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Mechanism System to Reduce the Pendulum Effect of a Load for Delivery Drone

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Abstract: Unmanned aerial vehicles (UAVs), also referred to as "drones," are becoming more widely accepted as a typical form of transportation for a range of purposes in the logistics sector. Drones are anticipated to outperform traditional vehicles in a number of ways, including with a constant, quick speed, travel is straightforward, there is no exposure to traffic, and there is no requirement for physical transportation infrastructure. When an aircraft is in a sideslip, these surfaces generate sideward lift forces, which is known as the pendulum effect. The keel effect, also known as the "Pendulum Effect," occurs when the effect of sideways forces above the center of gravity in producing a rolling moment is increased by having a lower center of gravity. The load shift, also known as the pendulum effect, reduces flight efficiency and may unbalance the UAV, resulting in catastrophic failure. The purpose of this project is to construct a mechanism system to reduce the pendulum effect of a load for the delivery drone and to investigate the numbers of pendulum sway with the different types of loads. The mechanism for this project was constructed by using a 3D printer. The experiment process was used to carry out this project. This project's variables included various types of loads, string length, and the number of sways. The data obtained in this project are important to determine which design is the best for the delivery drone. Unfortunately, the data from the experiment gave the same result for all designs. For future studies try to come up with new concepts for how to construct the mechanism system to reduce the pendulum effect of a load for delivery drone and compare all the concepts.

Keywords: Unmanned aerial vehicles, pendulum effect, 3D printed, SolidWorks

1. Introduction

Unmanned aerial vehicles (UAVs), also referred to as "drones," are becoming more widely accepted as a typical form of transportation for a range of purposes in the logistics sector. Drones are anticipated to outperform traditional vehicles in a number of ways, including with a constant, quick speed [1], travel is straightforward, there is no exposure to traffic, and there is no requirement for physical transportation infrastructure [2]. They're anticipated to decrease delivery times and boost logistics systems' responsiveness. These advantages of UAV-based delivery are particularly noticeable in urban settings due to ongoing urbanisation, the rapid increase in direct e-commerce deliveries, and rising densities and levels of congestion. But on the other hand, there are now many use cases for drones for rural package delivery, particularly for medical supplies and emergency services in underdeveloped regions due to the frequently underdeveloped road infrastructure in rural areas and the limited resources available for infrastructural development in developing countries.

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A pendulum is a weight that is suspended from a pivot and can swing freely. [5]. A pendulum experiences a restoring force from gravity when it is side to side moved from its resting, equilibrium position, which stimulates the pendulum back toward the equilibrium position. When the pendulum is let go, the restoring force acting on its mass causes it to oscillate, swinging back and forth, around the equilibrium position. The duration is the amount of time needed to finish one cycle, one left swing, and one right swing. The length of the pendulum and, to a lesser extent, the amplitude, or the width of the pendulum's swing, determine the period.

1.1 Problem Statement

Crane- or winch-based unmanned aerial vehicle (UAV) package delivery mechanisms currently suffer from a load shift or pendulum effect while in flight. When an aircraft is in a sideslip, these surfaces generate sideward lift forces, which is known as the pendulum effect. The keel effect, also known as the "Pendulum Effect," occurs when the effect of sideways forces above the centre of gravity in producing a rolling moment is increased by having a lower centre of gravity. The load shift, also known as the pendulum effect, reduces flight efficiency and may unbalance the UAV, resulting in catastrophic failure.

Therefore, this will cause the delivery package to be damaged. It might also affect the delivery company itself in terms of quality and profit. Thus, a need exists for a package delivery assembly that reduces the pendulum effect, improves stability, and reduces sway of the package.

1.2 Significance of Study

This study focuses on conducting experiments on how to reduce the pendulum sway effect of a load and improve the stability of a delivery drone. This study will conduct with a different type of variable which is a load of the package, string length and the number of sways of the package. After the experiment, the investigation needs to be held to observe that the mechanism system can reduce the pendulum effect or vice versa.

2. Materials and Methods

This chapter will discuss the methodology used to generate the conceptual design of mechanism system to reduce the pendulum effect of a load for delivery drone and do the experimental for the mechanism system. Fig. 1 shows the flow chart of the methodology.

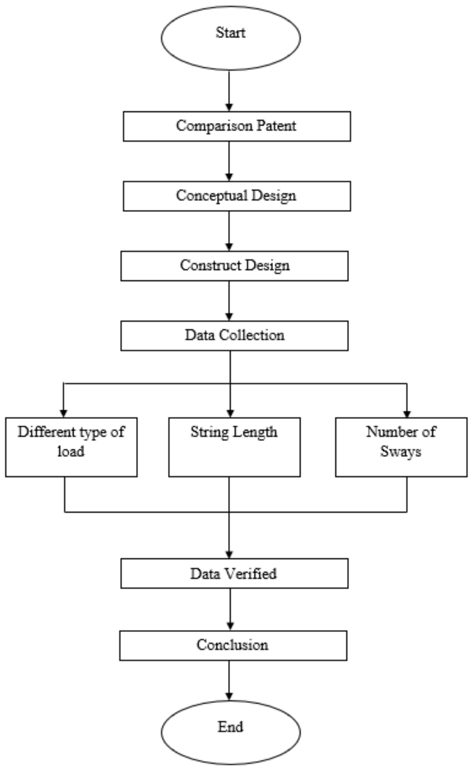

Fig. 1 - Flowchart of methodology

2.1 Conceptual Design

The design process begins with this conceptual stage. Conceptual designs are scalable diagrams that outline the fundamental specifications of the project. They frequently lack specifics, measurements, and technical notes, making it simple for you to review and alter the design. These designs are still in the early stages of development. The software used in this study to create the conceptual design is SolidWorks 2021.

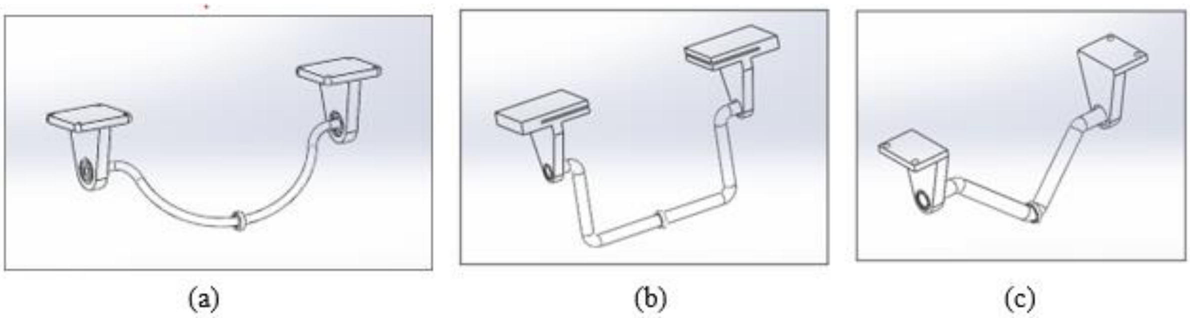

Fig. 2 - (a) Design 1; (b) design 2; (c) design 3

2.2 Construct Design

This construct design is a phase in which the conceptual design is manufactured into the physical object. The following subchapter explained the process or step to construct the design.

2.2.1 SolidWorks Drawing

First, the drawing of the design was set up in SolidWorks software by using the dimensions from the conceptual design. The drawing of the design must be in 3D form. The Fig. below shown the interface window for SolidWorks (2021).

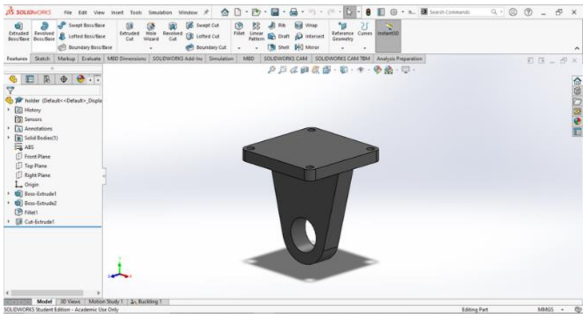

Fig. 3 - Design of conceptual 1 in SolidWorks (2021)

2.2.2 Ultimaker Cura

Once the SolidWorks drawing is finished, the file needs to be opened in the Ultimaker Cura software to generate the g-code for the 3D printer. An open-source slicing programme for 3D printers is Ultimaker Cura. The way Ultimaker Cura operates is by creating a printer-specific g-code by layering the user's model file. After it is complete, the g-code can be sent to the printer to produce the actual object.

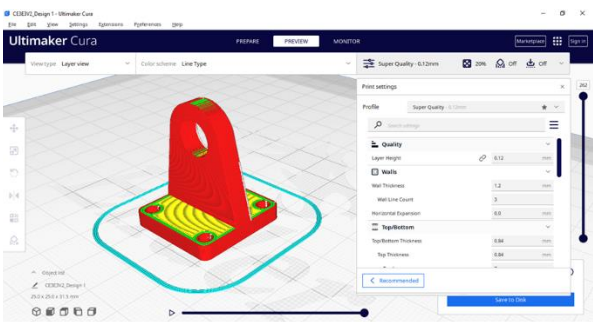

Fig. 4 - The conceptual design 1 after slicing in Ultimaker Cura

2.2.3 3D Printing

This project was conducted by using 3D printing to build the design of the mechanism. A three-dimensional object is created using 3D printing, also referred to as additive manufacturing, using a CAD model or digital 3D model.The model of the 3D printing used to succeed this project is from brand Creality which is Ender-3 Pro 3D printer as shown in Fig. 5(a). 3D printing filament serves as the thermoplastic feedstock for 3D printers that use fused deposition modelling.The filament used in this project is Polylactic Acid, commonly known as PLA shown in Fig. 5(b).

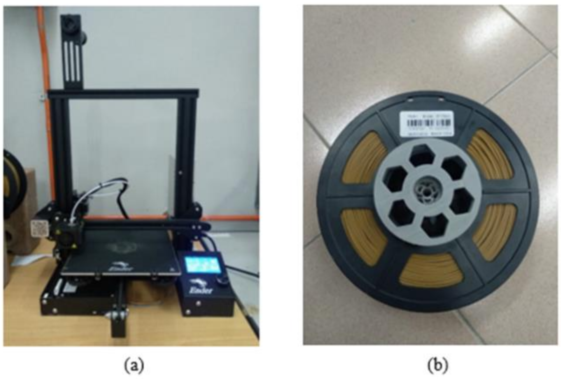

Fig. 5 - (a) Ender-3 Pro 3D printer; (b) PLA filament

All design was successfully printed using 3D printing as shown in Fig. 6(a). The next step was a finishing process that involved spraying the holder with red paint. The Fig. 6(b) shown holder after the spraying process.

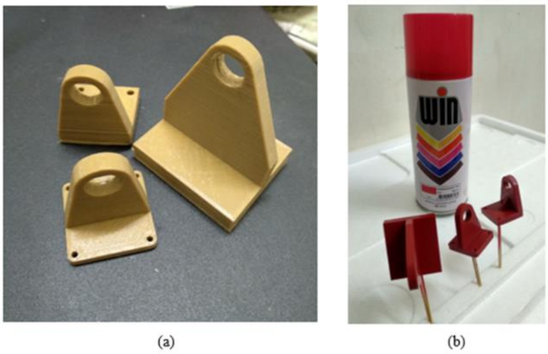

Fig. 6 - (a) Holder printed by using 3D printer; (b) spraying process

2.2.4 Concept Design Assembled

Finally, the design was printed using a 3D printer. All the components for the conceptual design were assembled. After that the completed design attached to the base of quadcopter drone to run the experiment based on Fig. 7.

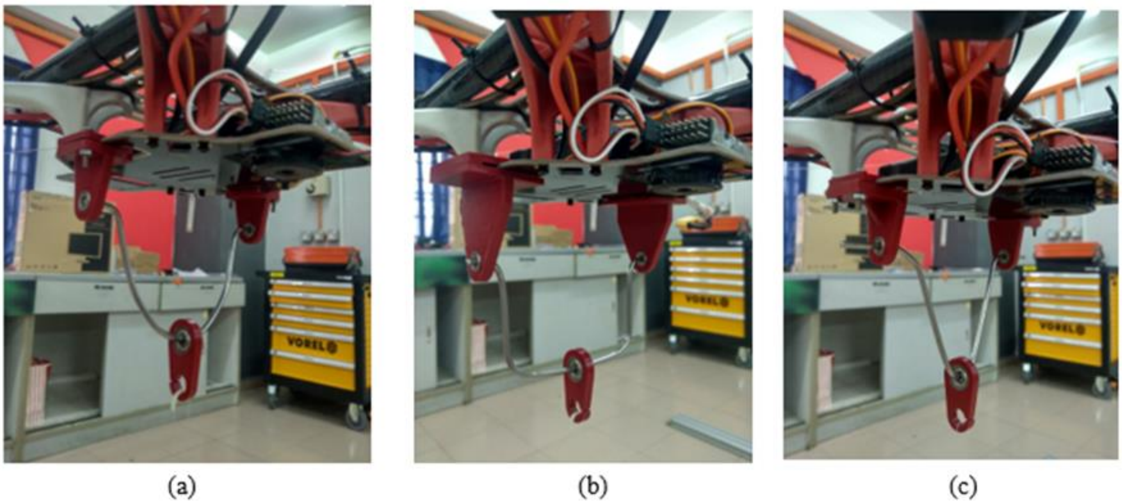

Fig. 7 - (a) Completed design 1; (b) completed design 2; (c) completed design 3

2.3 Material

2.3.1 Data Collection

After assembling the parts for each design, the next step is to conduct an experimental experiment to collect data for this study. The variable in this study is a different type of load, string length, and number of sways. The experiment will be observed by using recording a video from the camera.

2.3.2 Different Type of Load

The first variable is a different type of load. The different type of load mention in this variable is represented for weight. So basically, for this experiment, there are different types of loads being used. The load is represented as a load for the package. Attached the load to the conceptual design 1 with different type of loads. Since the quadcopter drone for this project is small, the drone is incapable of carrying a heavy load. So, the weight started at 20 grams and above. Next, run the delivery drone from one point to the second point. The length of the point maybe 2 meters. During the flight, observe the movement of the package whether the swing is too fast or slow. If the swing is slow, the assembly may remain balanced and improve the stability of the delivery drone. Repeat the previous experiment with different types of loads to other designs by following the same step.

2.3.3 String Length

The second variable is a string length. This experiment was carried out to determine whether the length of the string affected the sway of the package load. So basically, the load of the package constant, and the variable is string length. The string length for this experiment started at 40 centimeters and 60 centimeters. The procedure of the experiment also same with the first variable which is the drone run from one point to second point in 2 meters. Observe the sway of the package movement during the flight to determine whether it is too slow or too fast. Repeat the previous experiment with different string length to other designs by following the same step.

2.3.4 Number of Sways

The final data set is the number of sways. This information is used to calculate the package's swing. The sway of the package was produced by the experiments for the first and second variables. So, measure the amount of swing in the package and keep record of the number of sways.

3. Results and Discussion

The findings and the results of the experiment has been discussed in this chapter. For this project, the mechanism of the conceptual design was successfully assembled. The drone that used in this experiment is quadcopter drone. Unfortunately, the drone test ran into a problem. The flight controller on the quadcopter drone was malfunctioning. The drone's inability to stabilize while flying makes it difficult to control and always falls when flying. The drone is also costly to fix if it crashes. To ensure the success of this project, simulation was used to collect experiment data.

The simulation was carried out by hanging the drone with string. That drone was also tied with string to pull it. The movement measured 2 meters in length. This procedure was carried out in order to visualize the drone flying in real life. Fig. 8 illustrated the drone being hung with string to simulate the process.

Fig. 8: Simulation process

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.1 Result for Different Types of Loads

Since the experiment was carried out by simulation process. As a result, the drone cannot move from one point to another. For this experiment, the drone only hung at one point, while it was in static or stabilize mode. Therefore, the number of sways for different types of loads obtained when the drone is at the static position. The number of sways was taken in two axes which is x-axis and y-axis. The sway angle was set to 90o, and the starting load was 20 grams. The time required to calculate the number of sways was only in 60 seconds. The length of the string was fixed at 60 centimeters.

Table 1 - Data for 20 grams of load

		Design 1			*Design 2*			*Design 3*		
X- axis	Number of sways	36	37	36	36	36	35	36	35	36
	Average	36.33 ≈ 36			35.66 ≈ 36			35.66 ≈ 36		
Y- axis	Number of sways	36	36	37	35	36	36	35	36	36
	Average	36.33 ≈ 36			35.66 ≈ 36			35.66 ≈ 36		

Table 2 - Data for 40 grams of load

		Design 1			*Design 2*			*Design 3*		
X- axis	Number of sways	37	36	36	35	36	36	36	35	36
	Average	36.33 ≈ 36			35.66 ≈ 36			35.66 ≈ 36		
Y- axis	Number of sways	36	37	36	36	35	36	36	36	35
	Average	36.33 ≈ 36			35.66 ≈ 36			35.66 ≈ 36		

From the table 1 and 2, the result revealed that the number of sways for design 1, design 2, and design 3 was the same, which was 36. So, in summary, the experiment was carried out in the same way as with the oscillation of a simple pendulum. A simple pendulum is made up of a ball suspended from a length of massless string and fixed at a pivot point P. When the pendulum is displaced to an initial angle and then released, it swings back and forth with periodic motion.The length of the string was fixed at 60 centimetres in this experiment, and the variable was the weight of the load, which was 20 grams and 40 grams. Therefore, the period of a pendulum does not depend on the mass of the ball. The shape of mass also not affected the period of a pendulum. Because the number of sways was the same in this experiment, no any design for mechanism to reduce pendulum effect was chosen.

3.2 Result for String Length

The procedure was the same as in previous experiments, but the variable was only the length of the string. The starting lengths for this experiment are 40 and 60 centimeters.

Table 3 - Data for 40 centimeters string

		Design 1			*Design 2*			*Design 3*		
X- axis	Number of sways	42	40	40	41	40	41	40	41	41
	Average	41.66 ≈ 42			41.66 ≈ 42			41.66 ≈ 42		
Y- axis	Number of sways	40	42	40	41	41	40	41	41	40
	Average	41.66 ≈ 42			41.66 ≈ 42			41.66 ≈ 42		

From the table 3, the result number of sways for 40 centimeters was the same, which was 42 per 60 second. This is because the length of the string affects the period of the pendulum, so the longer the length of the string, the longer the period of the pendulum. This also has an impact on the frequency of the pendulum, which is the rate at which it swings back and forth. The swing rate increases as the string length decreases. The number of sways increases as the swing rate increases.

Table 4 - Data for 60 centimeters string

		Design 1			*Design 2*			*Design 3*		
X- axis	Number of sways	36	37	36	36	36	35	36	35	36
	Average	36.33 ≈ 36			35.66 ≈ 36			35.66 ≈ 36		
Y- axis	Number of sways	36	36	37	35	36	36	35	36	36
	Average	36.33 ≈ 36			35.66 ≈ 36			35.66 ≈ 36		

From the table 4, the result number of sways for 60 centimeters was the same also, which was 36 per 60 second. The time it takes for the simple pendulum to oscillate is proportional to the length of the pendulum string. As a result, as the length of the pendulum's string increases, so does its time. The length of a pendulum determines its frequency or swing rate. The pendulum swings slower as the string gets longer. In this case, the load constant at 20 grams and the variable was only at the length of string. For discussion get from this experiment, the period of a pendulum is purely driven by the length of the string, not by the mass of the ball. Two pendulums with different masses but the same length will have the same period. The periods of two pendulums of different lengths will differ. In fact, the pendulum with the longer string will have a longer period. There was no design for mechanism chosen to reduce pendulum effect because the length of string was the same for all designs. There was no specific string length set to the design 1, design 2 and design 3.

4. Conclusion

The first objective of this project, which was to construct a mechanism system to reduce the pendulum effect of a load for the delivery drone, was achieved. The parts of mechanism system successfully constructed by using 3D printer. After that, assemble all of the parts and conduct the experiment to determine the number of sways for each design. Sadly, the drone test ran into a problem which is the flight controller for the quadcopter drone was malfunction. So, the experiment had to conduct by simulation process. The number of sways was obtained from the simulation process, but the result for all testing resulted in the same number of sways.

This is because the simulation process was similar to oscillation of simple pendulum experiment or theory. In a basic pendulum, the point mass is suspended from a fixed support by a thin, non-extensible string. From the discussion, it can be inferred that the period of a pendulum depends only on the length of the string and not on the mass of the ball. From the second experiment in this project which is the variable was the string length, the resulted shown the number of sways for all design also same. Therefore, there no design selected for mechanism system to reduce pendulum effect of a load for a delivery drone. This is because the concept for all design was same. There just only changed in shape of rail but the movement for all design same which is move in x-axis and y-axis.

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