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Analysis of Flight Mechanism and Fluid Dynamics Based on Dandelion Model

Zelei Zheng[1, *]

[1]School of Physics and Science, Tongji university, Shanghai, China
*Corresponding author: 2253962@tongji.edu.cn

Abstract:

The elevation angle of dandelion crown hairs is investigated by controlling the angle of the fan to investigate the stability factors of dandelion flight, and the theoretical knowledge is deduced and analyzed to get the conclusion. Taking the structure of badminton ball as the basic reference, three motion states of dandelion are set, and the exit wind speed of the wind tunnel is measured respectively. Through Fluent flow field analysis, a low-pressure vortex detached from the body exists above the center of the dandelion model during flight, and a high-pressure airflow field exists below, the size of which decreases with the increase of elevation angle. The velocity field is unfolded by the semicircular arcs on both sides of the vortex and decreases gradually, and the velocity maxima appear at the left and right vertices of the elliptical vortex, and the range of the semicircular arcs of the velocity field increases gradually with the increase of elevation angle. In the elliptical vortex, there are two vortices with different velocity directions, the left velocity direction is clockwise and the right is counterclockwise.

Keywords: Dandelion; fluid; motion; flight mechanism; vortex.

1. Introduction

Dandelion (as shown in Fig. 1) this kind of device like upward turning up the parachute, but with the usual recognition of the physical model are not the same, but also through the natural horizontal wind direction to do a wide range of long-distance propagation, and dandelion seeds of different will also make the dandelion being thrown away from the respective dispersal of the dandelion to carry on the flight and movement in the air, there may be some special mechanism, the topic will focus on the study of dandelion model of the flight mechanism and the hydrodynamic study. In this study, by reviewing the landing principle of dandelion and reading many related literatures, about the application of this kind of unpowered bionic flight, all of them are still relatively rare in the military [1]. A study by Wu showed that the dandelion parachute-shaped crown hairs would receive the influence of environmental humidity, and the crown hairs of this plant would decrease with the increase of humidity, which would then spread to a wide range and a long distance by the wind [2]. In a study by Mami Nakayama at the University of Edinburgh, UK, on the bypassing of vertical wind tunnels, free-flying and stationary dandelion seeds, it was found that the dandelion crown hairs have a stabilizing bubble, a vortex ring, which is separated from the seed proper, yet stably maintained at a fixed distance from the end of the crown hairs [3].

Cathal Cummins in A separated vortex ring underlines the flight of the dandelion first analyzed the flight of two different plant mechanisms, and also used the same method to build a wind tunnel and control the porosity of the crown hairs of the dandelion to analyze the movement of the dandelion when acting in a vertical wind direction. The principle of motion of the dandelion when acting in the vertical wind direction was analyzed by analyzing the change of vortices above the dandelion as the porosity changed [4]. This article argues that the bristle structure of dandelion is very skillful in causing a kind of cyclone that helps dandelion seeds to be able to stay in the air for a longer period of time. This study mainly refers to this literature dandelion‘s separated vortex ring model for physical simulation and subsequent theoretical conjecture establishment.

Wu established an aerodynamic model of plant seeds floating with the wind in describing the probabilistic model of wind propagation distance of plant seeds, and this literature is also the basis of mathematical derivation for the establishment of dandelion solid model, which is more important in this paper. Su et al. established an airflow field measurement study based on the optical flow method, and in the experimental study, the airflow field of a small wind tunnel was used as the object of the study, and a high-speed video camera was used to continuously photograph the particle movement, and then the optical flow method was used to calculate the trajectory, direction and velocity of the particles, thus reflecting the airflow field [5-8].

This study refers to the experimental method of building a vertical wind tunnel in the literature, and build a dandelion-like physical model (seen from Fig. 2). By constructing a physical model similar to the dandelion shape, selecting different independent variables and dependent variables from those in the literature, this project investigates the effects of different wind speeds and the elevation angle of the crown hairs on the dandelion-shaped model from the stationary to the stable circling to the process of flying away, and then analyzes the different vortices of the fluid line and the difference of the pressure of the dandelion model in the process of flight by combining the theoretical mechanics and the fluid dynamics, so as to get the final theoretical conclusions and the application research.

Fig 1. A sketch of Dandelion.

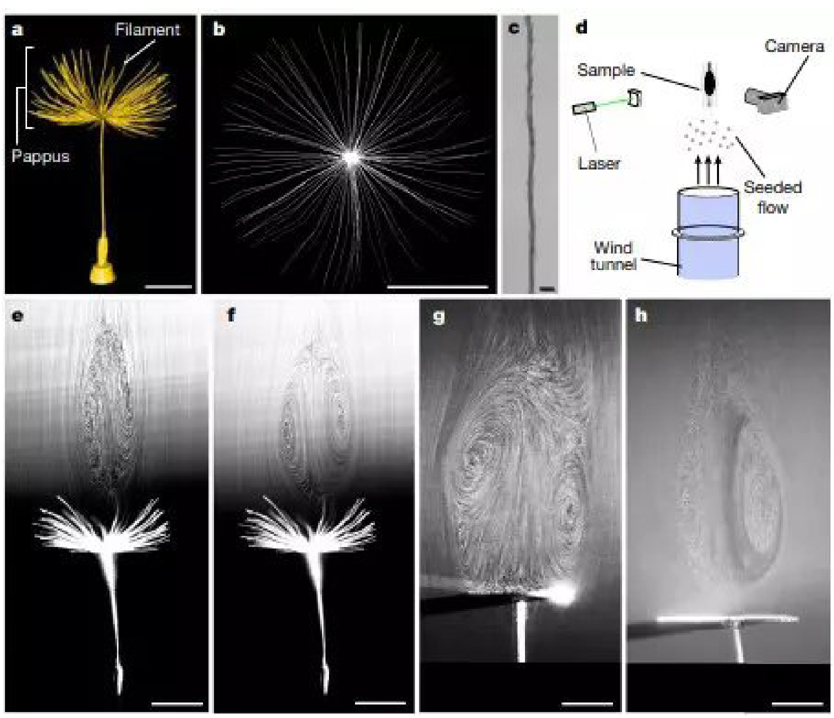

Fig. 2 Airflow analysis of the dandelion flight model

2. Methodology and Assumptions

According to the existing literature base, the existing theoretical research on the dandelion model only investigates the mechanism of motion of the dandelion plant moving in a horizontal constant wind, and the porosity of the crown hairs of the dandelion plant was chosen as the main dependent variable for the experiment, and the dandelion is rotating during the process of motion and forms a more stable situation under a certain wind speed due to the nature of the rotation itself. Therefore, based on the shape of the dandelion model, the authors speculate that the flight mechanism of this type of physical model is likely to be influenced by the elevation angle of its rigid fluff and its mass and center of gravity.

The authors initially chose a smaller mass of high-density foam inserted on a more uniform rigid or soft crown hairs, the lower end plus a larger mass of playdough to simulate dandelion wind tunnels to carry out experiments, but the results of this attempt is not ideal, found that the shape of the badminton is very suitable for this experiment, so the authors will be linking badminton at the scissors in order to change the tilt angle of elevation of it, and the badminton lower end inserted with a stick with a larger mass than the upper end of playdough to carry out experiments. The quality of the playdough at the lower end of the badminton ball is larger than that at the upper end to carry out the experiment. As the research object of this experiment is the study of dandelion similar physical model, do not need to do on the dandelion this plant is more similar to the porosity and the structure of the bionic, so the badminton device can be better in line with the needs of this experiment. Table 1 lists the paramter.

Table 1. Parameters of the dandelion model.

Parameters of the dandelion model	
Mass	10g
Number of roots	16cm
Length of hair	6.3cm
Length of rod	15cm

By borrowing the wind tunnel experimental setup mentioned in the literature above, this study built the experimental setup for this experiment by using the rectification chamber, the airflow chamber and the fan (shown in the Fig. 3). This experiment was planned to put the constructed model of dandelion into the airflow chamber with the upper end of the rectification chamber, and to observe the model‘s rotation by gradually adjusting up the wind speed, and due to the authors‘ preliminary experiments, it was found that the experimental setup of the The rectification chamber of the experimental setup can easily jam the dandelion model with rubber clay at the lower end, and for such a long vertical wind tunnel (as shown in Fig. 8 on the right), the airflow velocity at the lower end of the vertical wind tunnel is smaller than that at the upper end, so the authors put the dandelion model in the wind opening and observe its stability, and then because this dandelion model can form a stable state at different positions under multiple wind speeds, the whole experiment is divided into three phases. Therefore, the whole experiment is divided into three stages: stable rotation, dynamic levitation, and spinning away. The rectification chamber and the airflow chamber are used to make the fan blow a vertical and stable airflow to control the wind speed in order to carry out the experiment.

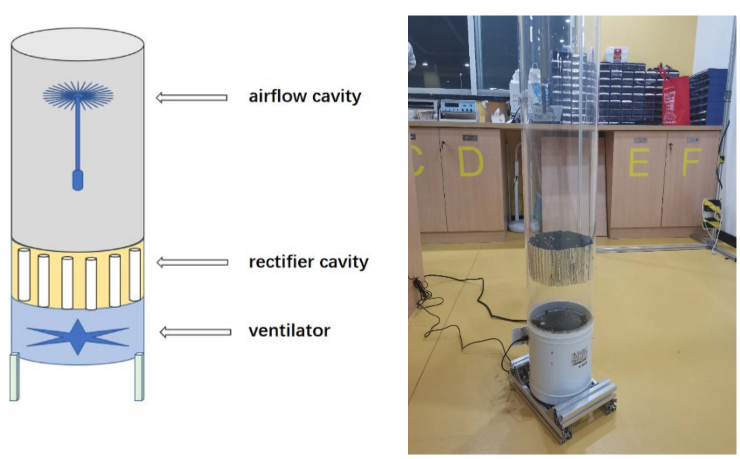

Fig. 3 Design and construction of the experimental setup.

3. Results and Discussion

3.1 60° and 45° Elevation Angle Model Trajectory and Motion Analysis

The experimental records show that the initial stabilization stage of the dandelion model at 60°elevation angle (average) wind speed is 4.88m/s, and the model rotational speed is 10r/s, which can be seen in Fig. 4, and the dynamic motion period is between 1.1s~1.3s. The suspension stabilization stage (average) wind speed is 5.24m/s, and the model rotational speed is 15r/s, and the motion period is between 1.3 s~1.5s. The rising stage model speeds up, and there is almost no obvious up-and-down change, which means that the airflow at this wind speed breaks the original dynamic cycle, which is longer than the previous stage. Between, than the previous stage of the cycle is long; rise stage model speed up, almost no obvious up and down floating changes, at this time (average) wind speed of 5.7m/s, that is, this wind speed airflow breaks the original dynamic balance, because the wind speed has a law of attenuation as well as non-uniform distribution of the airflow, the model reaches a certain height deviates from the original vertical trajectory, from the figure can be seen in the horizontal direction of the model deviation from the position, also reflects the inhomogeneity of the airflow. The figure shows the deviation of the horizontal position of the model, which also reflects the non-uniformity of the airflow and the vortex and other characteristics of the airflow itself.

The experimental records show that at 45°elevation angle, the initial stabilization stage of the dandelion model (average) wind speed is 3.38 m/s, and the model rotational speed is 20 r/s. From the Fig. 4, it can be seen that the dynamic motion period is between 1.2 s and 1.4 s. The hovering stabilization stage (average) wind speed is 3.64 m/s, and the model rotational speed is 26 r/s, and the motion period of the model is between 1.1 s and 1.3 s, which is shorter than that of the former stage, which is shorter than the previous stage. which is shorter than that of the previous stage; the model speeds up in the ascending stage, and the wind speed is at 4.28 m/s, which is similar to that at 60°and there is almost no obvious up-and-down change.

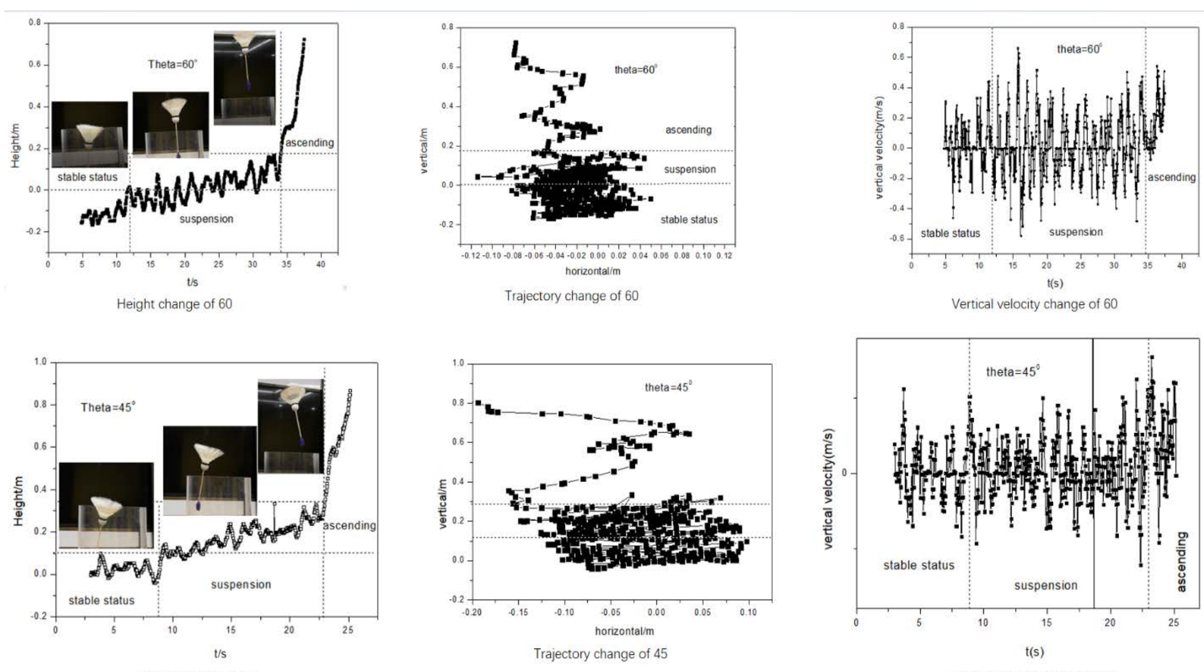

Fig. 4 Altitude, trajectory, and velocity changes in the vertical direction.

3.2 Analysis of Dandelion Model Upper and Lower Floats

In the course of the experiment, the authors found that most of the models float up and down when they are in motion, which is due to the fact that the pressure at the vortex is less than that below the dandelion model, and the model moves upward and then forms a more stable motion state under a certain wind speed due to gravity. On this basis, it is assumed that if the dandelion model receives a constant airflow field, then the lifting force given to the dandelion model by the airflow field when it is rotating is constant, and its gravity is also constant, so that ideally, the model can be stably stationary at a certain wind speed. The up and down cycles of the dandelion model are not obviously related to the wind speed, both in the two elevation angles where the trajectory was photographed earlier and in the subsequent models where the motion could not be clearly photographed. Therefore, it can be judged that the main reason for the up and down movement of the dandelion model in the experiment is the instability of the experimental environment and the airflow of the device.

3.3 Analysis of Experimental Data

In the above two angles of study, the author found that dandelions exhibit three different motion states at 45 ° and 60 ° angles. However, in subsequent experiments, the author found that gradually changing the elevation angle of dandelions can only make the dandelion model maintain a relatively stable state during motion. Therefore, the author decided to choose the dynamic suspension process in the above experimental process as the main research object. The results are summarized in Table 2.

Through the preliminary analysis of the data in the above table, the authors can relatively obviously find that the stabilization speed of the dynamic levitation of the dandelion model increases with the increase of the elevation angle. And since the lifting force of the dandelion model is caused by the pressure difference formed by the vortex above it during its rotation, thus the authors speculate that the decomposition of the force caused by the different elevation angles and the change of the vortex at different elevation angles may have an effect on the results of the experiment.

Table 2. Wind speed (m/s) variations at various angles.

Angle (°)	30	45	50	60	70
1	3.4	3.8	4.9	4.6	6.4
2	3.1	3.5	4.8	5.1	5.9
3	3.3	3.2	4.9	5.1	7.4
4	2.9	3.5	5.8	5.5	6.7
5	3.6	4.2	4.3	5.9	8.1
average v	3.6	3.64	4.94	5.24	6.9

3.4 Fluent Simulation

In the flow field simulation of this experiment, since the rotation of the dandelion model is facing the same direction no matter how it is placed, the authors speculate that the main reason for this result may be the Coriolis force (which is also commonly referred to as the geostrophic bias force), based on this similarity, since the mass and porosity of the dandelion model are all the same at this stage of the experiment, the authors simplify it into two dimensions to analyze the pressure and velocity fields under a steady wind speed in the Fluent flow field simulation. into two dimensions to analyze the pressure and velocity fields under steady wind speed. The simulation results are shown in Fig. 5.

Through the analysis of the above Fluent flow field diagrams, it can be found that: all dandelion models under the influence of such a constant airflow field, above the model will be detached from the center of the formation of an independent vortex, the vortex inside the air pressure is lower than the outside, and in the lower part of the vortex there will be a high-pressure vortex airflow field, in which the highest value of the air pressure in the connection between the crown hairs and the thin rod (let's call it the center for the sake of the project), with the elevation angle of the vortex airflow field, the pressure and velocity of the vortex airflow field will increase. This research will call it the center. With the increase of elevation angle, the size of the vortex pressure field decreases gradually, while the velocity field is expanded by the semicircular arcs on both sides of the vortex and decreases gradually, and the maximum value of the velocity occurs at the left and right vertices of the elliptical vortex, and the range of the semicircular arc-shaped velocity field increases gradually with the increase of the elevation angle. For the analysis of the local velocity vector diagrams, it can be found that in the elliptical vortex there will be two vortices with different velocity directions left clockwise and right counterclockwise, and in the real situation, the size of the airflow fields of the left and right vortices will be different due to various conditions such as the Coriolis force.

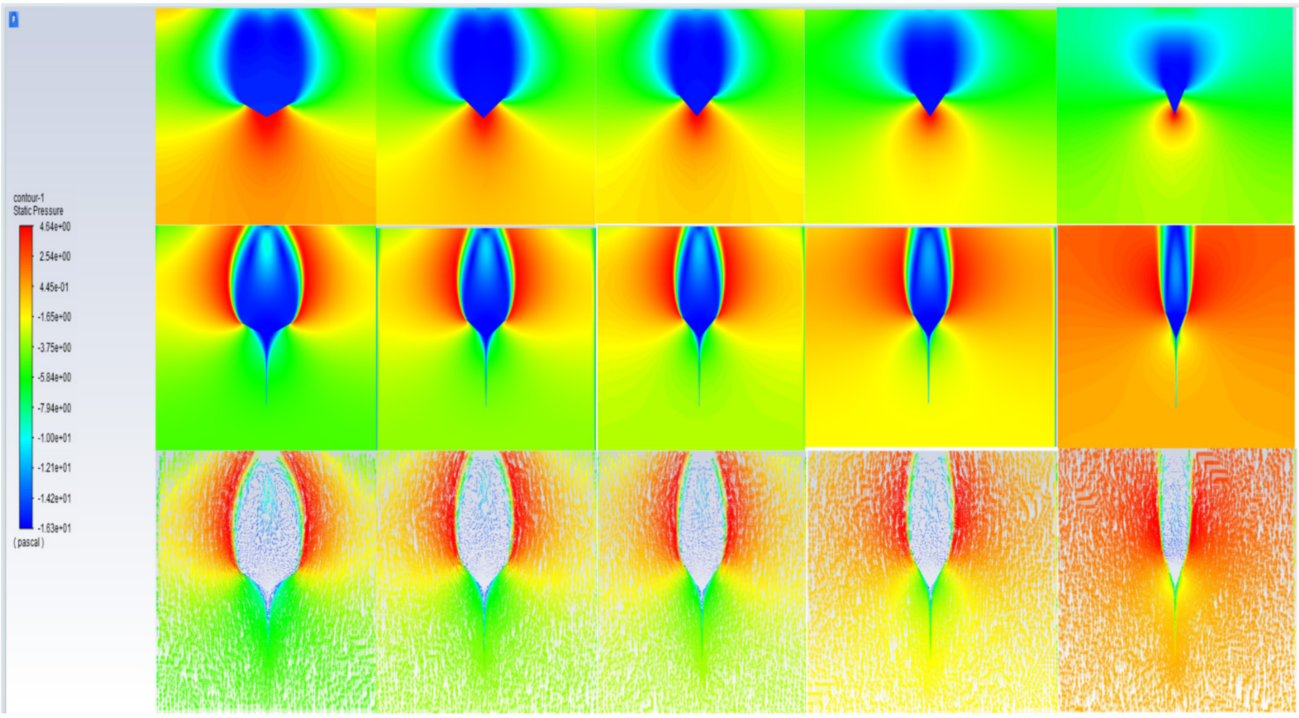

Fig. 5 From left to right, the pressure field, velocity field and velocity vector field for elevation angles of 30, 45, 50, 60 and 70, respectively.

3.5 Prospect

Further study will continue to change the center of gravity and mass of the dandelion model to study the effects of other variables on its trajectory, and verify the possibility of the above-mentioned air purifier, flying machine and other practical applications through experiments and theories. After completing the experimental data collection and the analysis of the motion state, the author will refer to the results obtained from Fluent simulation software and study the hydrodynamics related problems to investigate the theory of the flight mechanism of the dandelion model and get the hydrodynamics study of the flight mechanism of the dandelion model.

4. Conclusion

To sum up, the dandelion model is simulated by taking the badminton structure as the basic reference, adjusting the angle of the dandelion hair as well as meeting its rigidity, and setting the three motion states of the dandelion, i.e., smooth period, levitation period, and ascending period, by constructing a wind tunnel, and measuring the exit wind speed of the wind tunnel respectively. After analyzing the data extracted by shooting video, the following conclusions can be obtained. The dynamic equilibrium (i.e., floating up and down) period of the dandelion is not obviously correlated with the wind speed, but the rotational speed of the model is positively correlated with the wind speed (to be followed to improve the research). The wind speed at which the dandelion model maintains stable flight increases with increasing elevation angle. A low pressure vortex detached from the body exists above the center and a high pressure airflow field exists below, the size of which decreases with increasing elevation angle. The velocity field unfolds from the semicircular arcs on both sides of the vortex and decreases gradually, and the velocity maxima appear at the left and right vertices of the elliptical vortex, and the range of the semicircular arc-shaped velocity field increases gradually with increasing elevation angle. There are two vortices with different velocity directions in the elliptical vortex, the left velocity direction is clockwise and the right is counterclockwise. It is found that the trajectories of the models with different masses and different center of gravity positions also have deviations, which can be experimented in depth and find the laws in the subsequent research. In addition, in terms of theory, future research will continue to use fluent simulation software to simulate the dandelion model in the center of gravity position, different elevation angles and other variables.

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