The Sweet Spot: Problem Handouts

The Sweet Spot

Stage 1: Part 1

"Do we need more injuries?" asked Rick Hughto. "Do we need more kids getting hit in the head, being airlifted?" (source: Channel 7 News, Boston, MA)

In May 2001 during a baseball game in Massachusetts, Wellesley high school pitcher Billy Hughto was struck in the head by a line drive off an aluminum bat. Hughto's skull was cracked and an artery was severed, forcing doctors to perform emergency surgery that required a set of screws to hold his shattered skull together. Coaches and parents, believing that balls hit from aluminum bats are significantly more dangerous, lobbied the league to switch to conventional wooden bats.

Imagine that you are a member of a task force that was formed by the board of directors for the Massachusetts Interscholastic Athletic Association for the purposes of investigating the impact on safety, game statistics, and economics if high school baseball were to switch from aluminum bats to wooden bats. The board asks your committee for a report that is based, when possible, on quantitative and objective data.

Questions:

1. Using data from amateur baseball records, which statistics show differences upon switching to or from aluminum bats? Are any of these significant?
2. Gather facts that will help you estimate the difference in cost per season if a high school team were to switch to wooden bats.
3. List some factors that you believe are involved in determining whether a pitcher has sufficient time to avoid being hit in the head by a ball traveling at him.
4. What physics principles are involved in determining the trajectory of a ball? List some factors that you believe are involved in determining whether a hit ball will be a home run.
5. What properties of a bat can lead to faster hit balls? Are any of these unique to aluminum bats?

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Stage 2: Part 2

"The problem with an aluminum bat is the reaction time for a ball hit back at the pitcher is much smaller than a ball hit with a wooden bat," said Greater Lowell Tech baseball coach Dave MacLaughlan. (source: Lowell Sun, MA)

Assessing the risk of personal injury to pitchers depends on a variety of factors, some of which can be difficult, if not impossible, to quantify. Even so, it is reasonable to expect that the post-impact velocity of the baseball is an important factor.

Even if the initial speed of a thrown ball and the rotational speed of a bat are held constant, the post-impact speed of the ball depends on where the ball strikes along the length of the bat. The sweet spot of the bat is generally associated with a particular position on the bat some distance away from the knob that has two distinct qualities, namely comfort and maximum post-impact velocity. Balls striking the bat away from the sweet spot set up vibrations in the bat that can cause discomfort to a batter's hands and arms. The vibrations also divert energy that could be used to increase the post-impact velocity of the ball. Such vibrations are greatly reduced for impacts near the sweet spot. Figure 1 shows how the post-impact launch velocity varies along the length of a bat.

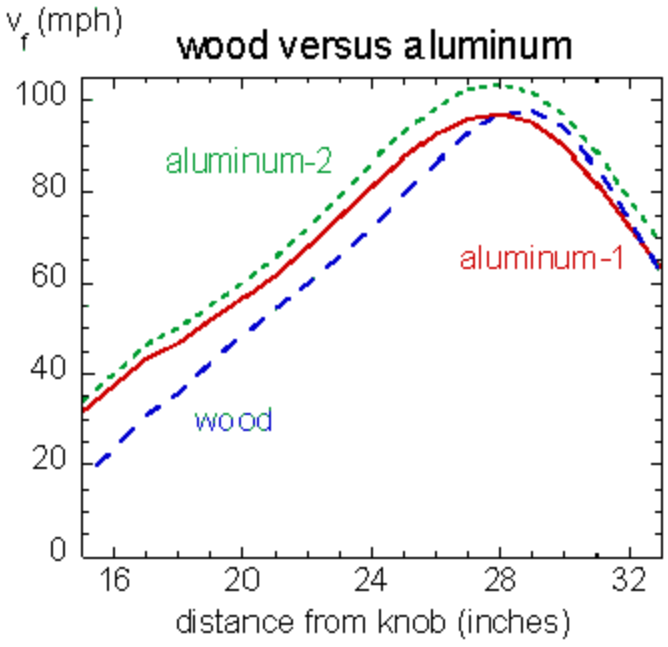

Figure 1. Estimate of post-impact ball launch velocity from a 34 inch bat. For all this data, the initial speed of the ball and rotational speed of the bat were held constant. (source: L. Noble, Department of Kinesiology, Kansas State University)

Questions:

6. Using the data in Fig. 1, calculate the shortest time needed for the ball to reach the pitcher for both the aluminum-2 (short dashes) and wood (long dashes) bats. List any assumptions that you had made in calculating these times. Compare your results with a human's typical physiological response time.
7. Assume that a hit ball must travel for 100 milliseconds before the eyes of a pitcher can see the ball and send an image to the brain. Moreover, assume that it takes another 125 milliseconds for the brain of the pitcher to process the information, extrapolate the ball's trajectory, decide whether to move defensively and what direction to take. For the two types of bats, what is the percent difference in time that remains for the pitcher to move? Make your own judgment as to the difference in reaction times for aluminum *vs.* wooden bats.
8. If it takes a pitcher 225 milliseconds to look, think, and decide, and then another 250 milliseconds to move or defensively protect his head, above what velocity threshold would a head collision be certain? More generally, would you expect aluminum bats to be less forgiving on pitchers than wooden bats? Explain.

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Stage 2: Part 3

Many coaches are concerned that a switch to wood bats will alter the balance between offense and defense, significantly in favor of defensive play. CICL statistics show marked decreases in runs, hits, and home runs per game along with an increase in the number of strikeouts per game. Of these statistics, home run statistics are perhaps a good choice for an objective measure for examining the effect of aluminum vs. wood bats. Whereas runs and hits depend on many factors, such as a batter's running speed and a fielding team's defensive abilities, a flyball is either a home run or not.

Without losing generality, consider the case of Major League Baseball (MLB) switching to aluminum bats. Pick your favorite ballpark or use the dimensions for the Philadelphia Phillies' new ballpark where straightaway center is 401 feet with a 6 foot wall. **For these questions you may assume no wind, air resistance, or ball spin. You'll examine the validity of this assumption in the last question.**

Questions:

9. Choose a post-impact angle and determine the minimum post-impact speed that the ball must have in order to clear the wall.
10. Based on your results and using the data in fig. 1 compare the size of the sweet spot (for home runs) for aluminum and wood bats?

CICL = Central Illinois Collegiate League

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Stage 2: Part 4

Assume that MLB wants to protect its historical home run statistics. It decides to do this by lengthening the outfield or by raising the outfield wall. This has the effect of shrinking the size of the sweet spot for aluminum bats and presumably reducing the number of home runs.

Questions:

11. If it were decided that the size of the sweet spot on aluminum bats should be reduced to match that of a wood bat, what would be the corresponding minimum velocity for baseballs hit within this shorter sweet spot? Use your results for the wood bat from Question 10.
12. By how much would the straightaway center distance have to be changed if a ball hit at this new velocity should just clear the outfield wall? Alternatively, how high should the wall be if the straightaway center distance remains unchanged?

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Stage 2: Part 5

Properly designed metal bats using aluminum alloys can lead to enhanced performance. This has led governing bodies of amateur baseball to regulate certain aspects of non-wood bats. For example, the National Federation of State High School Associations' Baseball Rules Committee requires the diameter of a bat barrel to be no greater than 2 5/8 inches and a minus-3 differential between the length and weight of the bat (a 34-inch-long bat, for example, cannot weigh less than 31 ounces). In addition, for the 2003 season each regulation non-wood bat must carry a Ball Exit Speed Ratio (BESR) certification mark that ensures a maximum exit speed of 97 miles per hour (for a pitch speed of 70 mph and a bat swing speed of 68 mph) and that the bat has met certain moment-of-inertia requirements. In effect, aluminum bats are being made to behave more like wood bats.

Questions:

13. How much time does your home run ball (from question 9) spend in the air? Plot the trajectory of your home run for 10 to 20 points spaced equally in time. How does the trajectory vary with angle? For a fixed speed is there an optimal angle that maximizes the range?
14. Using the data in fig. 1, compare the maximum attainable range of a home run ball for the aluminum and wood bats. Do these distances seem consistent with your experience and the design of major league ballparks? If not, what do expect accounts for the discrepancy?