

# To Design a Fire Extinguisher Ball Launcher Attachment to Drone

Wan Muhammad 'Izzat Ruzain Mohamad Rudi <sup>1</sup>, Abd Khalil Abd Rahim <sup>1\*</sup>

<sup>1</sup> Department of Mechanical Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

\*Corresponding Author: [khalil@uthm.edu.my](mailto:khalil@uthm.edu.my)

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## Abstract

Countries like China, India, and America have already started using drones for these operations, which increases the percentage of survival and thus gives more percentages to rescue and put out fires. Some of the products use water, and some use fire extinguishing balls. This project is the design of a fire extinguisher ball launcher as the newest technology of this design was designed to only drop them from a higher ground. As mentioned before, dropping the FEB could cause damage to the drone. Drones need to fly above the fire source, thus causing updraft forces to be inflicted on the drone. These forces can cause drone pilots to lose control, which can result in drone crashes.

## 1. Introduction

These Drones are multifaceted pieces of equipment that have risen to provide an enhanced solution that can adapt to various categories, which are aerial imagery and mapping, inspections, search and rescue (SAR) operations and agriculture [1]. This research paper focuses on drone application in SAR operations involving fire accidents or situations. The characteristic of the fire itself, which is unforeseeable, makes it tremendously dangerous and has the potential to cause permanent damage to one's life. In less than a minute, a small flame can be turned into a large-scale flame due to the fire's properties and its surroundings [2].

The average rate of fire accidents in Malaysia was around 1024.67 fires per million populations per year from 2006 until 2014. Converting the data to the rate of fire victims per million people in Malaysia was approximately 7.53, with 3.07 fatal consequences per million populations per year [3]. In order to solve the problems mentioned, which involve fire, we suggest the use of drones. To be more specific in our approach to reducing the worst possible outcomes from fire incidents, we propose the use of firefighting drones. Old machinery such as ladders, hoses, and trucks will not be as efficient as using assistance from drone technologies.

The development of buildings, urbanization, traffic, and the material used in construction have the potential to oppose harm to their surroundings when intense heat is applied, which will make firefighters have second thoughts regarding the old method. Approaching an era filled with drone tech, it would be a logical approach to replace the old types of machinery. Moreover, the use of fire extinguishers is still one of the most effective methods to put out flames due to the substances inside them. Drones are smaller in size compared to humans. Therefore, it is suggested to use a fire extinguisher ball due to its similar traits to the normal fire extinguisher but smaller in size [4].

A compressed dry ammonium phosphate mono, which is also known as a fire extinguisher's dry chemical, takes approximately two seconds to explode and release the chemical dry powder stored inside is how the fire extinguisher ball works in a simple explanation [5]. Dropping the fire extinguisher ball using a drone which is located above the fire would be considered to be risky as the pilot has a higher probability of losing control of the drone rather than extinguishing the fire. The force causing the drone to lose control is known as updrafts

originating from the fire itself [6]. In this paper, a different approach has been used: a launcher attached to an Unmanned Aerial Vehicle (UAV) that uses a Fire Extinguisher ball as its bullet. Drone pilots will not have to be flying near the fire itself, resulting in more composed and focused flight operations.

Unmanned aerial vehicle systems (UAS) have found excellent applicability. Throughout the evolution of latest technology, it has developed into a promising technology for a wide range of applications. Meanwhile, health care, an important system in modern society, faces unexpectedly strong pressures. The flexibility of UAS as additional support for health logistics systems under high-stress conditions. The rapid development of Air 11 transportation networks is a definition of a logistics network model [1]. Not only in healthcare but the advancement in technology, the fight against fire remains difficult. With the expansion of the city, our society has turned into a high-rise concrete jungle, which has become inaccessible in crises, especially in the event of a building fire. Advances and developments in drone technology have made it possible to leverage the use of drones for firefighting services [2]. Drone technology is advancing rapidly, with significant progress in GPS navigation and automation. One promising development is morphology technology, which enables drones to change their shape. Our objective is to create a functional morphological fire-fighting drone by combining morphological drone technology with firefighting capabilities. Research has led to a technique for using swarms of these firefighting drones to combat wildfires. By deploying hundreds of drones simultaneously, they can simulate the effect of rain by continuously spraying water or other fluids to extinguish flames. The focus is on developing a self-coordinating system that effectively executes these firefighting tasks [7]. Thus, the objectives of this study are to design a launcher suitable to launch a fire extinguisher ball to a designated target with three different adjustable projectile distance

## 2. Methodology

Fig. 1 shows the flow of the design process.

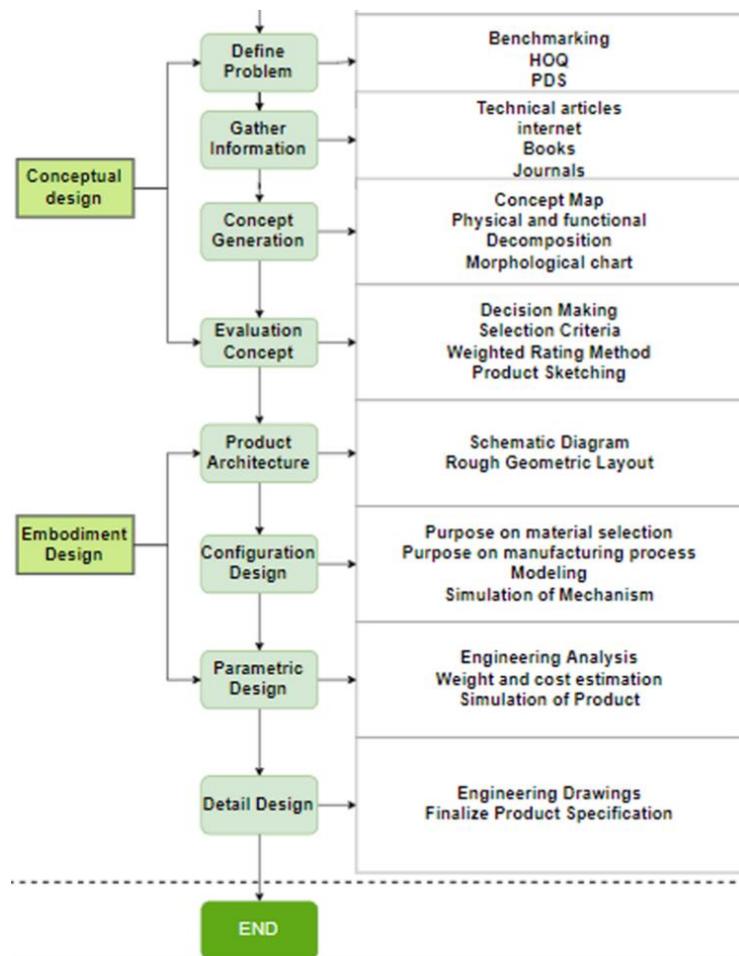


Fig. 1 The flow for the design process

During the conceptual design stage, it is required to set out every possible factual point which undeniably suits their designs while fully considering the engineering characteristics. It is followed by the House of Quality (HOQ), which involves co-relating the needs of customers and transforming them into engineering characteristics

or terms. HOQ correctly facilitates and observes the product's possible features and performance that was initially intended to solve the problem. HOQ is the PDS branch, also known as Product Design Specifications. HOQ was implemented in this step to determine the design's liability due to its close relationship with the needs of the consumer or customer.

Upon completion of the previous step, followed towards idea generation. The generated idea must be based on the previous information gained from the step above. In this stage, an individual's critical thinking and creativity will be tested to create multiple ideas of designs that can fulfil the engineering concepts and customer needs. A brainstorming session can be conducted with individuals who are knowledgeable in the engineering field or even with friends. A further understanding of the problem statement must be made in order to have a smooth discussion or brainstorming session as the generated ideas is align to the problem that individuals or groups were facing.

Furthermore, concept evaluation must be done to complete the previous step. Several methods can be used to evolve multiple concepts into a single concept. Decisions must be made in order to select the most suitable idea to be implemented in the final design. In order to have a correct identification of a good idea, one must relate them to the objectives of the decisions to be made. Onto the last stage of conceptual design, which is the weighted decision matrix. The weighted decision matrix is an evaluation method for multiple concepts to compete with their own speciality and to be arranged one by one according to their design specification with weighing factors. An objective tree diagram comes in handy to guide students to understand the weighted decision matrix.

Embodiment design can be explained in a simple term which is the design concept is translated into a physical state. It involves the three tasks that were Product Architecture, Configuration Design and Parametric Design. In this phase, the parts were given dimensions and adjusted to satisfy the three sustainability pillars.

In the detailed design stage, it can be considered that the product has reached its final stage of completion. The drawn parts were completely assembled and ready to undergo simulations to test the product. On this part, all of the incomplete information will be filled from the arrangements until the material itself is to be filled as well. Cost estimation will be done in this part as how the materials or product being manufactured is to be taken into account as well. The aim of this stage is to decide and make sure that the product itself can be produced and ready to be produced. Updated versions of PDS which is the Product Design Specifications is the decider for the variables mentioned.

### 3. Results and Discussion

The main focus of this process was to ensure the process was to be strictly followed until the completion of the design was achieved. Table 1 shows the table of weightage values in each significance level. One of the best way to identify customer's requirements by observing them in a tree diagram. In an objective tree diagram (Fig. 1), the weightage of the demands was determined based on the importance of the customer's need. A hierarchical objective diagram gives a clear view of their chosen requirements, previously translated into a table form. This method was introduced in order to have a much simpler view and easier understanding for readers to consume in a much more structural and preferred method by many.

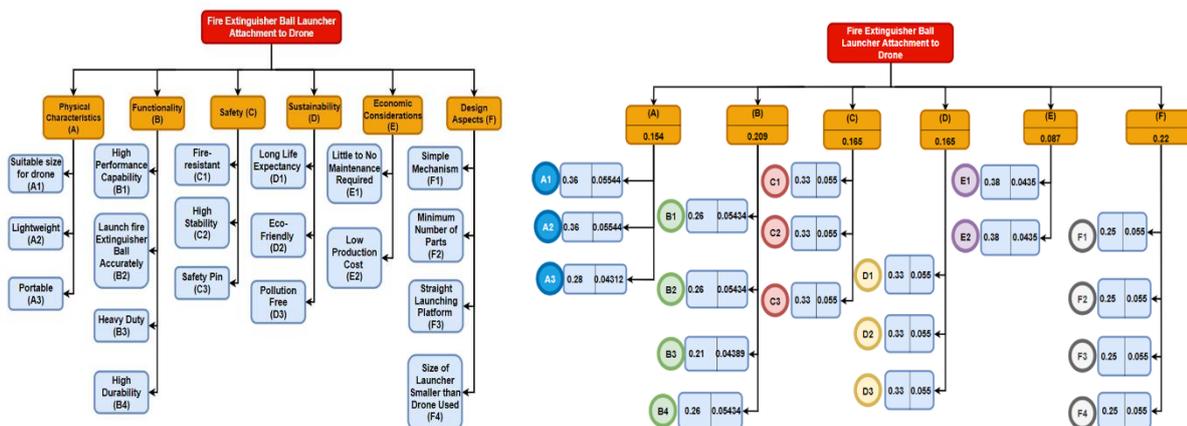


Fig. 1 Objective Tree Diagram with weightage

Table 1 Table of Weightage value in Each Significance level

Customer's Requirements	Score	Average	Weightage
<b>1. Physical Characteristics</b>		4.7	0.154
Suitable size for drone	5		0.36
Lightweight	5		0.36
Portable	4		0.28
<b>Total</b>	14		
<b>2. Functionality</b>		4.8	0.209
High Performance Capability	5		0.26
Launch fire extinguisher ball accurately	5		0.26
Heavy duty	4		0.21
High Durability	5		0.26
<b>Total</b>	19		
<b>3. Safety</b>		5	0.165
Fire-resistant	5		0.33
High stability	5		0.33
Safety pin	5		0.33
<b>Total</b>	15		
<b>4. Sustainability</b>		5	0.165
Long-life expectancy	5		0.33
Eco-friendly	5		0.33
Pollution free	5		0.33
<b>Total</b>	15		
<b>5. Economic consideration</b>		4	0.087
Little to no maintenance required	3		0.38
Low production cost	5		0.38
<b>Total</b>	8		
<b>6. Design aspects</b>		5	0.22
Simple mechanism	5		0.25
Minimum number of parts	5		0.25
Straight launching platform	5		0.25
Size of launcher smaller than the drone used	5		0.25
<b>Total</b>	20		
<b>Total of all values</b>	91	28.5	1.00

### 3.1 House of Quality and Product Design Specification

Fig. 2 shows the House of Quality (HOQ). The House of Quality gives the best piece of design information translated to have a smooth evaluation of potential design concepts. Each engineering characteristic that was translated has its own relative weight and importance. Furthermore, the result obtained was to be used in the design process of this product.

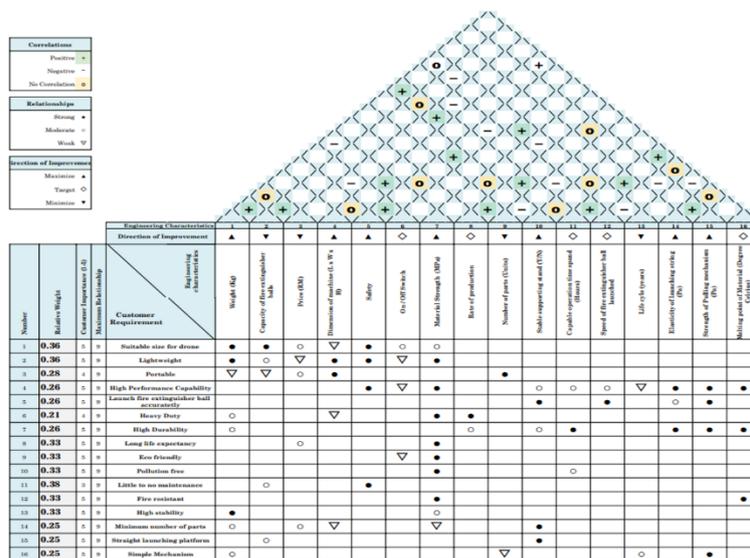


Fig. 2: House of Quality (HOQ)

The product design specifications (PDS) of the fire extinguisher ball launcher attachment to a drone are to be designed based on the information obtained from HOQ. Each of the customer's requirements was outlined with each criteria and components.

### 3.2 Concept Generation

Concept generation will include mapping concepts, physical and functional decomposition, morphological chart and function structure as shown in Fig. 3.

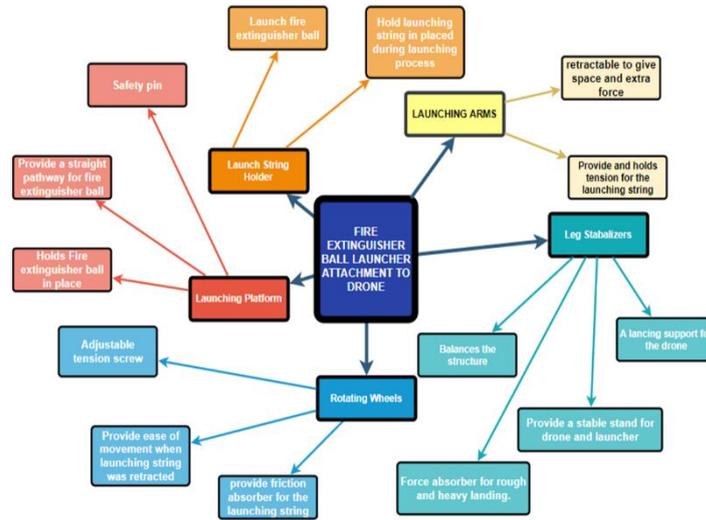


Fig. 3 Mapping Concept of Fire Extinguisher Ball Launcher

Three design concepts were compared, as shown in Fig. 4. Based on all the criteria listed, Design 3 shows the highest weighted rating. The fire extinguisher ball launcher parts involved the main body, launching arms, landing gears, rotating wheels for arms, rotating wheels for the body, rotating rods (  $d = 15$ ,  $d = 20$  ), body connectors and gears Shown in Fig. 5 and Fig. 6.

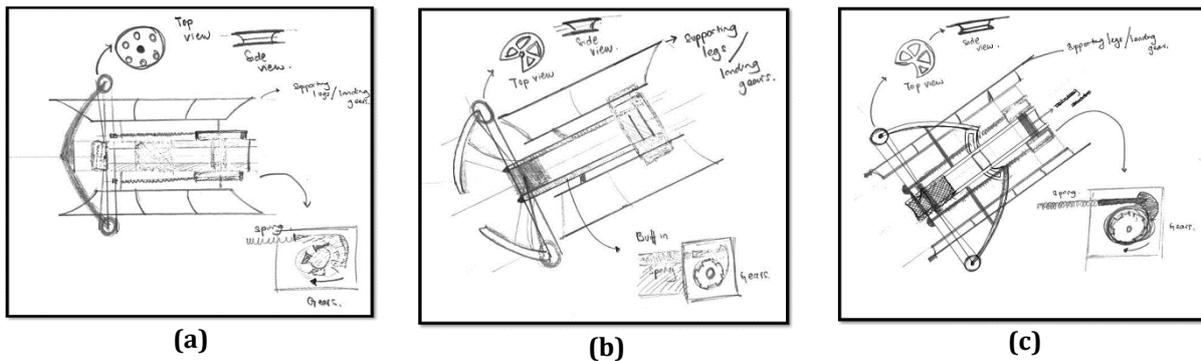


Fig. 4 The design concept of (a) Design 1, (b) Design 2, and (c) Design 3

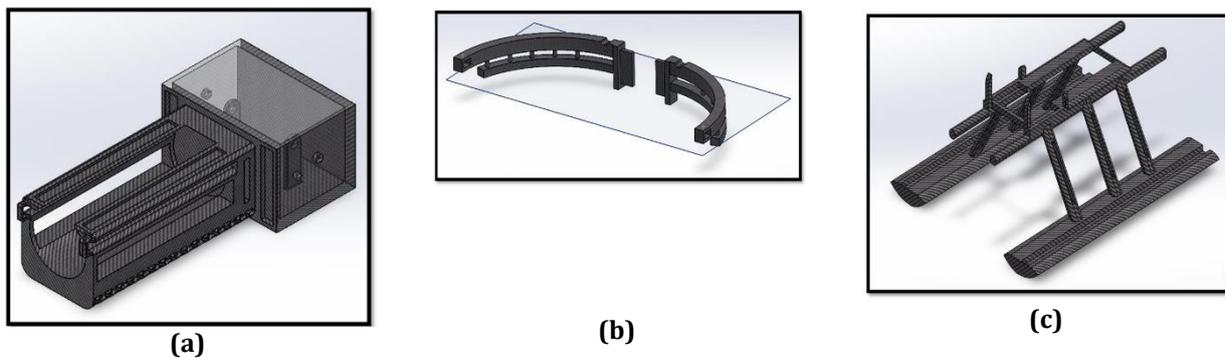
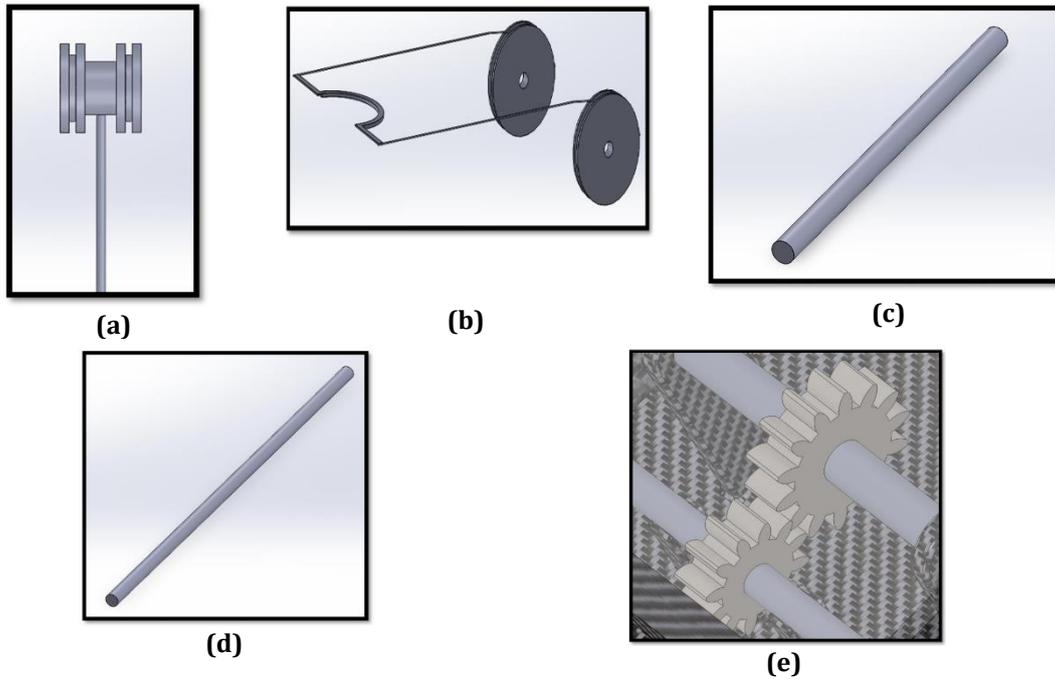
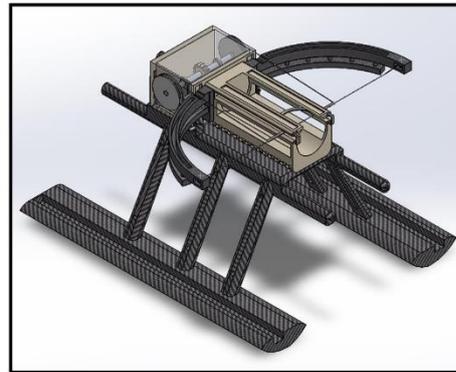


Fig. 5 The fire extinguisher part (a) Main body, (b) Launching Arm, and (c) Landing gear



**Fig. 6** The fire extinguisher part (a) Rotating Wheel for arms (b) Rotating Wheel for body (c) Rotating rods (d) Body connector (e) Gear

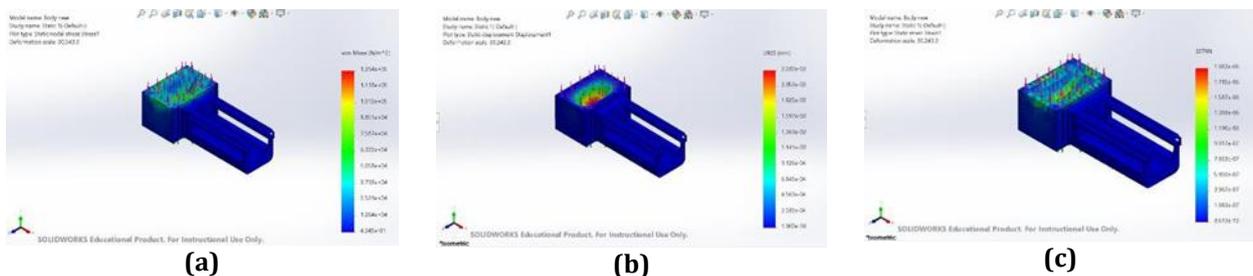
After all of the parts were mated, the final product was a solid and rigid stance, as shown. The string was attached to each of the rollers involved. Fig. 7 illustrates the isometric view of the Fire Extinguisher Ball Launcher.



**Fig. 7** Isometric view of the design

### 3.3 Structure Analysis

This section illustrates and discusses the structural analysis of the launcher. It is separated into 3 major parts: the main body, launching arms and landing gears. Three different analyses were made on the three major parts: stress analysis, displacement analysis and strain analysis. Fig 8 shows the analysis of the main body. The main body should be able to support and withstand the weight of the drone based on the data obtained as the material is strong enough to withstand the pressure.



**Fig. 8** (a) Stress analysis, (b) Displacement analysis, (c) Strain analysis of the main body

Fig. 9 and Fig. 10 show the analysis of the launching arm and landing gear, respectively. Launching arms will face resistance from the gravitational force as it is the only part that must withstand its weight. Especially at the furthest part of the launching arms. In this simulation, the material will be changed from Thornel Mat VMA to Magnesium Alloy as it has approximately the same mass density with 300 Kg/m<sup>3</sup>.

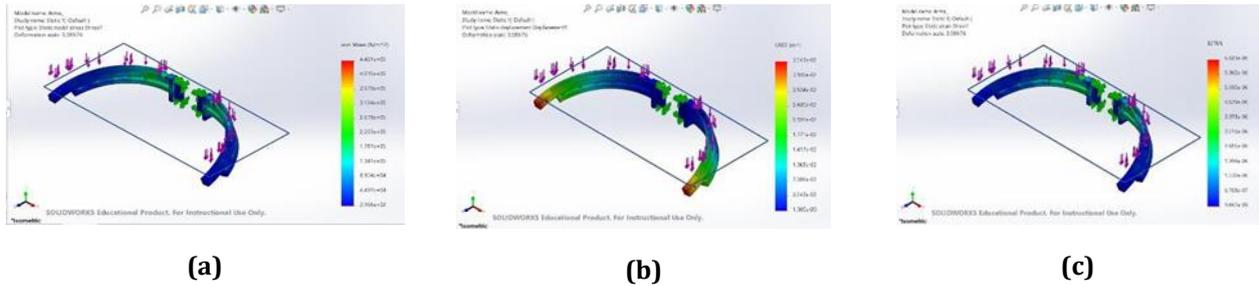


Fig. 9 (a) Stress analysis, (b) Displacement analysis, (c) Strain analysis of the launching arm

Landing gears play a huge role in the stability of the design and will be the crucial part in holding every weight there is on every other part. In this simulation, the material will be changed from Thornel Mat VMA to Magnesium Alloy as it has approximately the same mass density with 300 Kg/m<sup>3</sup>. The force acting on the landing gears was 23.502 Kg, which was the part that sat above the landing gears.

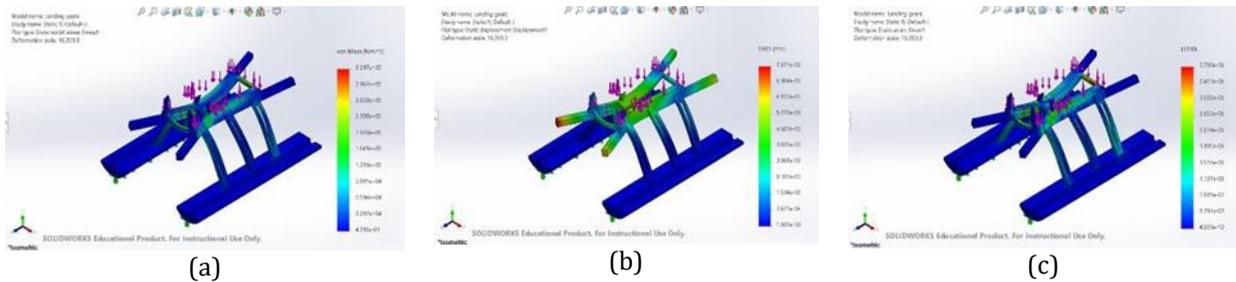


Fig. 10 (a) Stress analysis, (b) Displacement analysis, (c) Strain analysis of the landing gear

### 3.4 Cost Estimation

Table 2 shows the calculation for cost estimation.

No	Part Name	Material	Weight (Kg)	Price	Weight (Kg) x price per Kg
1	Main Body	Magnesium Alloy	17.424	RM 14.59	RM 254.21
2	Launching Arms	Thornel Mat VMA	5.221	RM 485.93	RM 2,537
3	Landing Gears	Thornel Mat VMA	76.926	RM 485.93	RM 37,380.65
4	Rotating Wheels (Main Body)	Hexcel AS4C (300 Filaments)	0.541	RM 176.30	RM 95.37
5	Rotating Wheels (Arms)	Hexcel AS4C (300 Filaments)	0.009	RM 176.30	RM 1.58
6	Rotating rod 20 mm	Hexcel AS4C (300 Filaments)	0.202	RM 176.30	RM 35.61
7	Rotating rod 15 mm	Hexcel AS4C (300 Filaments)	0.100	RM 176.30	RM 17.63
8	Body Connector	Hexcel AS4C (300 Filaments)	0.005	RM 176.30	RM 0.88
Cost estimation of the product by manual Calculation					RM 40,322.93

### 4. Conclusion

The conclusion of this design is the objective of this design has been achieved by overviewing the existing products in the market and designs in various research papers from multiple countries. This product, in particular, has not been in the market as widely as possible. Therefore, the amount of references was limited, as well as aviation material data that was preferably being used. SolidWorks has limited data for carbon fibres and none for aviation materials. These limitations took a toll on the process of designing this product.

This type of product will need further research and understanding as one of the customer's requirements was not achieved, which is the cost of the product. It is considered to be expensive for the price of RM 166,936.93. The implication of a price too high would be even fewer customers to have the urge to purchase this product or even manufacture it. The supply and demand of this product will be low as well as the cost will be too expensive. However, some of the obstacles that were found along the way could be solved, thus reducing the weight and the cost as well. A solution to this problem will be shared in the recommendation section. Fire extinguishing balls are also considered to be one of the newest methods regarding firefighting, and not many countries use them, as well as drone technology.

## Acknowledgement

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## References

- [1] Quintanilla García, I., Vera Velez, N., Alcaraz Martínez, P., Vidal Ull, J., & Fernandez Gallo, B. (2021). A quickly deployed and UAS-based logistics network for delivery of critical medical goods during healthcare system stress periods: A real use case in Valencia (Spain). *Drones*, 5(1), 13, <https://doi.org/10.3390/drones5010013>
- [2] Sujatha, C. N., Lakshmi, P. S., Reddy, Y. S., & Sai, I. M. (2020). Application of fire fighting drone in containment of small-scale fires. *J. Crit. Rev.*, 7, 7533-7539. <https://doi.org/10.31838/jcr.07.19.859>
- [3] Tan, Y. R., Akashah, F. W., & Mahyuddin, N. (2016). The analysis of fire losses and characteristics of residential fires based on investigation data in Selangor, 2012-2014. In *MATEC Web of Conferences* (Vol. 66, p. 00109). EDP Sciences, <https://doi.org/10.1051/mateconf/20166600109>.
- [4] Dixit, A., Singh, A., Pandey, A., Tyagi, A., Sharma, L., Deshmukh, S., & Gupta, P. (2024). Involvement of Drone Technology and Fire Extinguishing Balls in Firefighting. *Educational Administration: Theory and Practice*, 30(5), 2317-2326, <https://doi.org/10.53555/kuvey.v30i5.3282>.
- [5] John Manley (n.d), The Comeback of Fire Extinguishing Balls and their Benefits, <https://www.fire-extinguisher101.com/article1108-fire-extinguishing-ball.html>
- [6] Aydin, B., Selvi, E., Tao, J., & Starek, M. J. (2019). Use of fire-extinguishing balls for a conceptual system of drone-assisted wildfire fighting. *Drones*, 3(1), 17, <https://doi.org/10.3390/drones3010017>.
- [7] Valmiki, S., Chavan, M., Jolada, S., Ladde, M., & Mateen, M. (2024). Fire Fighting Drone Using Fire Extinguisher Ball. *Journal of Scientific Research and Technology*, 27-36, <https://doi.org/10.61808/jsrt117>