Research Progress in Mechanical and Manufacturing Engineering Vol. 3 No. 1 (2022) 921-928
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RPMME

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

A Study on Drone Design for Packages Delivery Services

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DOI: https://doi.org/10.30880/rpmme.2022.03.01.098
Received 01 Dec 2021; Accepted 01 April 2022; Available online 30 July 2022

Abstract: Drone, well-known as an unmanned aerial vehicle, is a flying robot controlled autonomously using a remote control. Drone technology has been seen to be applicable in various applications, such as in the transportation industry. This study investigates the drone's possibilities to ease item delivery for courier services. The use of drones in courier services will shorten the time taken to deliver goods. The objective that needs to be achieved in this study is to identify the parameters involved in developing a drone for courier services. The development of drones must be able to lift and resist a minimum of 5 kg of payload. A design process model by George E. Dieter's approach has been referred to as the methodology. The design of the 3D CAD model of the drone, along with the analysis and simulation, used SolidWorks software. The cost estimation for the proposed drone design is about RM 14,247.46. The drone weight is estimated at 20.1328 kg, and the overall dimension of the drone is 1065.45mm in length and width and 432mm in height. In conclusion, the drone for package delivery services has been designed and theoretically functioned.

Keywords: Drone, Unmanned Aerial Vehicles, UAV, Courier Services, Delivery Vehicles

1. Introduction

Delivery services are one of the earliest pieces of evidence of communication in humans, from engraving words on a lump of clay to using animals to send letters and packages. It is beyond doubt that today delivery services are one of the easiest and most common ways to dispatch and receive goods without face-to-face contact.

As the transportation technology grows, delivering services are becoming faster and more efficient with the existence of heavy goods vehicles that became available for the delivery of a variety of items

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and eventually set the pace for the advancing world of courier service vehicles. With the rapid commercialization of unmanned aerial vehicles (UAVs), there is growing interest in using drones to perform last-mile parcel delivery, defined as the final leg of the delivery process to the customer's home or business. As the demand for commercial deliveries within cities grows, businesses face a fundamental limitation regarding surface road capacity. Drone delivery aims to overcome this limitation by utilizing the vertical dimension above the city streets.

In Malaysia, courier services such as the Pos Laju Sdn Bhd and ABX Express face difficulties delivering packages to their customers, especially in rural areas. This is because most courier services still use the conventional ways of delivering packages to their customers, such as via ground vehicles such as minivans or motorcycles. Nowadays, the conventional delivery methods are not the fastest and most efficient. Being stuck in the traffic could somehow prolong the duration of the packages being delivered. Furthermore, courier services could expose unwanted events such as accidents, which can prolong even more time to deliver the customer packages.

As transportation technology progresses, more prominent companies such as Amazon have initiated a fully autonomous delivery system designed to safely deliver goods to customers in a well-timed manner using drones [1]. This initiative by Amazon has enhanced customer services by providing rapid package delivery. According to Jiyoon Park (2018)[2], a drone that was introduced by the Amazon company called "Octocopters" could deliver packages or parcels up to 25 kg within half an hour to a customer within a radius of 16 km. The application of drones in courier services can help reduce delivery time and potentially conserve energy [3].

Thus, this study has been conducted to propose a drone design that can overcome the problem faced in the delivery services. This study identifies several required parameters in developing the drone for delivering goods, and the proposed design concept for lifting a payload of 5 kg is analyzed. In addition, it is hoped that this study could guide courier service companies in developing a good and well-operated drone based on the existing technologies.

2. Methodology

2.1 Flowchart of Study

A flowchart is commonly used to brief text and graphic elements to give an overview of a multistep process, a theory, or a comparison [4]. Figure 1 shows the flow chart that has been applied from the beginning of the study until the achievement of the expected outcome.

2.2 Design Process

A design process model by George E. Dieter's approach has been referred to as the methodology. The design of the 3D CAD model of the drone, along with the analysis and simulation, used SolidWorks software. The design process consists of 3 phases: conceptual, embodiment, and detailed design [5].

2.2.1 Conceptual Design

Conceptual design is the first phase in the engineering design process. This phase of the design process is an evolution of a product, where several design concepts are generated, evaluated, and then selected for further development. The design process is started by identifying or defining the problem of the study. In this state, the product purpose, problem, and scope of the project are stated. After identifying the problem, the next step is to gather data or information regarding the project. Many methods can be used to carry out this task, such as the internet, journals, questionnaires, and surveys. The next step after gathering information is conception generation. Activities such as brainstorming, functional decomposition, and morphological chart are used in this step. Finally, concept evaluation is the next step in the conceptual design. The weighted rating method and decision matrices are examples of activities or tasks involved in this process.

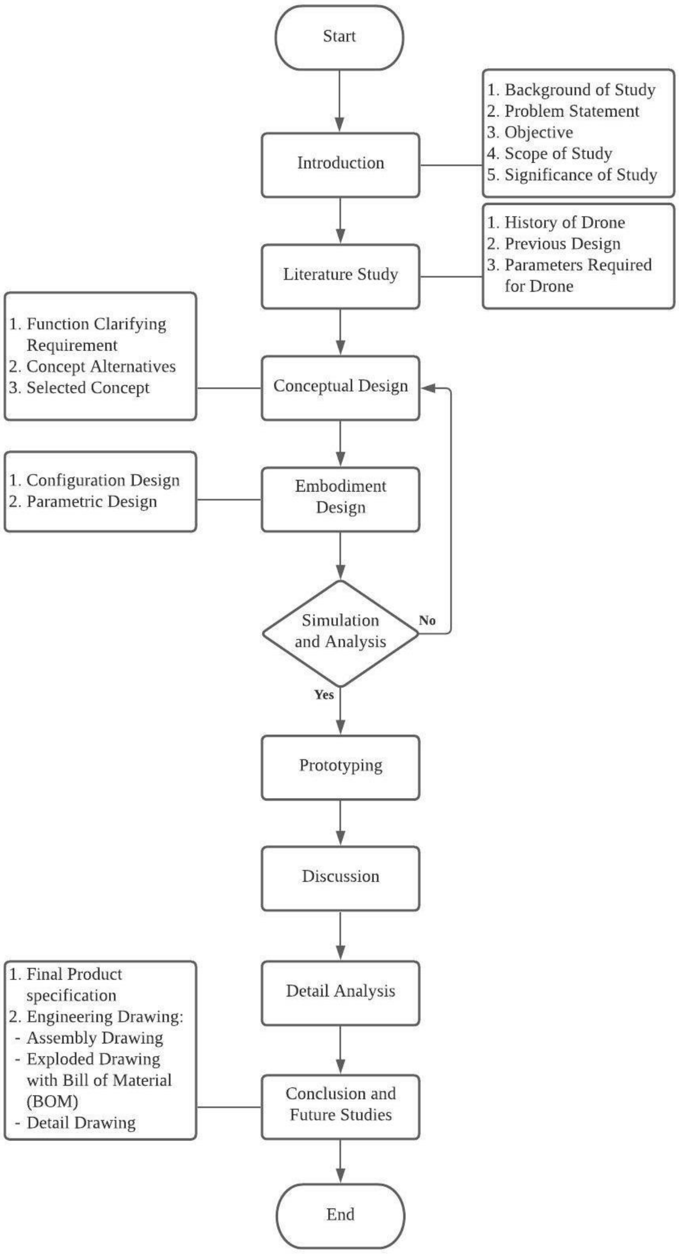


Figure 1: Flowchart of study

2.2.2 Embodiment Design

Subsequent phases are embodiment design, consisting of three main tasks: product architecture, configuration design, and parametric design. In the first task, product architecture, the components' shape, and general dimensions will be established, while the exact and tolerances are established in the parametric design task. In this section, every selection concept was developed further in detail so that the result regarding the product's function need can be obtained. Each of the components may be added with some unique features so that it can deliver better function. For section configuration design, decisions regarding the types of part feature, the number of features, how the features are arranged, and what the relative dimensions are decided. Next, the parametric design starts with information on the configuration of the part and its target to establish its exact dimension and tolerance. Final decisions on the material and manufacturing process are also established if this part has not been done previously. The most crucial aspect of parametric design is to examine the part, assembly, and system for design robustness.

2.2.3 Detailed Design

The final phase of the engineering design process is detailed design. This step of the design phase is brought to the stage of a complete engineering description of the tested and producible product. The detailed drawings present the product specifications and bill of material (BOM). Missing information shall be added to each part's arrangement, form, dimension, tolerances, materials, and manufacturing process. The model is drawn using SolidWorks 2020, including the model's analysis and simulation.

3. Results and Discussion

3.1 Customer Requirement

A researched via internet sources was conducted to gather information needed for this project. The data regarding the customer requirement is gathered from the Computing Technology Industry Association (CompTIA) website, which then will be translated into several aspects of customer requirements. Figure 2 shows the customer rate of their drone experience.

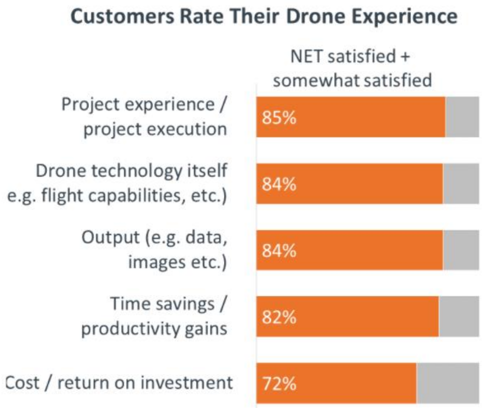


Figure 2: Customers rate their drone experience

Figure 2 shows the NET satisfaction with somewhat satisfied percentages, rated by customers who had already experienced drone technology. From this data, the maximum percentage is 85%, represented by the project experience or execution. The drone technology itself is rated about 84% by the customer. The customer has also rated about 72% on the cost of a drone. Based on the data gathered, we can translate the project experience or execution into several customer requirement aspects: durability, function or performance, technology, environment, and cost. This customer requirement is tabulated in Table 1.

Table 1: The customer requirement

No.	Customer requirement
1	Function or Performance
2	Technology
3	Durability
4	Environmental
5	Cost
6	Appearance

3.2 Development of Drone

The drone's conceptual design for package delivery services is based on the requirement and criteria gathered from the data in Table 1. Figure 3 shows the drone design developed with several sub-assemblies, the propulsion system, the storage, the landing gear, and the frame. The frame sub-assemblies consist of 3 components; the arm, which is mounted to the top, and the base body plate. The propulsion system sub-assemblies consist of the motor and propeller. As for landing gear, it is assembled with the landing gear, which links to the main body, landing gear joint, and the landing stick. The last assembly is the storage which consists of a locking mechanism, storage cover, and customed hinge.

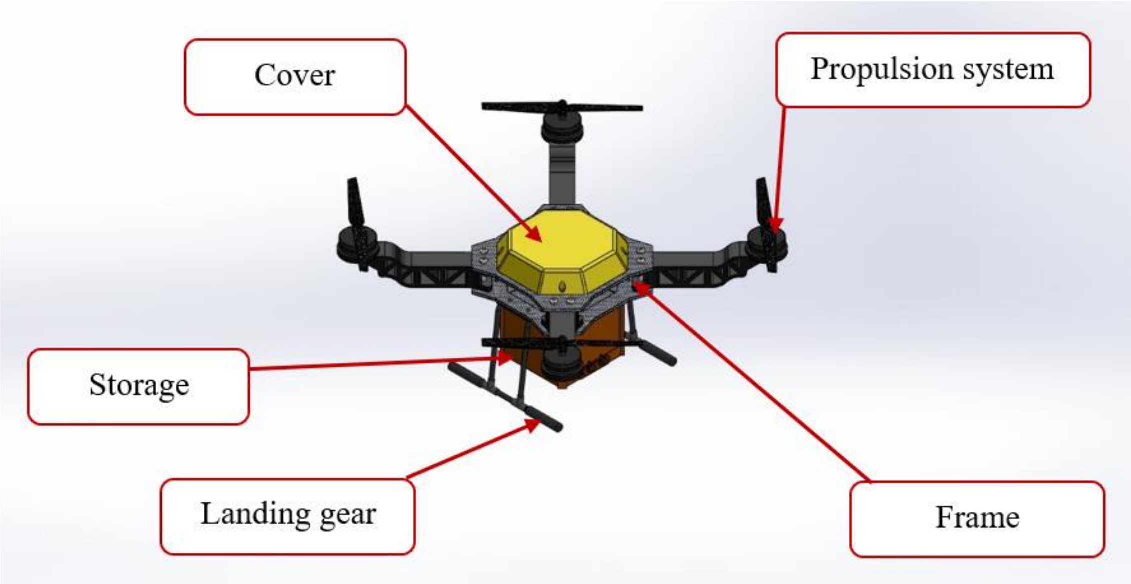


Figure 3: Full assembly of the drone

3.3 Material Selection

The selection of material for each component of the drone plays an essential role in avoiding failure when it is being operated. Besides, it is crucial to ensure the drone is developed using a lightweight material with high-strength mechanical properties to ensure it is safe and able to fly. Table 2 shows the selected material for each component of the drone.

Table 2: Selected Material and Component

Materials	Components
Acrylonitrile butadiene styrene (ABS)	Storage, Storage Cover, Hinge, Cover
Polyether ether ketone (PEEK)	Landing Gear, Landing Gear-Joint, Landing Stick, arm
Carbon Fibre Hexcel AS4C (3000 filaments)	Propeller, Top and Base Body-Plate

3.4 Component Analysis

A simulation of static analysis is performed on the selected component of the drone to ensure the material assigned to the component is working well and safe. The Von mises-stress, displacement, and strain analysis are performed on the selected component. The selected component for this simulation is the arm and the landing gear. Generally, this component is subjected to a specific load of other components. For example, the arm is subjected to the weight of the propulsion system while the landing gear is subjected to the drone’s whole weight, including the target payload (5kg). The result of the static analysis is shown in Table 3. The load applied to the arm, and the landing gear is calculated below.

i. Applied force on the arm.

Total load (N)=Total mass (kg)×Gravitional acceleration (m/s^2)

Total load (N)=1.028 kg ×9.81 m/s^2

Total load=10.08 N

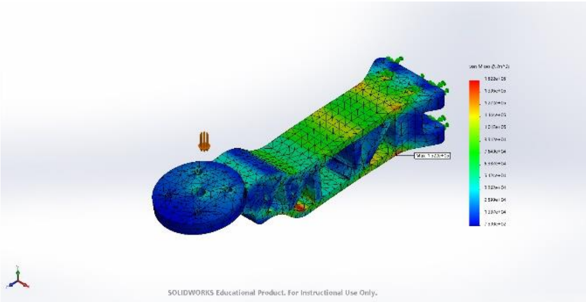
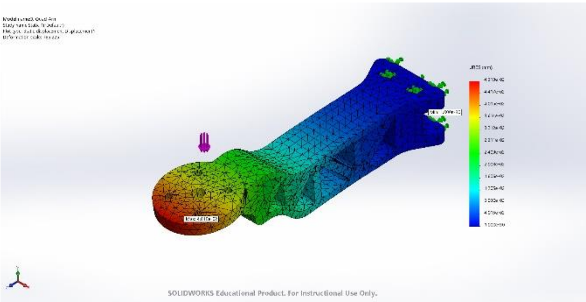
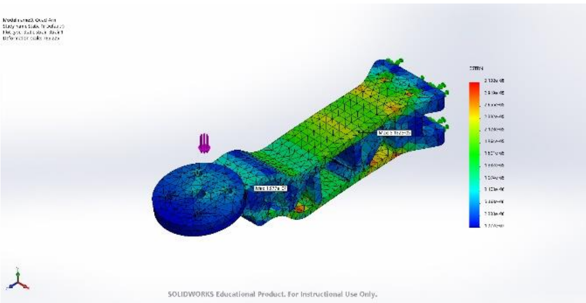
ii. Applied force on the landing gear.

Total load (N)=Total mass (kg)×Gravitional acceleration (m/s^2)

Total load (N)=15 kg ×9.81 m/s^2

Total load=147.15 N

Table 3: Simulation result

Simulation Results	Description
1. Arm.  Figure 4: Von Mises-strain result.	Based on Figure 4, The maximum stress recorded after the simulation is located near the main drone body with 1.552 × 105 N/m^2.
 Figure 5: Displacement-stress Analysis	Based on Figure 5, the maximum displacement is 4.818 × 10^{-2} mm, where the propulsion system is mounted.
 Figure 6: Strain Analysis Result	Based on Figure 6, the maximum value recorded is 3.182 × $10^{-5,}$ while the minimum value is 1.977 × 10^{-7}.
2. Landing Gear	Based on Figure 7, the maximum value recorded for Von Misses stress is 1.279 × 10^7

N/m2, while the minimum value is 2.608 × 10^{-3} N/m2.

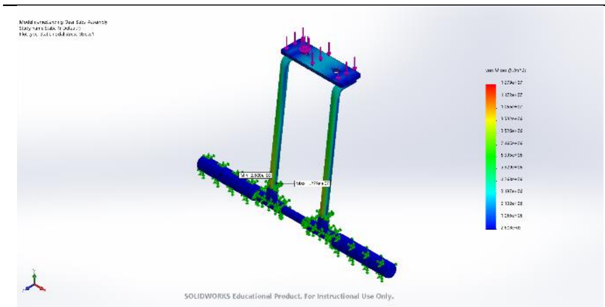


Figure 7: Von Mises-strain result.

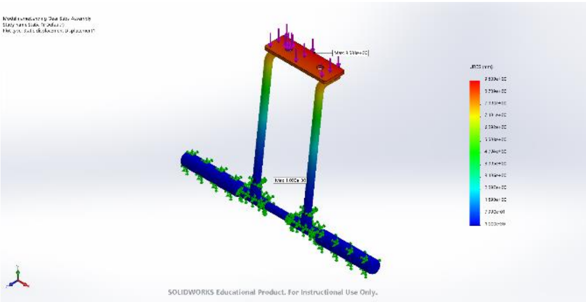


Figure 8: Displacement-stress Analysis

As shown in Figure 8, the maximum value for displacement analysis recorded on the landing gear is 9.588 mm, while the minimum value is one × 10^{-30} mm. The displacement analysis records the maximum and the minimum values at different locations. The maximum value is near the main body, while the minimum is located at the joint of the landing gear.

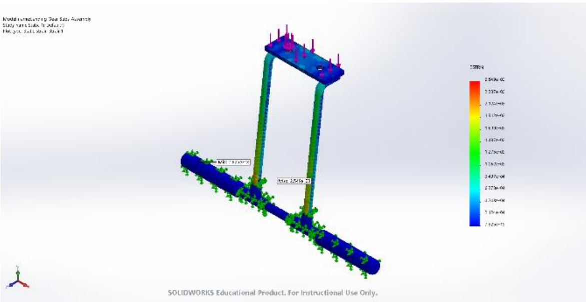


Figure 9: Strain Analysis Result

Based on Figure 9, the maximum and minimum recorded value is 2.549 × 10-3 and 7.825 × 10-13, respectively.

3.5 Product Specification

Once the detail design stage is completed, this study has summarized the details of product specification on the proposed drone design for package delivery services, as shown in Table 4.

Table 4: Details on product specification

Product Specification	Description
Dimension (L × W × H)	(1065.45 × 1065.45 × 432) mm
Motor	T-Motor MN1018 KV72
Overall weight	20.1328 kg (≈ 21 kg)
Total Cost	RM 14 866.47

4. Conclusion

In conclusion, the engineering design process by George E. Dieter's led and helped this study to design the package delivery drones successfully. It is essential to ensure every step and all phases in the engineering design process are followed to suit the customer's needs. Besides, all the objectives of the project are achieved. The parameters involved in developing a drone for delivery services are successfully gathered through research on previous products, literature reviews, and related websites such as the drone lab. Next, the 3D CAD model of the package's delivery drone is successfully created according to the engineering design process using the SolidWorks 2020 software. The drone's design has been analyzed to ensure the drone is capable of lifting and delivering 5 kg of payload. The simulation was done based on static analysis, and the results show that the selected material for the drone component can resist the 5 kg payload, including its weight. The drone's dimension was designed within the target range of 1 m to 2 m in diameter.

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for the support in implementing the research.

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