HOW TO MAKE A BOOMERANG RETURN

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Introduction and Methodology

Although anthropologists have written widely on the apparent significance of boomerangs in prehistoric and aboriginal societies, boomerang mechanical dynamics have been the subject of relatively few previous papers. An early detailed study by Walker (1897) analyzed the boomerang's stability. A layman's description of the dynamic behavior was given by Hess (1968) and Walker (1979a,b). Hess later measured aerodynamic forces and moments in a wind tunnel for several spinning boomerang models, simulated the flight characteristics of these, and compared them to experimentally measured flight paths (Hess, 1975). An iterative method for calculation of initial conditions leading to exact return was proposed by Hubbard (1991). We use similar techniques to describe completely exact return initial conditions for a single boomerang.

An L-shaped boomerang thrown right-handed with the L-plane approximately vertical, first "lies down" toward a smaller bank angle (Hess, 1968) that allows the precession of its spin angular momentum by the rolling moment produced by the larger lift on its outside arm. It gradually turns to the left on a path with a roughly circular projection on the horizontal plane that again approaches the thrower. This somewhat circular return path is not steady, however, with substantial variations of bank angle, spin and speed. Near the end of this leftward turning path the speed slows to the point that lift is unable to counteract gravity, the downward vertical velocity and angle of attack increase, and the leftward turning viewed from near the center of the path changes direction. From this point, called "turn-around", the path gradually approaches an asymptotically stable downward rightward turning helical trajectory with constant radius, bank angle, speed and spin rate. The speed at turnaround is near a minimum and hence this is a candidate point to catch the boomerang easily. Using the aerodynamic data for model L1 of Hess, we explore the set of initial conditions that allow capture before, at, and after turn-around. Initial conditions are varied to "pull" the trajectory toward the return point using several optimization methods.

Results

With initial velocity v_o held constant, four other initial conditions uniquely determine the path: ω_o, the initial spin rate, rev/s (or, equivalently, the advance ratio $U = v/r\omega$ where r is the boomerang radius) ; α_o, the initial incidence angle or angle of attack of the L plane; ψ_o, the initial flight path angle; and θ_o, the initial tilt of the spin axis from vertical. For several velocities (v_o = 25, 30 m/s) we present curves of ϕ_o vs. θ_o, parameterized for constant α_o, and U_o, that yield exact return. When return is specified to occur at turn-around, three initial conditions must be specified and v_o , ϕ_o and θ_o are given for constant α_o, and U_o. The return conditions are remarkably sensitive in certain regions of the parameter space.

References

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