be removed from its socket. Manually remove the dead lamp from the lamp holder with your hand, then attach the new lamp to the lamp holder. Position the lamp right at the mouth of the lamp holder on the ceiling. Press the button to rotate the lamp holder clockwise so that the new lamp is properly installed in the ceiling lamp socket. Once the lamp is installed, pull the lamp changer until it comes off the lamp and adjust it to its original length by pulling the locking lever. Place the lamp changer in a safe place and out of reach of small children.

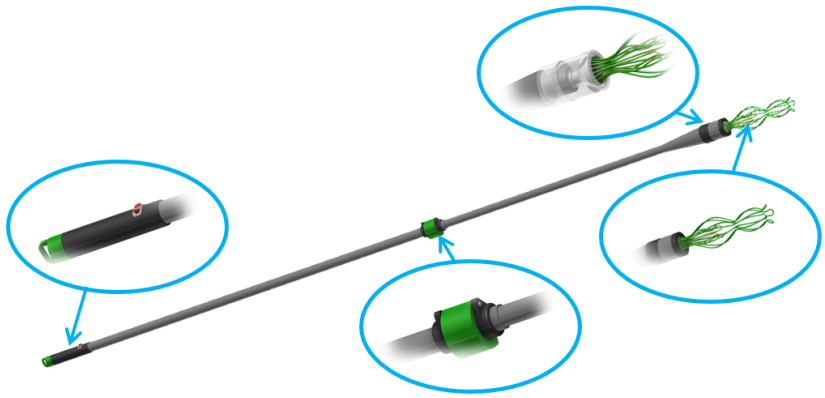


Figure 3. Selected concepts

RESULTS AND DISCUSSION

Detail Design of Selected Concepts

Lamp Holder

The part that functions as the ceiling lamp holder. The material is made of stainless-steel wire, which is ductile, slightly flexible, and rust resistant. This part consists of three components: wire 1, wire 2 (which is smaller in size), and a wire holder, as shown in Figure 4.

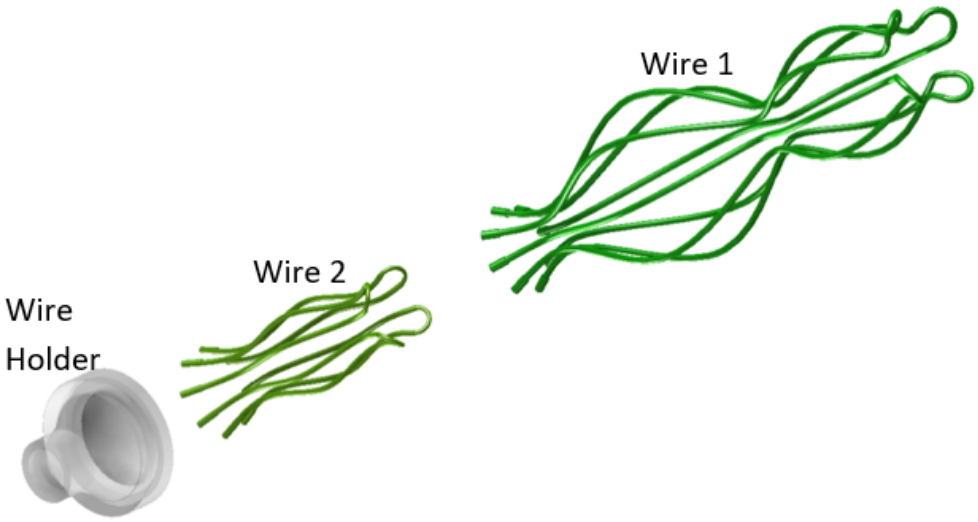


Figure 4. Lamp holder

Drive Motor

It is the driver of the lamp holder, the gear on the motor is directly connected to the gear housing on the base or the bottom part of the wire holder on the lamp holder. The component details on the drive motor are explained in Figure 5. The motor used is a type of Brushless Direct Current motor, often referred to as a stepper motor, where the input required for this motor to rotate is 12 volts.

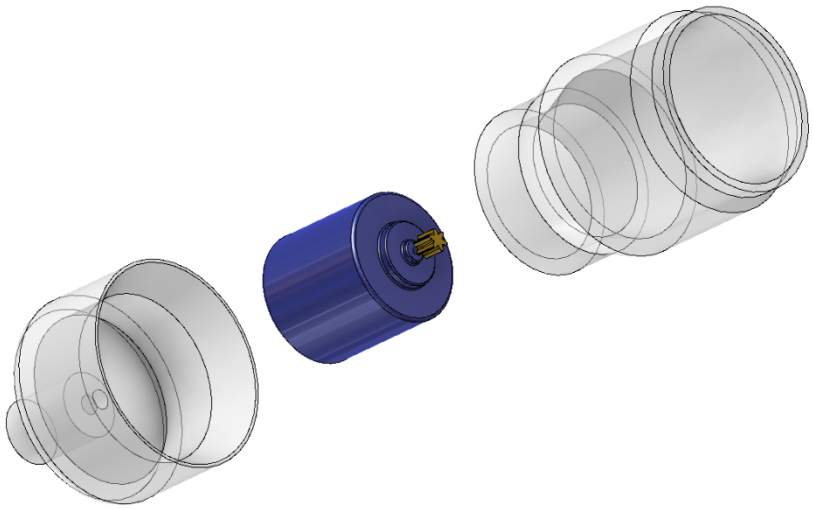


Figure 5. Drive motor

Arm Lock

This part functions to maintain the arm at a specific position or length.

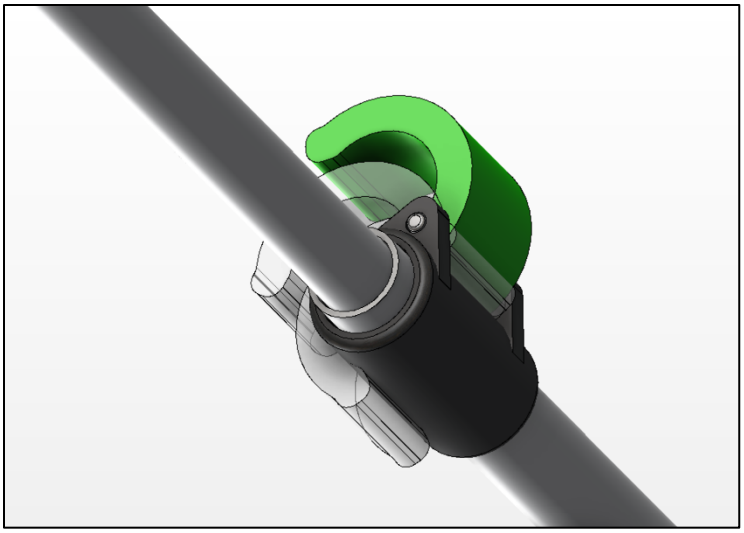


Figure 6. Arm lock

Control Switch

It is a control system whose working principle is that when a button is pressed, it will rotate the electric motor and then rotate the lamp holder clockwise or counterclockwise. The buttons are located on the lamp changer handle, which consists of two buttons that will return to their original position (no electrical current connection) when stopped being pressed. One button is for rotating the lamp holder clockwise and the other button is for rotating the lamp holder counterclockwise. Figure 7 shows the position of the buttons on the lamp holder handle and also the position of the battery with an output of 12 volts. Meanwhile, the planned switch model that will be used is shown in Figure 8.

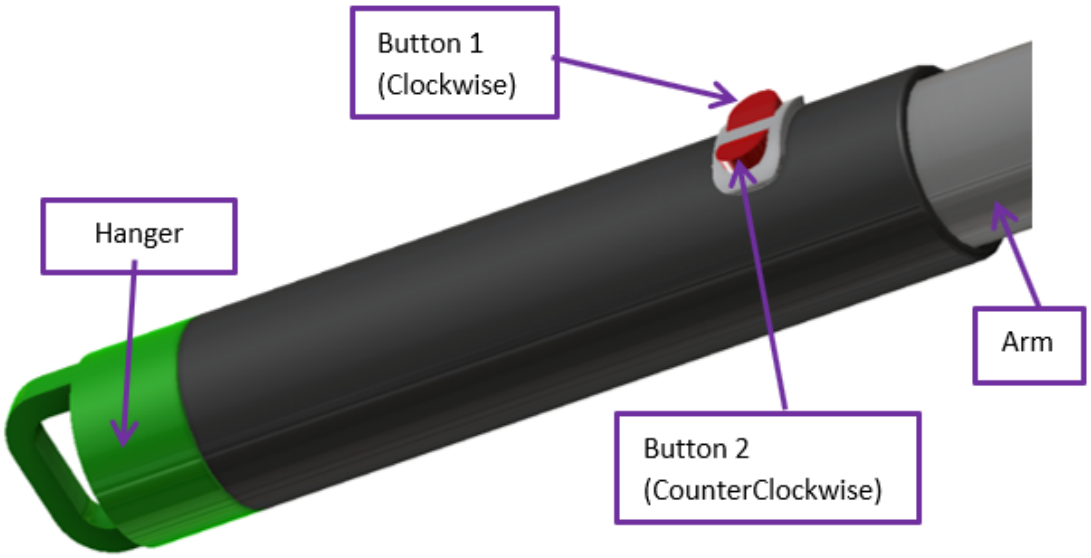


Figure 7. Control switch

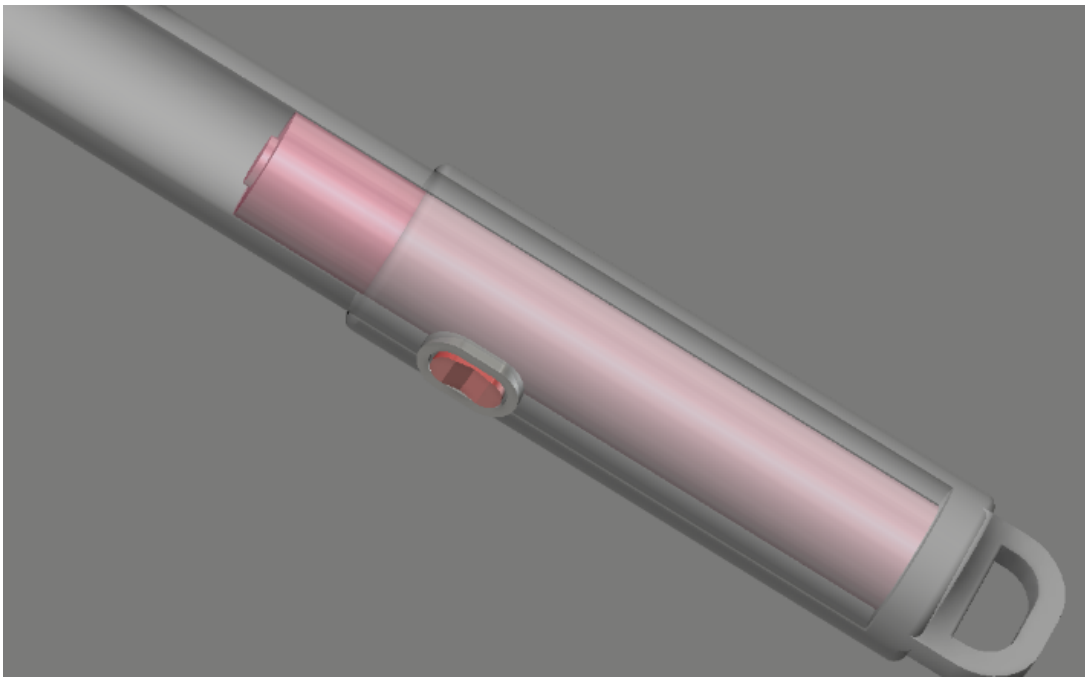


Figure 8. Battery position

Rapid Upper Limb Assessment (RULA)

It is a method to determine the ergonomic level (comfort) of a product when used. This method is based on assessing the risk level of injury to a person's body parts and muscles when performing activities with a particular product (tool). In this paper, an assessment of the injury level of a person when using a lamp changer is simulated using CATIA V5 R17 software. Human modeling (manikin) is done using a female model with an average Asian height. This human modeling is then arranged to represent the actual human position when using the lamp changer product. After that, it is analyzed using the RULA method, and the results are shown in Figure 9.

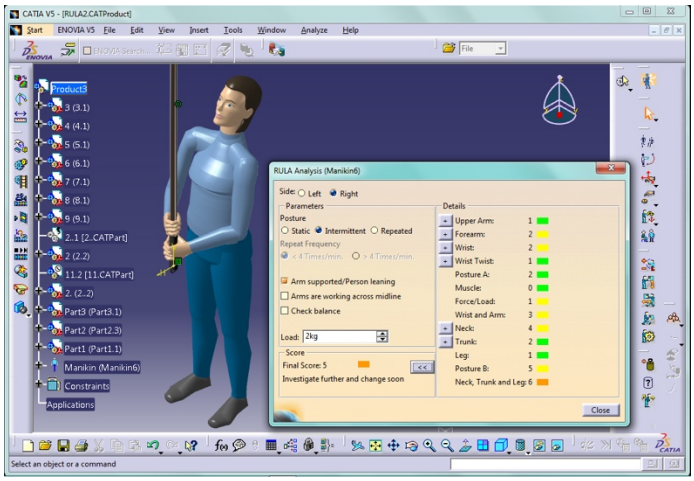


Figure 9. RULA analysis using CATIA V5 R17 (right side)

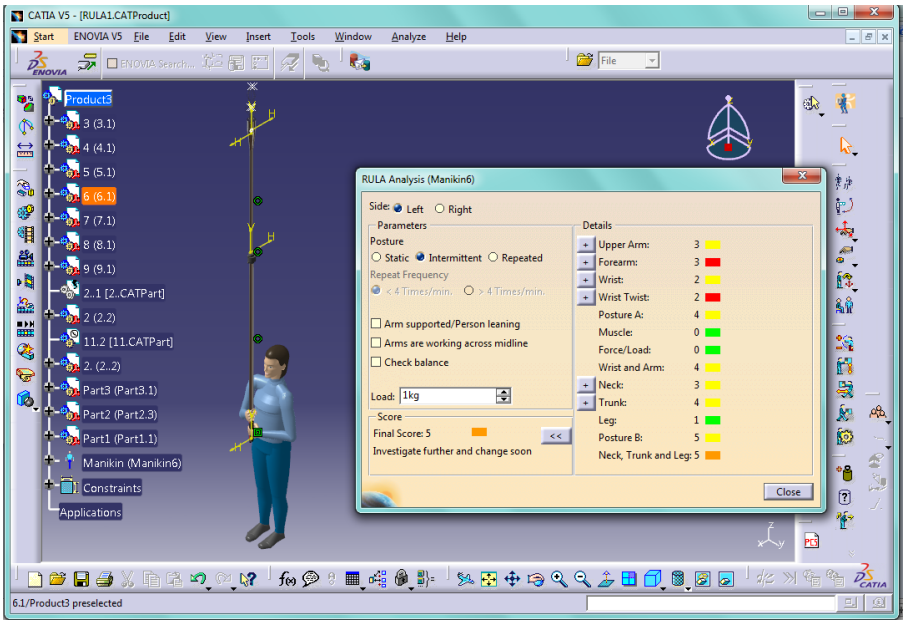


Figure 10. RULA analysis using CATIA V5 R17 (left side)

Based on the RULA analysis in Figure 9 (for the right manikin side) and Figure 10 (for the left manikin side), it can be seen that the final score is 5. This final score represents the risk level of injury from using the tool. The number 5 indicates a medium risk level of injury. This cannot be denied because the main object, the ceiling lamp, is above the operator or the person who will replace the ceiling lamp. This condition inevitably forces the operator to slightly pull their back and slightly tilt their head up. This position causes the risk of injury to reach a score of 5. Both Figure 9 and Figure 10 show the risk level for the back and neck positions being at level 6.

The modeling of the lamp changer tool usage shown in Figure 9 and Figure 10 is a proposed body position that minimizes the risk of injury when replacing ceiling lamps with this lamp changer tool. It is possible for the operator to use positions other than those shown, and this is entirely the operator's right. However, it is important to remember that using positions other than the proposed ones will increase the risk of injury, which is important to consider.

CONCLUSION

Based on the insights presented, the "Easy Ceiling Lamp Changer with Adjustable Arm" product design offers several significant advantages. The integration of a control switch system with a motor for lamp rotation greatly simplifies the task of removing and installing ceiling lamps, making the process much more convenient for users. Furthermore, the adjustable arm concept, featuring a two-way (pulling and locking) hand motion, substantially contributes to the tool's ease of use and time efficiency. The strategic use of aluminium as the primary material, complemented by plastic components, effectively minimizes the product's overall weight while maintaining good strength. Moving forward, it would be beneficial to conduct extensive user testing across diverse demographics to gather feedback on usability and identify areas for refinement. Additionally, exploring alternative lightweight, high-strength materials or modular design components could

further enhance the product's value and adaptability, potentially opening avenues for wider market adoption.

REFERENCES

Arifin, A. A., Indarmawan, K. B., & Patriawan, D. A. (2022). Perancangan dan pengembangan produk CNC mini 2 axis dengan metode Quality Function Deployment (QFD). *Politeknik Negeri Tanah Laut*, *9*(2), 90–98.

Aulia, A. S., Karmiadji, D. W., & Sudiro, S. (2018). Penerapan DFMA pada desain produk mobile file berbasis kompleksitas produk dan proses. *Jurnal Ilmiah TEKNOBIZ*, *8*(1), 23–28.

Comunian, R., Faggian, A., & Jewell, S. (2015). Digital technology and creative arts career patterns in the UK creative economy. *Journal of Education and Work*, *28*(4). https://doi.org/10.1080/13639080.2014.997683

Firdhaus, A., & Santoso, D. T. (2022). Analisis design for assembly dinding mesin power thresher. *Univ. Singaperbangsa Karawang*, *10*(2), 79–84.

Ichsan, K., & Hafizh, I. (2021). Re-desain produk wellhead untuk menurunkan cost dan waktu instalasi dengan metode DFMA. *Jurnal Teknik Mesin Unsyiah*, *9*(1), 20–24.

Kačerauskas, T. (2015). Technologies in Creative Economy and Creative Society. *Technological and Economic Development of Economy*, *21*(6). https://doi.org/10.3846/20294913.2015.1036325

Kumpulainen, K., Mikkola, A., & Jaatinen, A. M. (2014). The chronotopes of technology-mediated creative learning practices in an elementary school community. *Learning, Media and Technology*, *39*(1). https://doi.org/10.1080/17439884.2012.752383

Luqyana, D., Ilham, M. I., Symaidzar, R. D., Raissa, Z. Y., & Annas, M. S. (2019). Analisis desain produk dengan metode DFMA untuk talenan berpemotong. *Prosiding Seminar Nasional Teknik Mesin – Politeknik Negeri Jakarta*, 1080–1084.

Marques, L., & Borba, C. (2017). Co-creating the city: Digital technology and creative tourism. *Tourism Management Perspectives*, *24*. https://doi.org/10.1016/j.tmp.2017.07.007

Muchlis, A., Ridwan, W., & Nasibu, I. Z. (2021). Rancang bangun mesin CNC (Computer Numerical Control) laser dengan metode Design for Assembly. *Jambura Journal of Electrical and Electronics Engineering (JJEEE)*, *3*(1), 23–27.

Nasution, Z. M., Sari, D. Y., Nabawi, R. A., & Rifelino. (2022). Metode perancangan produk dalam teknik mesin. *Univ. Negeri Padang*, *4*(3), 20–29.

Putri, S. L. N., Sutrisno, A., & Punuhsingon, C. (2020). Penerapan metode quality function deployment untuk pengembangan desain produk. *Univ. Sam Ratulangi*, *9*(1), 1–9.

Timoshenko, A., & Hauser, J. R. (2019). Identifying customer needs from user-generated content. *Marketing Science*, *38*(1), 1–20.

Urlich, K. T., & Eppinger, S. D. (2016). *Product Design and Development* (6th ed., Ed.). Penerbit Mc. Graw Hill, Inc.

Weingarten, E., Meyer, M. W., Ashkenazi, A., & Amir, O. (2020). Human Experts Outperform Technology in Creative Markets. *She Ji*, *6*(3). https://doi.org/10.1016/j.sheji.2020.07.004