A very small amount about the physics of baseball

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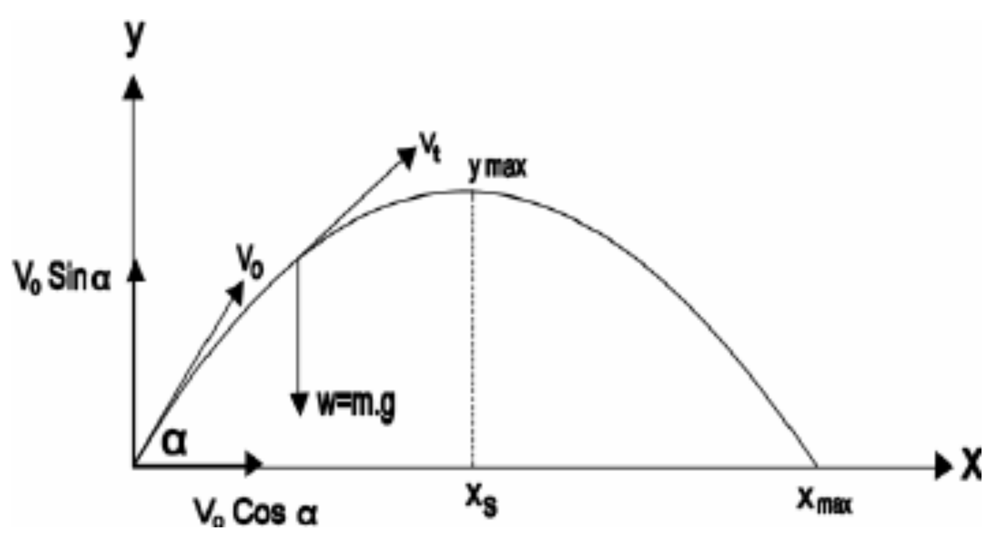
Two Dimensional Kinematics

What is the path of a ball? We can determine this path by using the equations of two dimensional kinematics and then solving for time such that we are left with just x and y as variables:

$$x = v_0 \cos(\theta) t$$

$$y = v_0 \sin(\theta) t - \frac{1}{2} g t^2$$

$$y = \tan(\theta)\, x - \frac{1}{2} g \left(\frac{x}{v_0 \cos\theta}\right)^2$$



In reality, with air resistance and aerodynamics a typical home run leaves the bat at 100 mph, traveling 380ft. However in our ideal world, our 100 mph batted ball launched at a 45 degree angle goes 678 ft.

Introduction

In this presentation, I discuss the physics of ball trajectories, ball-bat collisions including both kinematics and a ballistics model. I explore and model the physics of the collision, including the sweet spot of a bat.

The Collision: A simple model

Any non-ideal physics world collisions are extremely complex. However, we can make good estimates of the velocity out of the ball by modeling the collision as an elastic collision between a ball and a rigid log. Setting up the equations of momentum and energy conservation we get:

$$m v_0 = m v_1 + M v_{batf}$$

$$\frac{1}{2} m v_0^2 = \frac{1}{2} m v_1^2 + \frac{1}{2} M v_{batf}^2$$

Solving for v_1, the outwards velocity of the ball in the reference frame where the bat is not moving we get:

$$v_1 = -\frac{v_0\left(\frac{m}{M} \pm 1\right)}{\frac{m}{M} + 1}$$

Given some typical numbers for speed of the incoming ball and the speed of the bat for a home run swing give that the ball comes off the bat at 79 m/s (176 mph)

A less simple model

Of course, in real life this collision is somewhere between an elastic and inelsatic collision. So we must add a Q factor to our energy conservation equation to get that velocity out is equal to:

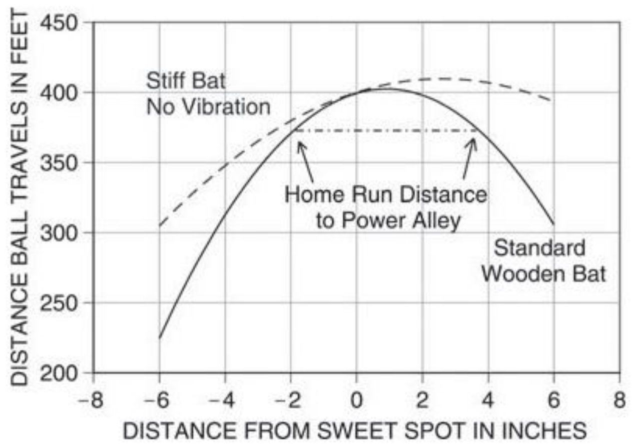
$$-\frac{\frac{m}{M} v_0}{\frac{m}{M} + 1} \pm \frac{v_0 \sqrt{1 - 2Q/\mu v_0^2}}{\frac{m}{M} + 1}$$

More and more complex

However, a baseball bat is not a rigid object. In addition, bats rotate if they are hit off of the center of mass and also vibrate.

Ball hits inside of center of mass (Bat vibrating and rotating)

Ball hits outside of center of mass



Therefore, where the ball hits on the bat strongly affects how far a ball will be hit, as shown on this graph to the left.

Acknowledgments

Image References:

Images from *The Physics of Baseball* by Robert Adair, mlb.com and http://baseball.physics.illinois.edu/