The Physics of Frisbee Golf

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Abstract

Most people have had the experience of throwing a Frisbee, or even played a game of disc golf. As one may have noticed a disc will have a seemingly predictable curve in its path. At first glance the discs may seem the same, but there are subtle differences that drastically alter the flight path. One of the key differences I would like to highlight is the size of the rim. This will have an affect on the stability and the overall path the discs will take.

Experimentally

Experimentation of a flying disc proved to be quite difficult due to the symmetry of the disc. Any discontinuity in that and all stability will be lost, so attaching an accelerometer was out of the question. However, to have experimental data to compare; we measured the average flight distance of three different discs: a short, mid, and long range disc. The specifications of each disc, such as weight and rim size, are listed by the PDGA.

Other quantities such as precession, roll, and angle of attack we were unable to calculate. Each disc manufacturer has an 'intended' flight path for their variety of discs. The manufacturer then rates the disc using PDGA guidelines based on the fight path. Using these ratings we can make correlations between characteristics of the disc and flight path.

References

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Lift and Drag

Lift is generally interpreted using Bernouilli's Principle: that for a fluid to increase in velocity it must also decrease in pressure. The design of a flying disc must be so where a pressure differential between the top and bottom is created. Which is why discs have a contour. Using Bernouilli's Principle the lift force can be represented by:

$$F_L = \frac{1}{2}\rho v^2 A C_L$$

Where rho is the fluid density, nu is the fluid velocity, A is the area of the disc, and C_L is a lift coefficient. The pressure differential also causes instability in the disc- an uneven net force.

Drag can similarly be calculated, but first needs a Reynolds number.

$$R = \frac{\rho v d}{\eta}$$

Here d is the diameter of the disc, and η is the fluid viscosity. The Reynolds number determines how the stream lines will flow. In this case it leads us to a relationship for the drag force

$$F_D = -\frac{C_D \rho A v^2}{2}$$

Where C_D is the drag coefficient

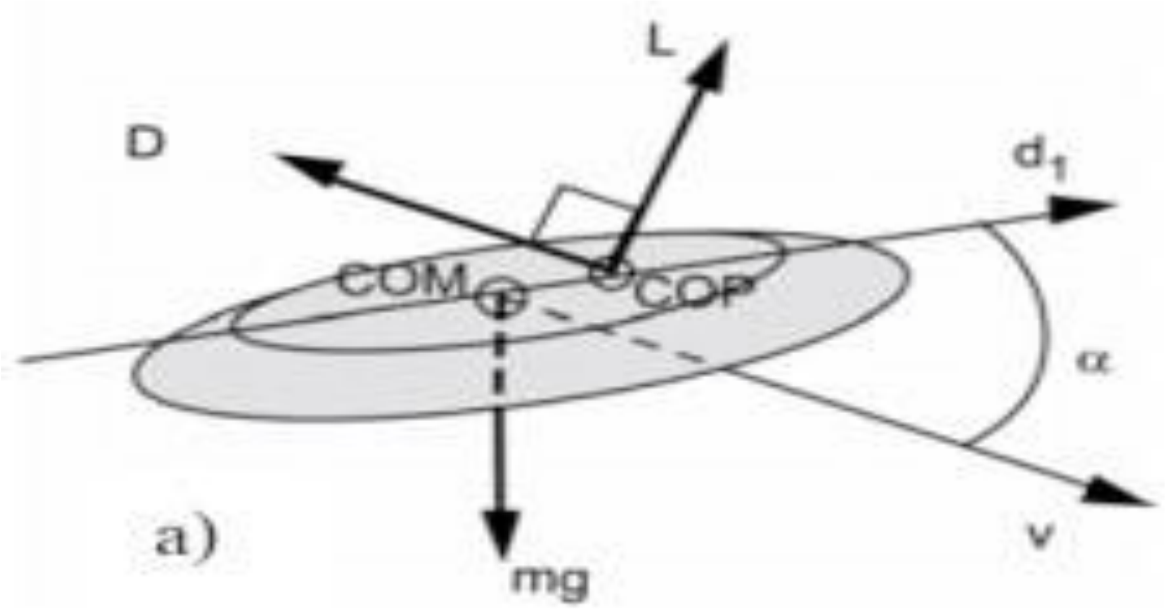

Figure 1) A graphic describing the direction of lift, drag, center of mass (COM), and center of pressure (COP). Morrison (2005)

Rotational Inertia

Rotational inertia is key in having stable flight. When a frisbee is thrown it is given spin. The resulting torque counteracts the uneven pressure differential since it works orthogonally to the plane of rotation. A general equation to describe this behavior is:

$$\tau = L\frac{d\acute{\omega}}{dt}$$

Where τ represents the torque, L is the magnitude of the angular momentum, and $\acute{\omega}$ is the axis of rotation.

Here the main driver of the torque exerted on the disc is the angular momentum. Which can be described as

$$L = I\omega$$

Where I is the rotational inertia and ω is the angular velocity. Angular velocity is largely dependent on the thrower themselves, but the rotational inertia is dependent on the characteristics of the disc. A general equation for inertia on a disk is

$$I = \frac{1}{2}MR^2$$

Where M is the mass and R is the radius of the disc.

Numerical Modeling

To compare our experimental results to a theoretical model we used a 2-dimensional model adapted from Morrisons' "The Physics of Frisbees." Here we input the specifications of a midrange disc (AVG = 60 m) to see the theoretical outcome.