Dynamic Simulation of a UAV Moving on Launcher [†]

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† Presented at the Innovation Aviation & Aerospace Industry—International Conference 2020 (IAAI 2020), Chumphon, Thailand, 13–17 January 2020.

Abstract: This paper presents a dynamic simulation of Unmanned Aerial Vehicle (UAV) moving on a launcher. The UAV launcher consists of a metal rail that is positioned at a launch angle, a spring and a winch to be able to stretch the spring. Prior to launch the spring is stretched into necessary tension and secured with safety pins, then released to launch the UAV. The influence of aerodynamic lift and drag forces on the mathematical model of a UAV will be considered in detail. Mathematical model a UAV moving on a launcher represented by differential equations are solved using a MATLAB software. The results of calculations are represented by a graph which shows distance, velocity and acceleration of a UAV while moving on a launcher as a function of time.

Keywords: UAV; launcher; spring; simulation; mathematical model

1. Introduction

Nowadays, the transportation technology has been developed quickly for shipping object and transport people to destination as fast as possible. The air transportation is what take into consideration. Many of them have people in charge of their control, however not with the Unmanned Aerial Vehicle (UAV). As the technology required the taking-off area so to solve the problem the Spring Drive UAV launcher has been developed. As a result, with the help of launcher it results in launching the UAV in the limited area at same initial input such as; work and specified velocity.

In our consideration, the launcher can gives some initial aspect for launching the UAV at the same conditions. So, the author wants to illustrate the dynamic simulation of the UAV moving on the launcher with the help from MATLAB software. The expectation that wanted to achieve are to know the approximate maximum distance that the tested UAV can be travelled by using work generated by the launcher. This will be included to the initial velocity that the launcher can produced and the velocity that will be appeared along the time it takes. Moreover, the acceleration due to that interval of time can also be known as getting the differential equation of velocity. Last but not least, with the help from the dynamic simulation then it can be used in many fields of work such as; making a design of UAV with the highest efficiency as possible due to the simulation can give the relevant data that are useful for estimating the distance, speed, and acceleration that the UAV can produced. This paper will include the simulation of the specified UAV and launcher as setting in the criteria by using the dynamic simulation as mentioned above [1].

2. Methodology

2.1. Spring Drive UAV Launcher

In Figure 1, the launcher consists of the glider which is forced to move along the rail and attaches to the sling straight through the two-wheel pulley and the spring which attaches to the other end of the sling. According to the law of conservation of energy, if both the glider and the spring are motionless then there is no energy stored. Then, if the glider is pulled along the rail by spring force and two-wheel pulley then the work is done by Hook's non-conservative force law. Finally, the glider is launched along the rail so it has the kinetic energy with varying velocity. Spring constant is very important parameter in the process of designing the launcher. There is a relationship between a spring constant and the stall velocity of the UAV [2–5].
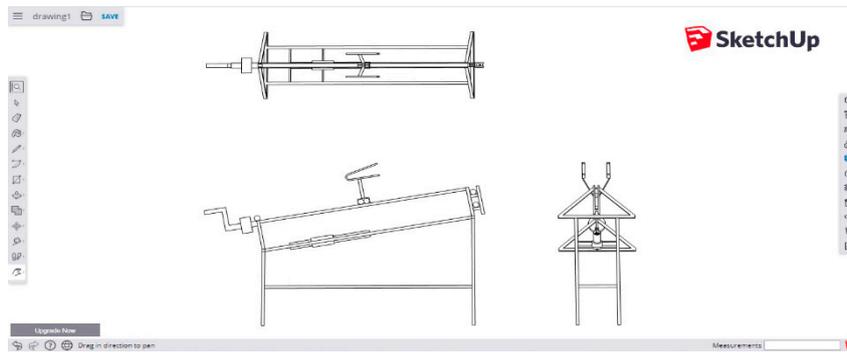

Figure 1. The sketching of the launcher using in the simulation.

2.2. Mathematical Model

As shown in the Figure 2 there are the forces acting on the UAV which can be write in the free body diagram as above. Furthermore, in the experiments the author made the assumptions for adjusting equations using in the dynamic simulations which are as the following [5]:

- Assumption 1

    The mass of both rollers and spring are neglected [5].

- Assumption 2

    The UAV drag force and lift force are neglected [5].

- Assumption 3

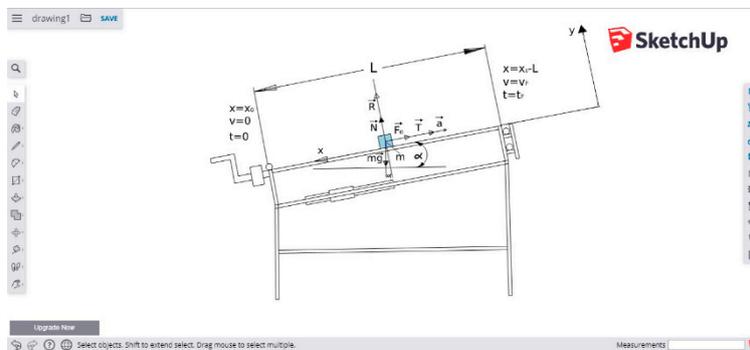   Considering the UAV propeller force is constant [5].

Figure 2. Free body diagram for the launch of a mass along a projected angle alpha.

For the assumptions that made above, then it can be write the equations as [5]:

$$x(t) = \left[x_0 + \frac{T}{q} - \frac{mg}{q}(\mu cos\alpha + sin\alpha) - b\right] cos\sqrt{\frac{q}{m}}t - \frac{T}{q} + \frac{mg}{q}(\mu cos\alpha + sin\alpha) + b \quad (1)$$

As for the equation above, it is the equation that used to find the displacement which is using the initial condition values equal to $t = 0$ and $x = x_0$. So, the equation for finding the displacement are as showing above. Furthermore, by differential of the displacement equation above then the velocity equation will be obtain as following [5]:

$$\dot{x}(t) = -\left[x_0 + \frac{T}{q} - \frac{mg}{q}(\mu cos\alpha + sin\alpha) - b\right]\sqrt{\frac{q}{m}}sin\sqrt{\frac{q}{m}}t \quad (2)$$

As for the velocity equation above, it can be used for finding the speed at various time. So, if the derivation of the speed equation then the acceleration equation can be expressed as [5]:

$$\ddot{x}(t) = -\left[x_0 + \frac{T}{q} - \frac{mg}{q}(\mu cos\alpha + sin\alpha) - b\right]\frac{q}{m}cos\sqrt{\frac{q}{m}}t \quad (3)$$

If the UAV drag and lift force are not neglected it must be included in the dynamic equations of UAV moving on the launcher [1].

3. Results and Discussion

Numerical Results

From the experiment, the author specify the criteria of the launcher and UAV for making the dynamic simulations using MATLAB. As a result, the UAV conditions that has been used in the simulation will be express as the following:

- Wingspan = 1.4 m
- Length of fuselage = 0.9 m
- Wing area = 0.42 m²
- Mass = 1.9 kg

By using the setting criteria above, then it can be distributed into the equation as using the assumptions above. Later on, with the help of MATLAB then to illustrate the values of displacement, velocity, and acceleration can be plotting in the graph as a function of time.

As the author use the MATLAB simulation for illustrating the result of horizontal distance that the UAV will reach. In Figure 3, it shows that the maximum horizontal distance will be approximately 15.8016 m. So, with the simulation shows the maximum distance that this UAV can travelled with no thrust are used. As a result, these show that the horizontal distance travel is based on the glide performance of the UAV that we used in the experiment.
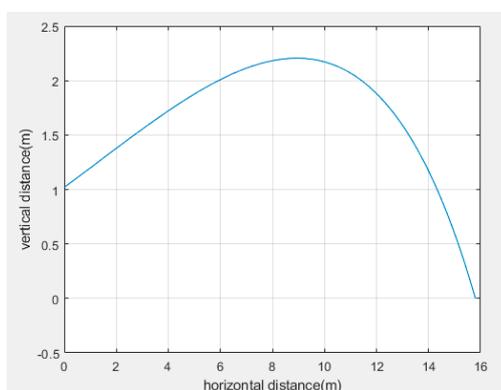

Figure 3. Results from MATLAB showing the maximum horizontal distance of used UAV with no thrust included.
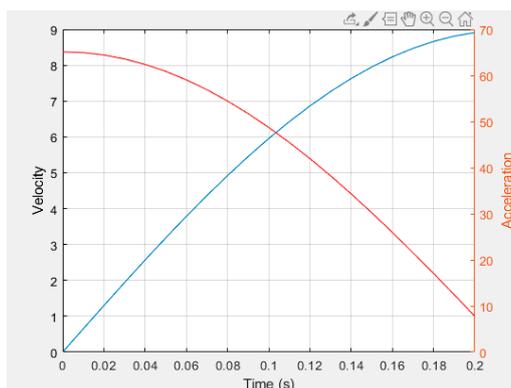
Figure 4. Results from MATLAB showing velocity and acceleration as function of time.

In Figure 4, the blue line represents the velocity and for the red line represents the acceleration in which both are function with time. Moreover, the results of calculations are represented on the graph which can be consider the launching velocity estimate about 9.8 m/s when $t = 0.2$ s. As a result, the calculation that shown in the plot, can be predicted to have slight error as the trust are being used during the launching and after the UAV are being launched. So, the overall result can be acceptable for using in further calculation.

4. Conclusions

The paper aims to illustrate the dynamic simulation for predicting the displacement, velocity, and acceleration for the UAV that used launcher for taking-off process. The model is constructed by using the help of MATLAB to plot the graph as the function of time for each aspect. As a result, it shows that the Spring Drive UAV Launcher has advantage for launching the UAV at the limited area. Lastly, the dynamic simulation can be used for future works as the field of using UAV in the daily's life are increasing rapidly. So, with the simulation it can increase the design performance of UAV and others relevant information using in the next generations.

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