Analysis of Flight Characteristic of Paper Plane in 2D

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Abstract

We construct the wind tunnel for paper planes to test different flight parameters, including AOA, head angle, and AR, to get the lift and drag force in different condition to simulate the flight. Meanwhile, we make paper plane launcher to see the real flight status. That we know the difference between experimental measurement and actual situation.

1. Introduction

The paper plane is usually accompanied by our life, while we realize a little of its flight mode. Typically, it corresponds to the Bernoulli's law,

$$L = \frac{1}{2}\rho v^2 A C_L \ , \ D = \frac{1}{2}\rho v^2 A C_D \qquad (1)$$

where ρ is air density, v is velocity, A is wing area, and C is coefficient.

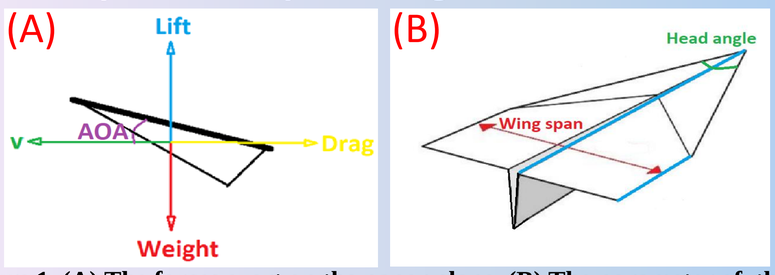

Figure 1. (A) The forces exert on the paper plane. (B) The parameter of the paper plane.

Besides, in Figure 1, we know the forces and the parameters of the paper plane that effect flight, including angle of attack (AOA), head angle, and aspect ratio (AR),

$$AR = \frac{(\text{Wing span})^2}{\text{Wing area}} \qquad (2)$$

2. Experimental Set-up and Method

Figure 2 shows the equipments and parameters to measure the lift and drag force and launcher to fly the paper. We use the numerical change of scale and angle of lines to calculate force.

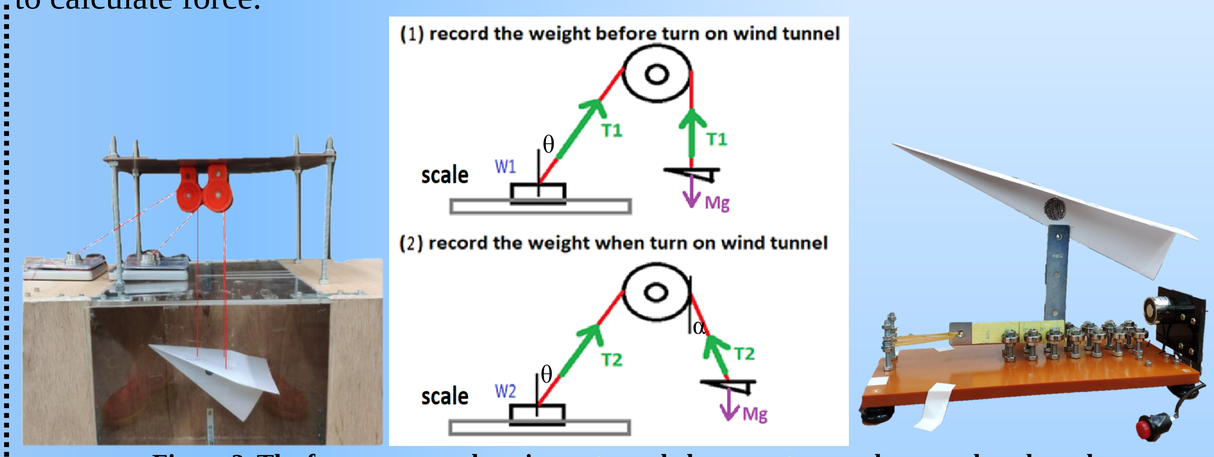

Figure 2. The force-measured equipment, needed parameters, and paper plane launcher.

In the part of simulation, we use data below, interpolated method and RK4 to run the flight trajectory; then, compare it to real situation.

3. Result and Discussion

3-1. Compare to Bernoulli's law

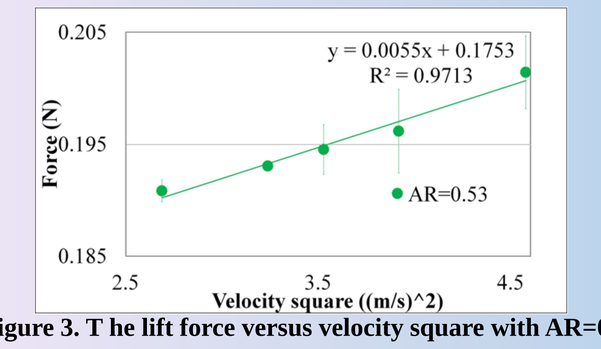

Figure 3. T he lift force versus velocity square with AR=0.53.

In Figure 3,we notice that it isn't in correspondence with the Bernoulli' law. The possible reason is that the wing of paper plane is just a flat, different to the original assumption of streamline shape.

3-2. The relationship in different AR

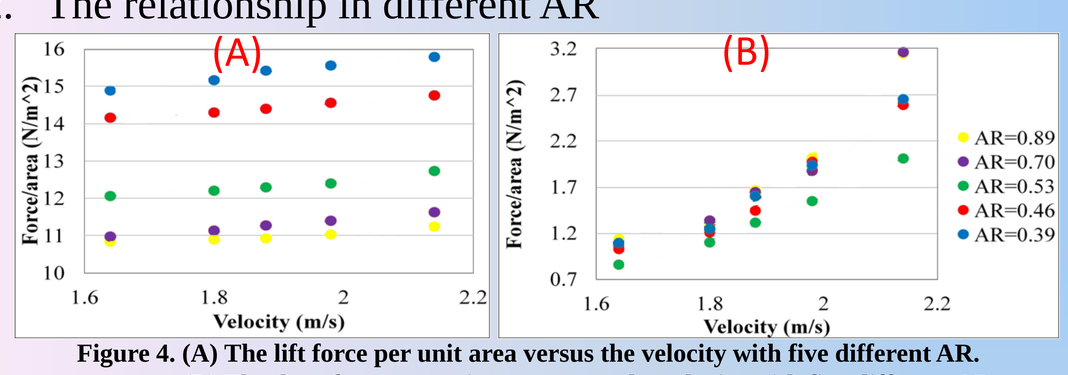

Figure 4. (A) The lift force per unit area versus the velocity with five different AR.
(B) The drag force per unit area versus the velocity with five different AR.

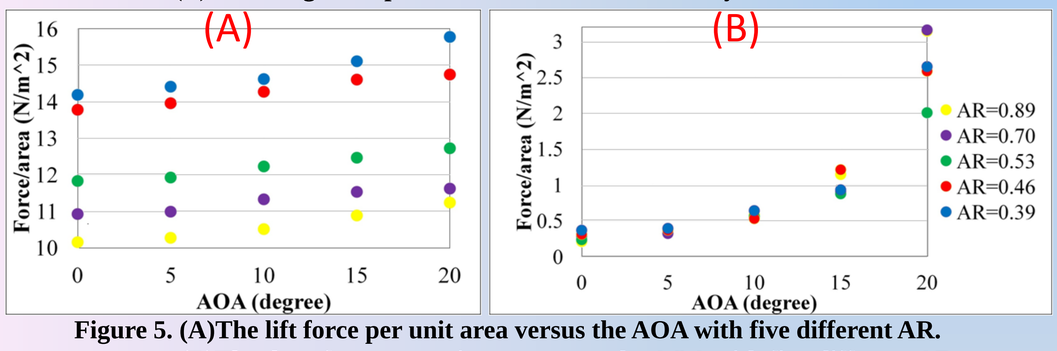

Figure 5. (A)The lift force per unit area versus the AOA with five different AR.
(B)The drag force per unit area versus the AOA with five different AR.

Figure 4 and Figure 5 present that whatever for velocity or AOA, the smaller the AR of paper plane is, the larger the lift force is; however, the variation of drag force is mainly resulted from the velocity or AOA. Hence, lift force is sensitive to the AR, while the drag force is sensitive to the velocity or AOA. By the way, we also can see that the paper plane with smaller AR is prone to fly both further and longer.

3-3. The relationship in different head angle

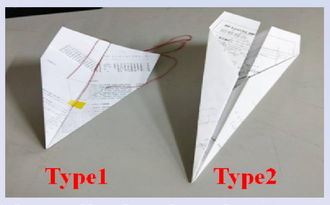

Figure 6. Paper planes with smaller head angle (Type1) and with bigger head angle (Type2).

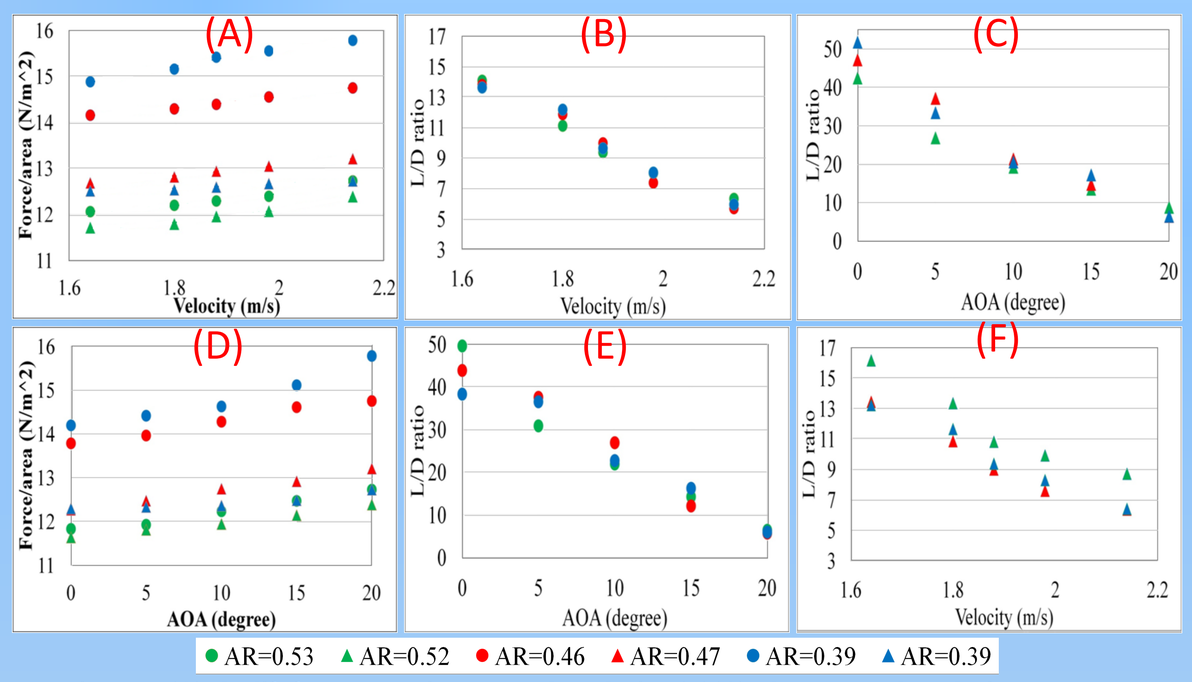

Figure 7. (A)The lift force per unit area vs. the velocity. (B)(C) The L/D vs. the velocity.
(D)The lift force per unit area vs. the AOA. (E) (F) The L/D vs. the AOA.

From the relationship showed in Figure 7, the lift force of Type2(Δ) are smaller than Type1(O)'s and the L/D of Type2 is bigger than Type1's. Therefore, we can speculate that Type1 paper plane is prone to fly longer, while Type2 paper plane tends to fly further.

3-4. Comparison of simulation and real flight

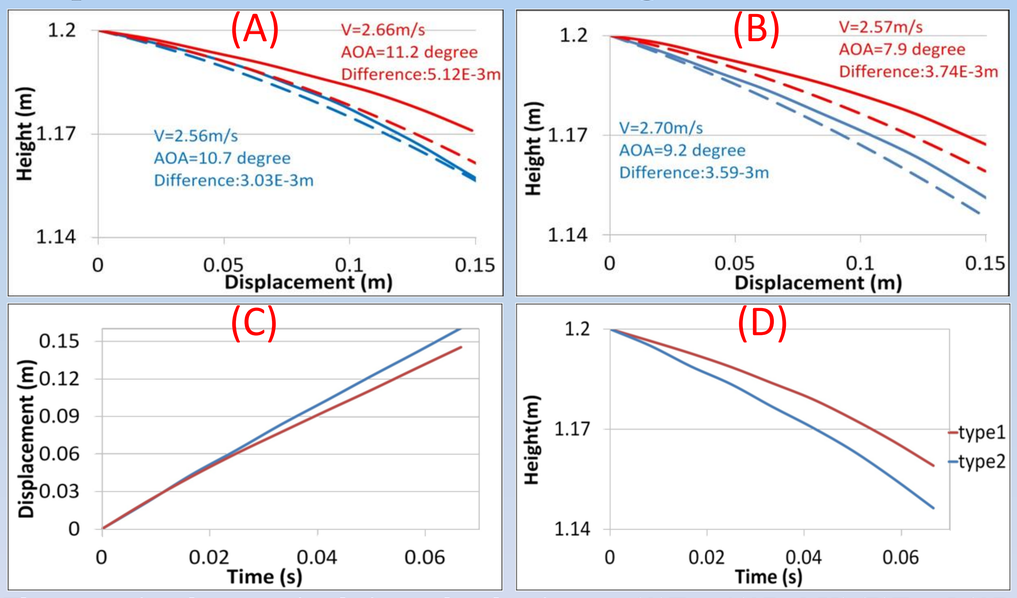

Figure 8. The comparison between simulation and real trajectory: (A)Type1(AR=0.52) (B)Type2 (AR=0.53).
(C) The displacement and (D) The height versus the time in two types.

As shown in Figure 8, we compare the simulated trajectory, using the data obtained from above experiment, to the real's. The difference between Type1 is smaller than Type2, and it can attribute to the uncertainty of the AOA in Type2 for its CM distribute being more forward. In addition, we can verify our previously postulation (3-3).

4. Conclusion

1. Both lift and drag force aren't proportional to the square of velocity, but only having positive correlation with the velocity.
2. Both lift and drag force versus the AOA have positive correlation.
3. The lift force is sensitive to the AR, while the drag force is resulted from the velocity and the AOA.
4. The paper plane with smaller AR is prone to fly both further and longer.
5. The paper plane with small head angle fly further, while the bigger head angle one fly longer.
6. Without considering yawing, our simulation can be in correspondence with the real trajectory when the paper plane don not fly too further.

Reference

[1] Natalia COOK (1995). Experimental Analysis of Paper Plane Flight Characteristics, The University of Queensland
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