Developing an Apparatus to Evaluate the Pace of Baseball Field Playing Surfaces

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Introduction

Baseball is popular sport in the United States played by numerous individuals. During a baseball game, the ball will strike the playing surface at a variety of speeds and angles. The speed at which the ball is moving after impact with the playing surface can be referred to as the pace of the surface. Wide variations in pace can reduce the safety and playability of baseball field surfaces.

Baseball playing surface pace has rarely been measured directly. Baseball playing surface pace has been indirectly evaluated through measurements of vertical ball rebound and ball to surface friction (Baker and Canaway, 1993; Goodall et al, 2005). Surface pace has been characterized qualitatively by asking players to rate surfaces as having a “fast” pace or a “slow” pace (Bell et. al, 1985).

Playing surface pace has been measured directly in sports such as tennis and cricket (Thorpe and Canaway, 1986b; Baker et. al 1998). Pace has been quantified by measuring the coefficient of restitution. The coefficient of restitution is defined as the ratio of two velocities; the velocity of a ball after impact with the surface divided by the velocity of the ball prior to impact (ASTM, 2005). No data of this nature has been collected on baseball field playing surfaces.

Objective

The principle objective of this project was to develop an apparatus to accurately measure the pace of different baseball field playing surfaces.

Materials and Methods

Machine Development

PENNBOUNCE is comprised of four ballistic screens (Model M-57, Oehler Research, Austin TX 78766) and an air cannon (Model # Storm 300, Air Cannon Inc., Denver, CO 80202) used to propel baseballs towards the playing surface. The inside diameter of the cannon is 74-mm, as it was designed specifically for the purpose of propelling baseballs. It is powered with compressed CO_2, and the pressure can be adjusted from 345 to 2760 kPa with the use of a high pressure regulator. Preliminary calibration determined that 2070 kPa generated a ball velocity of approximately 40.2 m s^{-1} (90 mph), while 896 kPa generated a ball velocity of approximately 31.0 m s^{-1} (70 mph).

A single screen stands 914-mm tall and 457-mm wide, with a testing area of 609-mm by 406-mm. Each screen contains a circuit board that houses a line 72 infrared emitting diodes. The screen is equipped with visible red diodes that indicate that the apparatus is functioning properly. Screens are powered using 120 volt AC power supplied using a standard 12 volt automobile battery (Type 31T190, New Castle Battery Mfg, New Castle, PA 16105) and a power inverter (Model# VECO34, Vector Inc., Ft. Lauderdale, FL 33312).

While in use, the 72 infrared emitting diodes create a plane of infrared light. When a baseball is propelled through the screen, the plane of infrared light is broken. This sends a nominal +12 volt pulse to a 35 x 2 chronograph (Oehler Research, Austin, TX 78766) mounted above the screen. If two screens are placed a set distance apart from one another (in the same plane), the ball will break both planes of light and two pulses will be sent to the chronograph. The chronograph then measures the time between these pulses (the time required to break both planes of light) in order to determine the velocity at which the ball is moving. PENNBOUNCE uses four ballistic screens in an arrangement such that one pair calculates the velocity of the ball prior to impacting the playing surface and the second calculates the velocity of the ball after contacting the playing surface (Figure 1).

Figure 1: PENNBOUNCE measuring the pace of a skinned (grass-free) infield surface

Two boxes, 965-mm high and 470-mm inches wide, were constructed to hold each pair of screens, with each screen bolted to the inside of the box. One box is equipped with a holster for the air cannon. This holster is comprised of a 216-mm long piece of 76.2-mm diameter pipe in which the cannon rests. This pipe is fastened to a metal sled piece with four 305-mm long pieces of angle iron. Channels are cut into this sled piece that allow for the cannon to move freely along the outside of the box frame, as the impact angle is changed.

These boxes are placed into a frame made of 3.17-mm thick angle iron. The frame measures 2388-mm long and 483-mm wide. This frame also houses the battery as well as a 30 liter CO_2 tank. While in the frame, the boxes are hitched in two places allowing them to move either closer or further away from the testing surface. This feature allows for evaluations of playing surface pace to be made at angles of inclination of 0.26, 0.44, 0.61 radians (15, 25, and 35 degrees).

The frame is also equipped with four wheels, 254-mm in diameter. The rear wheels are fastened to 864-mm long arms that are pinned to the frame during transport, thus lifting the frame approximately 102-mm off the surface. During testing the pins are removed, and the frame rests on the surface.

A steel plate (533 x 244-mm) extends from the front of the base frame. This plate is fastened to the frame using a hitch that allows it to rise and lower freely. The front wheels are attached to a 1118-mm long axel that is connected to this steel plate. The plate is equipped with a friction bearing and grease fittings that allow the machine to turn easily. While in transport, two metal bars (311-mm long and 19-mm in diameter) located on the outside edge of the frame restrict the vertical movement of the steel plate. The frame is switched from a transport position to a testing position by pushing down on the 978-mm long handle attached to the steel plate. This lifts the weight of the frame off the steel bars, which can then be slid back allowing the machine to be lowered to the testing surface.

A roller, 584-mm in length and 51-mm in diameter, is attached to the rear of the frame to allow for it to be moved to different testing locations without having to raise the frame back into the transport position. The roller also prevents the edge of the frame from cutting into the testing surface. A batting cage net (Jugs Inc., Tualatin, OR 97062) is also attached to the rear of the frame. The net is attached to a 1029-mm by 521-mm aluminum frame that fastens to the angle iron base frame.

Experimental Design

A study was conducted in April 2005 to determine the efficacy of PENNBOUNCE in determining the pace of different playing surfaces. Two synthetic surfaces, Astroturf (SRI Sports, Dalton, GA 37021) and Fieldturf (FTOS1-F, Dalton, GA 30721), were evaluated at the Joseph Valentine Turfgrass Research Center, University Park, PA. Natural turfgrass and skinned (grass-free) soil surfaces were tested at Beaver Baseball Field, University Park, PA. Surface pace was quantified by measuring the coefficient of restitution of baseballs propelled at the surface at angles of 0.44 and 0.61 radians of inclination and at velocities of 31.0 m s^{-1} and 40.2 m s^{-1} (70 and 90 mph). Replications were randomly assigned within each playing surface type. Six evaluations were made at each angle-velocity combination within each replication

Results and Discussion

Significant differences in pace were associated with playing surface type (Table 1). Skinned infield soil surfaces exhibited the highest coefficient of restitution, 0.598, while natural turfgrass systems exhibited the lowest coefficient of restitution, 0.378 (Table 2). Practically, this indicates that balls striking skinned infield soil surfaces will move forward at a greater velocity than any of the other surfaces tested. There were no significant differences between skinned surfaces and Astroturf, nor were there significant differences between Astroturf and Fieldturf (Table 2).

TABLE 1: Mean squares for coefficient of restitution measurements made on different playing surfaces in 2005

Source	DF	Mean Square
Surface (S)	3	0.115***
Replication (R)	2	0.008
Angle (A)	1	0.055*
Velocity (V)	1	0.012
S x A	3	0.016
S x V	3	0.003
A x V	1	0.018
S x A x V	3	0.012
Error	47	0.009

†,*,**,***Significant at $P \leq 0.10$, 0.05, 0.001 levels, respectively

The impact angle at which the ball struck the surface was also significant (Table 3). Balls contacting the surface with a angle of incidence of 0.44 radians exhibited a coefficient of restitution of 0.539, while those striking the surface at an angle of 0.61 radians exhibited a coefficient of restitution of 0.474 (Table 3). This is likely due to the fact that at shallower angles of inclination a smaller percentage of the surface area of the ball contacted the testing surface. This would result in less energy being lost to the surface, thus potentially explaining why balls move forward at a greater velocity at shallower impact angles.

TABLE 2: Mean coefficient of restitution values (COR) tested on different playing surfaces in 2005

Surface	N	COR*
Skinned infield soil	12	0.598 a
Astroturf	12	0.562 ab
Fieldturf	12	0.487 b
Natural turfgrass	12	0.378 c

*Means with different letters are significantly different from one another (Duncan's nMRT, p≤0.05)

The velocity at which the ball approached the surface was insignificant, as there was no statistically significant difference in the coefficient of restitution of balls approaching the surface at 31.0 m s^{-1} and 40.2 m s^{-1} (Table 3). All interactions between surface, velocity, and angle were insignificant (Table 1). This indicates that a single test angle and ball velocity be used when evaluating the pace of other playing surfaces in future studies.

TABLE 3: Mean coefficient of restitution values tested at different angles and velocities in 2005

Angle of incidence	**N**	**COR***
0.44 radians (25 degrees)	24	0.539 [a]
0.61 radians (35 degrees)	24	0.474 [b]
Velocity	**N**	**COR***
31.0 m s^{-1} (70 mph)	24	0.523 [a]
40.2 m s^{-1} (90 mph)	24	0.489 [a]

*Means with different letters are significantly different from one another (Duncan's nMRT, p≤0.05)

Conclusion

A machine referred to as PENNBOUNCE was developed to evaluate the pace of baseball field playing surfaces through measurements of the coefficient of restitution. PENNBOUNCE uses ballistic screens to measure the velocities of baseballs propelled at the surface both before and after impact, in order to calculate the coefficient of restitution. Differences in surface pace (coefficient of restitution) were associated with variation in playing surface type. Surface pace (coefficient of restitution) was highest on skinned infield surfaces, intermediate on infilled synthetic turf, and lowest on natural turfgrass surfaces. No significant coefficient of restitution differences were found between traditional and synthetic turf surfaces. With a method of directly measuring playing surface pace now in place, future research can be conducted to explore how characteristics of different playing surfaces alter playing surface pace.

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