COLLISIONS BETWEEN GOLF BALLS AND CLUBFACES

by nmgolfer © 2008

INTRODUCTION

> nmgolfer,
>
> I presume that the clubhead must have a finite amount of weight so that the clubface doesn't deform at impact. Presuming that the clubface is sufficiently rigid, you are presumably stating that additional clubhead weight and/or additional push-pressure thrust exerted by the golfer has no effect on ball flight distance (other than its effect on clubhead speed at impact). Is that correct?
>
> What about the possibility of clubhead **acceleration** through impact due to drive loading in a hitter's action. In your mathematical model, you are presuming that clubhead speed remains constant for the entire duration of ball-clubface contact in both situations. However, wouldn't increased drive loading (thrust force = push-force) allow the clubhead to continue to accelerate while it remains in contact with the ball for a duration of 1/4000 second? A hitter is not simply applying increased mass behind his drive loading action - he is also thrusting and accelerating the club through the impact zone.
>
> Jeff.

Science requires precision of thought and expression. If we allow the language to deteriorate we will lose our ability to express ideas and that would be a disaster. I shall strive to be precise in my language.

WEIGHT

We weigh something to determine its mass. Its "weight" is a product of gravitational attraction times its mass. But did you know that on Earth the gravitational attraction varies from one location to the next? Its true. Metrology labs must account for local variations in the gravitational constant. Therefore weight varies depending apon location but its mass does not. Mass is the property that interests us.

COLLISION PHYSICS

Ball mass (M_b), club head mass (M_a), club head velocity (V_o) and coefficient of restitution (e) are the parameters which determine the **initial velocity** (V_b) of the ball. Similarly it is not structural rigidity per se (of the clubface) but the coefficient of restitution (also called COR) of the impact that matters.

$$V_b = \frac{V_o(1+e)M_a}{(M_a+M_b)}$$

COR is a property of the collision not the ball or the clubface. COR varies with parameters such as velocity, temperature etc. For instance as all golfers instinctively know, the same swing (club head speed) will deliver different results depending on air temperature (elasticity of ball and to a lesser extent clubface).

To establish reasonable bounds and a fair playing field, the relevant parameters for both ball and driver as measured under specified test conditions are limited to not to be exceeded statistically determined maximum values by the game governing agencies. Of course equipment manufactures are always trying to game the system.

- During the inelastic collision of the club face and ball some energy is lost (it gets converted to heat during the deformation), but momentum is conserved.

COR is a measure of how much energy is lost. It is defined as the ratio of the relative speed after to the relatives speed before the collision. If you drop a golf ball on a hard surface, it will not rebound to the same height you dropped it from. This is because the collision of a golf ball with a hard surface is not elastic (its not inelastic either... it is something in between) , some energy is lost as the ball deforms. The amount of energy lost during the collision is $E=(1-e_o^2)$.

$$\text{coefficient of restitution: } e_0 \equiv \frac{v_{\text{rel},f}}{v_{\text{rel},b}}.$$

$\Delta E = mg\Delta h = mg\,(h1 - h2)$ and the e_o for the collision is: $\sqrt{(h2 \div h1)}$

COLLISION FORCES

- During the collision both ball and clubface experience a time varying force which is equal in magnitude but opposite in direction. We can estimate what that average force might be by calculating the impulse:

$$d(M_bV) = F_{ave}dt$$

From Newtons first law, since we know that mass of the golf ball and the time it takes for the collision to happen, we can calculate the average force acting on (both) the club face and ball during the event. Lets assume the ball has an initial velocity of 150 mph (220 ft/sec) and it weighs: 0.1014 lb_m. Furthermore lets assume that the total time elapsed (per Frank Thomas) from contact to departure is 0.00043 seconds or 1/2325 seconds. Then

$$F_{ave} = (0.1014x220) \div (0.00043x32.174)\ (lb_m\ ft/sec) \div (sec\ lb_m/slug\ )$$

$$F_{ave} = 1{,}612\ lb_f\ \therefore$$

Now we see that, even for a slow swing speed, the average force acting on the club head during a collision is approaching a ton. The peak force is propably 2½ times greater. Any force a "hitter" can generated pales in comparison to the forces generated during the collision itself.

A golfer cannot "apply mass" to the golf club. Mass is a property of the golf club and it does not change depending on how it gets swung. Yes… a golfer can accelerate a golf club before the collision, but his / her efforts during the collision cannot:

- Prevent the club from drastically deccelerating
- make the ball have a higher initial velocity

By the time the collision takes place, the golfer has done everything he/she can do to effect the outcome of the shot.