Master Thesis

Aerodynamic Analysis of Elongated Shape Body with Flight Trajectory

Ikuto Sugiura
Major in Mechanical Systems Engineering
Graduate School of Science and Engineering
Ibaraki University

Abstract

A body in flight receives aerodynamic force from air flow around it. This force affects the flight trajectory of the body. The aerodynamic characteristics of a body moving in the air are expressed with aerodynamic coefficients which are dimensionless quantities, and they are generally obtained in wind tunnel experiments. In wind tunnel experiments, fluid force acting on a body fixed in a uniform airflow artificially generated is measured. However, it has been reported that the aerodynamic coefficients of projectiles moving in the air with the acceleration and/or deceleration change temporally. This fact suggests that it is necessary to further investigate the aerodynamic characteristics of projectiles. It is also known that the shape of a body in flight influences fluid force acting on it. In fact, the angle of attack has important effect in the aerodynamic characteristics in body with elongated shape.

In this study, we consider javelins of javelin throw as an example of elongated shape body and estimate unsteady fluid force acting on it from their two-dimensional trajectory data. In particular, the angle of javelin is determined from the attitude in flight images, and it is related to the results of the aerodynamic coefficients in order to clarify the effect of the attitude of javelin in flight to fluid force.

First, the aerodynamic coefficients are estimated using two-dimensional trajectory data of a non-spinning table tennis ball which is a smooth sphere without seam nor roughness. We compare the results with the previous results, to investigate the accuracy of the estimation method used in this study. The comparison show that the variation of the estimated aerodynamic coefficients is smaller than that in the previous results and that the estimating range of aerodynamic coefficients increases in the present results. Then we can confirm the improvement of the estimation accuracy of the present method.

Next, we estimate fluid force from two-dimensional trajectory data of a javelin. As the result, several types of unsteady tendency in fluid force are obtained depending on the trajectories. The results are compared with those of trajectory data with long flight distance in the previous studies, and they can be classified into two types; one has similar tendency in unsteady fluid force and the other different in the variation.

Furthermore, in order to consider the attitude of a javelin in flight, the angle of attack of the javelin is obtained from the trajectory data. From the results of the angle of attack and fluid force, it is found that the tendency in the changes of fluid force is different in the early and the later phases of the trajectory according to the attitude of the javelin. In particular, two types of tendency in fluid force are observed. One type of the tendency shows that the drag and lift increase with the increase of the angle of attack. On the contrary, in the other the drag increases and the lift decreases drastically in the later phase of the flight trajectory although both of the drag and lift increase in the early phase of the trajectory. This fact suggests that the attitude of the javelin causes the stall due to flow separation at the leading edge of the javelin in the later stage of the trajectory.

In this study, we estimate aerodynamic coefficients from the trajectory data of table tennis balls and confirm the improvement of the estimation accuracy of the present method. This method is also used to estimate fluid force and the angle of attack of a javelin in flight, and it is shown that there are two types of tendency depending on the attitude of the javelin.

As one of the future works, it is interesting that the angular velocity in rotation around the center of gravity of the javelin in flight is calculated from the trajectory data. This approach will clarify the details of the effect of the attitude of a javelin in flight to the aerodynamic characteristics.