Portable Extendable Dining Table

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Abstract

Rapid urban expansion and the prevalence of small living spaces present a challenge for city dwellers seeking space-efficient and versatile furniture. This research project revolves around developing and evaluating a Portable Extendable Dining Table tailored to the specific needs of small house residents. The project's objectives encompass crafting a functional portable extendable dining table and conducting comprehensive calculations and simulations for this table. The project's scope includes designing a table with a maximum load capacity of 55 kg, suitable for flat surfaces, featuring a mechanical system based on gears and linkages, primarily for opening and closing the table flaps. Materials employed comprise rubberwood for the table's body, linkages, and gears for the mechanism, caster wheels for mobility, and a shunt DC motor for power. The methodology encompasses multiple aspects, including defining project functions, material selection, conceptual design, cost estimation, and more. Key findings indicate a favourable reception of the Portable Extendable Dining Table among small house residents, thanks to its adaptability and convenience, with a clear trend favouring sleek, minimalist designs and user-friendly extension mechanisms. The discussion emphasizes the significance of functionality analyses. Future work may focus on enhancing the mechanical system, refining the overall design, and incorporating smart features, making the Portable Extendable Dining Table a promising solution for those in compact living spaces.

1. Introduction

Everyone needs a comfortable home, and the environment around it impacts one's quality of life. Every house, no matter how big or tiny, must have a kitchen and a living room that need to be furnished. A dining table is among the pieces of furniture that must be present, particularly for tiny homes, which focus on smaller spaces for more sustainable living [1]. The environmental effect of small houses may be significantly decreased by using flexible and efficient equipment or furniture that is foldable, modular, space-saving, and/or multipurpose [2].

Because there isn't enough space, most people live in small buildings or apartments in some of the world's most densely populated cities. Foldability in a furniture item's design makes it more portable and more convenient

to use, especially in small places [3]. The challenge of small, enclosed spaces is addressed by improving modularity and multifunctionality in design [4].

While folding tables have been around for quite some time, their users still need help. Even though a folding table can be an excellent substitute for a standard dining table because of its space-saving trait to enable the available space to be used economically, there are also many flaws. Some of them are time-consuming and energy-draining to be unfolded. That does not include the safety factor that can cause injuries to the user.

Although not every folding table requires a lot of energy to open and close, there is one flaw that all folding tables share: the user becomes uncomfortable having to constantly open and shut the table manually. This problem can burden people who rush to set their table for their meals or elderly users. Hence, this project is made to overcome this problem by creating a button-pressed folding dining table to help multitask and make it easier for the users.

Nomenclature
F_y Force at the y-axis
M moment
M_{xx} moments about section X-X
M_{max} maximum bending moment
σ_b bending stress

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2. Literature Review

Many different types of folding tables have been created and used today. Among them are extendable dining tables, sets of dining tables, and flip-folding tables. Everything is widely sold in the market. This product is suitable for use by the community and commercially. This product has the advantage of being able to extend and shorten the table as desired up to a certain size. A fixed board mounted on a frame makes up an extended table. The frame is made up of two parallel extension tubes. The extension tube features an outer tube that receives two inner tubes. The outer tube has a gear wheel, and each of the two inner tubes has a gear rack that engages with the gear wheel, allowing the two inner tubes to move synchronously. The outer end of the inner tube is equipped with a moving component. Each movable board has one side attached to the moving component and the other end placed on the fixed board. Movable boards may be brought together to create a small tabletop or pulled apart to form an extended tabletop with the fixed board. Each inner tube has a lifting component that elevates the moveable board for simple expanding and retracting operations.

3. Methodology

The methodology is a flow of a process needed to achieve the project's objectives. In this case, the methodology of this process is all about improving the current extendable dining table by adding slide-crank and gear mechanisms [5].

3.1 Methods

This project was followed in a series of steps. First, we reviewed the literature to better understand the Portable Extendable Dining Table better. Then, we carefully selected the components according to certain criteria. We then created a computer-aided design (CAD) model of these components in SolidWorks. After completing the CAD model, we ran a simulation to visualize the load patterns. Using this 3D model, we developed a prototype and refined it until it was ready for final testing. The project was finalized by including the work process and test results in the report.

3.2 Materials

The material selection process has been carried out by following the aspects outlined below for guidance. The essential factor that should be considered in material selection is its strength [6]. The rubberwood base material was used in this project [4]. The different wood's strengths need to be considered: tensile, compressive, and yield strength [7]. The material chosen for the linkage mechanism is made of aluminium. The reasons for the selection are this material is suitable for its durability and strength in operating the opening and closing sequence of the table. This project will also use caster wheel tires, and the material for them is based on synthetic rubber. The tire was chosen because of its ability to move around the table easily. The selected material for the gear is aluminium [8]. This material was chosen because of the strength it holds to withstand the torque to move the table flaps.

3.3 Equations

This study involves several equations such as the bending moment and bending stress. These equations analyze the force based on the free-body diagrams drawn in Fig. 1.

Given the width of the table is 4.40 cm, and the height is 76 cm.
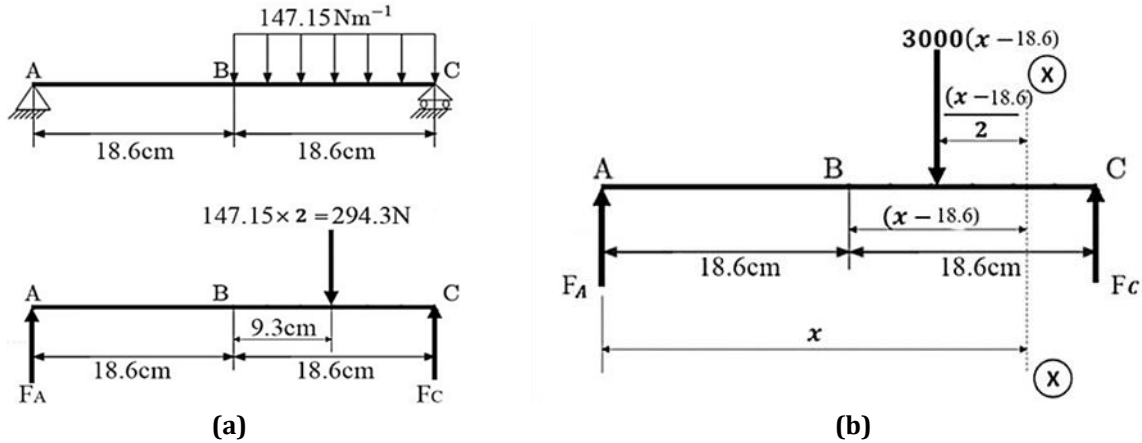
Fig. 1 *Free-body diagram for (a) equilibrium; (b) moments equation*

Applying the conditions of equilibrium,

$$\sum F_y = 0 \ (\uparrow \ +ve, \downarrow \ -ve)$$
$$F_A + F_C - 294.3 = 0$$
$$F_A + Fc = 294.3\text{N} \tag{1}$$

Taking moments about A,

$$\sum M = 0 \ (\circlearrowright \ +ve, \circlearrowleft \ -ve)$$
$$-F_C(37.2) + (294.3)(27.9) = 0$$
$$F_C = 220.725\text{N} \tag{2}$$

From Equation (1),

$$F_A + F_C = 294.3\text{N}$$
$$F_A = 294.3 - 220.725$$
$$F_A = 73.575\text{N}$$

Consider any section X-X acting at a distance x from A,

$$\sum M = 0 \ (\circlearrowright \ +ve, \circlearrowleft \ -ve)$$

Taking moments about section X-X,

$$M_{xx} = F_{Ax}x - 147.15(x - 18.6) \times \frac{x - 18.6}{2}$$
$$M_{xx} = 73.575 \, x - 73.75(x - 18.6)^2 \tag{3}$$

To find out maximum bending moment,

$$\frac{d}{dx}(M_{xx}) = 0$$
$$\frac{d}{dx}[73.575x - 73.75(x - 18.6)^2] = 0 \tag{4}$$
$$73.575 - 73.75 \times 2(x - 18.6) = 0$$
$$73.575 = 73.75 \times 2(x - 18.6)$$
$$1 = 2(x - 18.6)$$

$$\frac{1}{2} = x - 18.6$$
$$0.5 + 18.6 = x$$
$$x = 19.1$$

To find out the maximum bending moment and bending stress,

$$M_{max} = 73.575 \times 19.1 - 73.75(19.1 - 18.6)^2 \tag{5}$$
$$M_{max} = 1386.845 \text{Ncm}$$
$$M_{max} = 13.86 \text{Nm}$$

$$\sigma_b = \frac{M_{max}}{Z} = \frac{13.86 \times 1000}{\frac{1}{6}bd^2} = \frac{13.86 \times 1000}{\frac{1}{6} \times 4.4 \times 76^2} \tag{6}$$
$$\sigma_b = 3.272 \text{MPa}$$

4. Result and Discussion

Fig. 2 shows the drawing of the full assembly of the Semi-Automatic Folding Dining Table. The main components are the frame, linkage, flap, gear, and wheel. The general operating procedures for Portable Extendable Dining Table could be explained below:

- The table is put in the right place.
- The wheel is tightened.
- The switch is turned on to open the table, wait for it to open, and then close it.
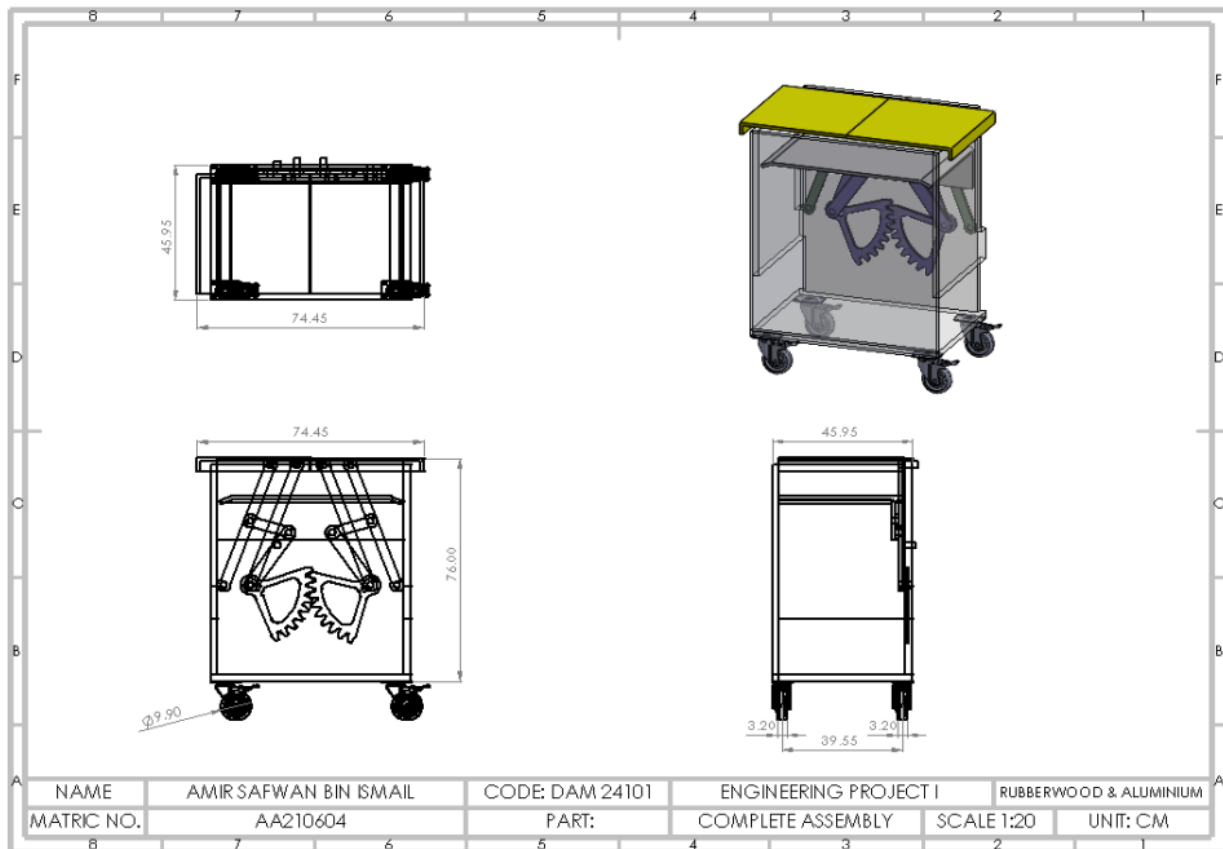- The switch is turned on to close the table, then wait until it closes.

Fig. 2 *Full Assembly of Semi-Automatic Folding Dining Table*

Table 1 *The cost of every component for the table*

No.	Component	Quantity	Amount (RM)
1	Wave 125 4HT Gear	2	176.00
2	Energizer Max 9V 1s 522BPIG	1	14.50
3	Grinding Wheels 2S 100*1.2	13	12.00
4	Iron Cutter	4	7.50
5	Plastic Bag	2	0.40
6	Chemi Bond Carpenter 7661 150 gms	1	3.90
7	Door Hasp 3In1 Set FJC3*VS	1	2.50
8	Super Glue Cry 502-13G	1	1.90
9	Bracket *PCS 40*40*30	1	5.30
10	KCD1 KCD-1 117S21x 15mm Rocker Switch	1	4.90
11	12V-24 V High Speed DC Small Motor Bracket RS-775	1	31.80
12	Single Core Signal Jumper Wire 18AWG Red, 2 mm	1	2.90
13	Single Core Signal Jumper Wire 18AWG Black, 2 mm	1	5.90
14	Quality 9 V Battery Snap Connector	1	6.55
15	Heavy Duty Rubber Flat Plate Castor Wheel with Stopper, 1.5" (38 mm)	4	22.66
	Total		298.71

The costs for all components of the Portable Extendable Dining Table are listed in Table 1. The estimated cost to construct this prototype is RM 298.71. Portable Extendable Dining Table is shown in Fig. 3(a) and Fig. 3(b). Based on the testing, the mechanism works as wanted, but the movement is slightly jagged. However, the table flaps need to be moved by hand because the motor in Fig. 3(c) does not have the required torque and power to move the mechanism. The front of the flaps does not have supports to keep them balanced when closed.

In Fig. 3(d), two loads of 5 kg water tanks are applied on both table flaps, and the flaps can withstand the loads well. Meanwhile, in Fig. 3(f), two students test comfortability by sitting on a chair while putting their books and papers on the table. Both rated the steadiness and stability of the table 8/10, while the table's safety is 6/10. Strength testing for both flaps refer to Fig. 3(d). The water tanks are set to be 14 cm in each other from the middle of the table (as the origin point). The distance is determined by moving the water tanks 7 cm apart.

Thus, using a protractor, measure the degree of bend of the flaps, θ. From this, it can be concluded that the degree of bending of the flaps decreases as the distance between the water tanks increases. The mechanism for the table is shown in Fig. 3(e). The first picture is the opening sequence of the table where the gear on the left with the motor rotates the linkage connecting to the flap. This process happens simultaneously for the right side as well. The second picture shows the closing sequence where the same thing happens, but the motor rotates anti-clockwise instead and makes the gears rotate to close the table. From the results of the tests, both objectives were achieved: to produce a functional portable extendable dining table, and to analyze the calculation and simulation for the portable extendable dining table.
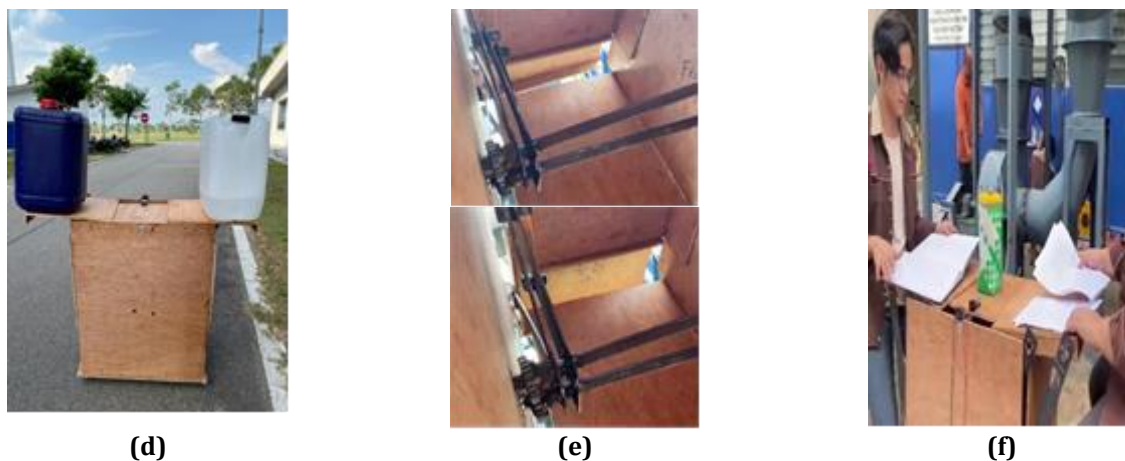

(a)

(b)

(c)

(d)

(e)

(f)
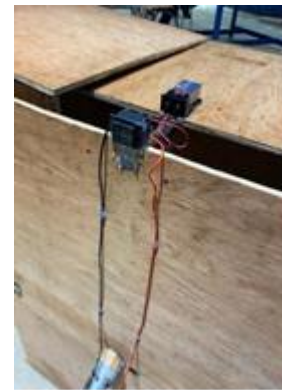
Fig. 3 *Procedures (a) (b) the test for opening and closing the table flaps; (c) testing for motor; (d) for applying loads on both flaps; (e) mechanism of the table; (f) testing for comfortability for two peoples*

4.1 Google Form Survey Analysis

Fig. 4 shows the responses of 30 students from Universiti Tun Hussein Onn Malaysia to our survey form about the portable extendable dining table. We received a positive response from the students on our project, which is a great contribution to the development and completion of our project.

The community was asked 6 questions about the use of a Portable Extendable Dining Table. In the first question, 57.5% of respondents agreed that the cost of the table was low. The second question was about the minimum number of people needed to lift the table. 50.0% were of the opinion that at least two people are required. The third question showed that most respondents agreed with the use of wheels to move the table.

Next, 70% of respondents agreed with the maximum weight that the table can support which is over 70 kg. In the next question, 70% of respondents agree with the use of a switch to open and close the table to save time. The final question concerned the public's opinion on the effectiveness of our product in solving the problem of limited space. All respondents agreed with the effectiveness of our product.
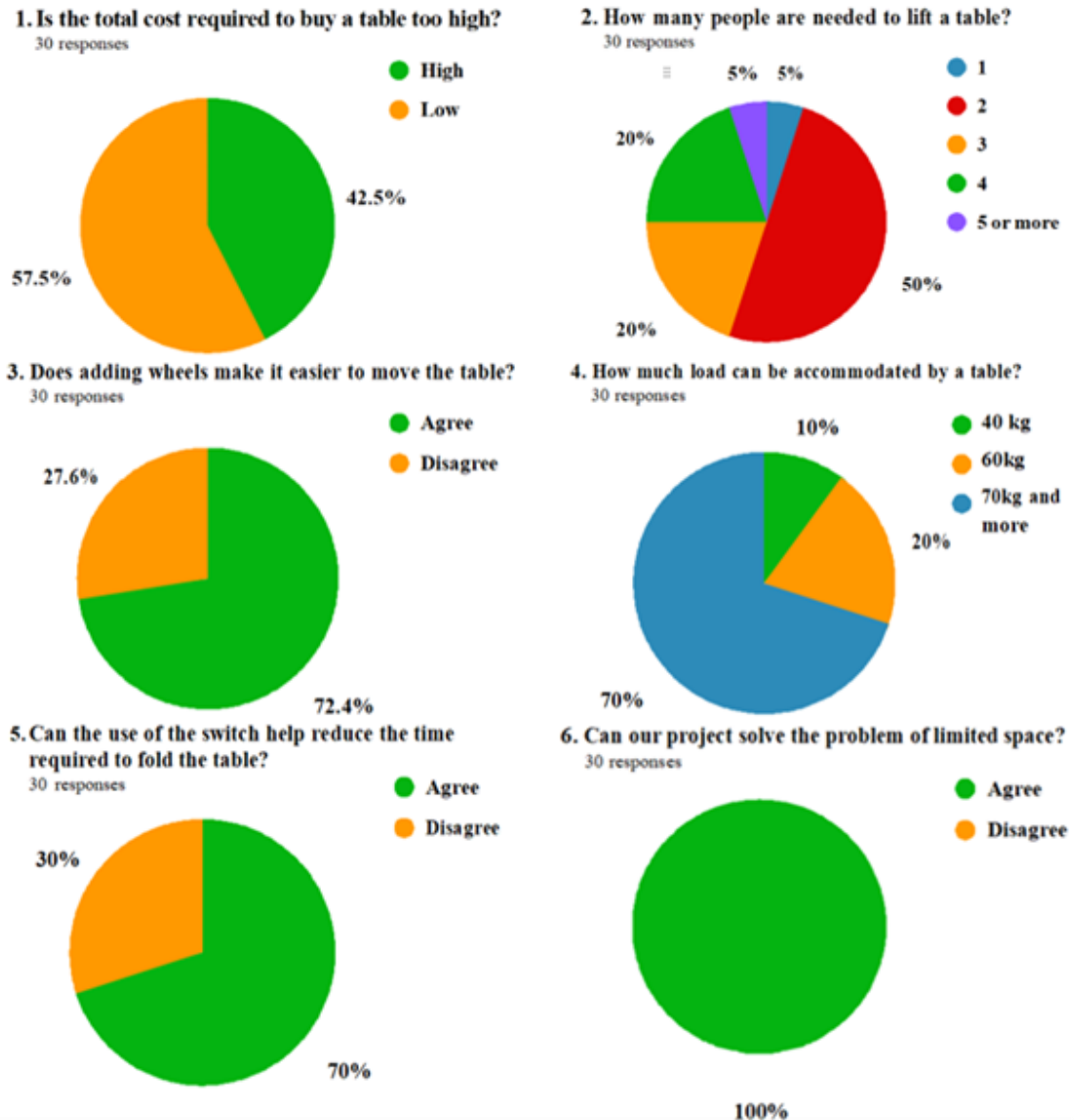
Fig. 4 *Responses from 30 college students at Universiti Tun Hussein Onn Malaysia*

4.2 Engineering and Body Structure Analysis

The purpose of the material specification is to show the specifications of elastic modulus, Poisson's ratio, shear modulus, mass density, tensile strength, compressive strength and yield strength and the overall dimensions of Table 2. In addition, certain product information has been created based on data that conforms to standards. Table 2 shows the product specifications of the machines designed in this study.

Table 2 *Material Specifications*

Material Specification	Description
Elastic Modulus	1.25×10^{10} N/mm^2
Poisson's ratio	0.36
Shear modulus	3500000 N/mm^2
Mass density	560 kg/m^3
Tensile strength	5500000 N/mm^2
Compressive strength	8600000 N/mm^2
Yield strength	25500000 N/mm^2

Penerbit
UTHM

Overall dimension	1350 mm × 400 mm × 760 mm

The findings of the Von-Mises stress analysis for the opened flap and closed flap are depicted in Fig. 5. The pressure reaches a maximum value of 1.62×10^5 N/m^2 when opened and 7.03×10^5 N/m^2 when closed.
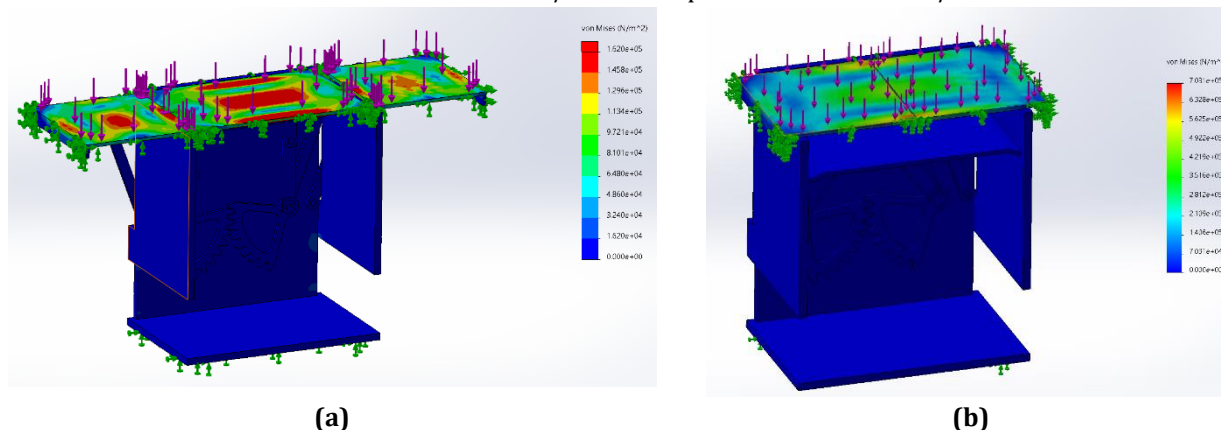

(a) **(b)**

Fig. 5 *Von-Mises stress analysis results (a) Opened flap; (b) Closed flap*

Acknowledgement

Conflict of Interest3

There is no conflict of interest with this paper, as it was identified by the authors.

Author Contribution

The authors have contributed to this past of the paper as follows: **study conception and design:** *Amir Safwan Ismail;* **data collection:** *Ahmad Basri Adnan, Mahmod Abd Hakim Mohamad;* **analysis and interpretation of results:** *Tuan Mohd Hafeez Tuan Ibrahim, Abdullah Wagiman;* **draft manuscript preparation:** *Muhammad Shahrul Zulkeflee, Nurfarahin Onn. All authors reviewed the results and approved the final version of the manuscript.*

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