WOOD AND ALUMINUM BAT STATISTICAL ANALYSIS FOR THE 2007 MLB AMATEUR DRAFT

PART I OF III

BACKGROUND INFORMATION, PHYSICAL DIFFERENCES, AND STATISTICAL HYPOTHESES

An example of bending deformation in a wooden baseball bat[1]

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BACKGROUND INFORMATION

In 1974, the NCAA permitted its member institutions to use newly designed aluminum bats instead of wooden bats.[2] The National Federation of High Schools soon followed suit, and the move to metal quickly spread to youth baseball leagues.[3] The initial reasoning behind this switch was to save money; wooden bats have a tendency to break on inside pitches. An aluminum bat is much more durable and does not need to be replaced nearly as often. Currently, 90% of amateur (college, high school, little league, etc.) baseball teams are estimated to use aluminum bats.[4] Bat makers such as Easton, Louisville Slugger/TPX, Wilson/DeMarini, and Nike introduce and heavily advertise new models every year, with the price of a top quality bat over $250 and as much as $380. These companies also sponsor amateur events and baseball tournaments, and have the money to oppose city legislation seeking to ban metal bats.

MLB has always had very simple regulations concerning wooden bats: the bat must be from a solid piece of wood, the barrel cannot be greater than 2¾ inches, and the wood has to remain unaltered.[5] On the other hand, aluminum bats can be made from a variety of alloys as well as outside materials such as fiber and rubber. The hollow barrel of an aluminum bat combined with all of the research and development money private companies spend on materials give aluminum the potential to drastically outperform wood. Until 1998, the bat regulations concerning these factors were largely futile. In 1989 the NCAA regulated that the length of the bat (in inches) could not exceed five numerical units of the weight (in ounces) and in 1994 the Brandt test—since been declared completely ineffective—was adopted to measure performance level.[6] Indeed, the 1995 College World Series saw a record 48 home runs in the 16-game series (the previous record was 29), until 1998 when 64 were hit. Without going too deep into the numbers, fans of college baseball quickly realized that aluminum bats threatened college baseball's balance of hitting and pitching.[7] The final score of 1998 CWS was 21 to 14, a score more befitting a football game than a baseball game. From 1998 on, the NCAA instituted new regulations aimed at making aluminum bats perform more like wooden bats. Current NCAA regulations require the bat length/weight differential to be -3 units, the barrel to be 2 5/8 inches, a minimum moment of inertia (more on that in the physical differences section), and a maximum Ball Exit Speed Ratio (BESR measures the ratio between the incoming and exit speed of batted ball).[8]

PHYSICAL DIFFERENCES

A wooden bat is made out of white ash or maple, and a 33-inch bat is typically 30 to 33 ounces depending on the type of material used. More importantly, the weight of the wooden bat is distributed differently. A wooden bat will generally have a thicker handle and thinner barrel (2½ inches versus 2 5/8 inches) than aluminum because a thin wooden handle is more likely to break. James Sherwood, Timothy Mustone, and Lawrence Fallon created an experimental model of both bats in order to analyze their differences:

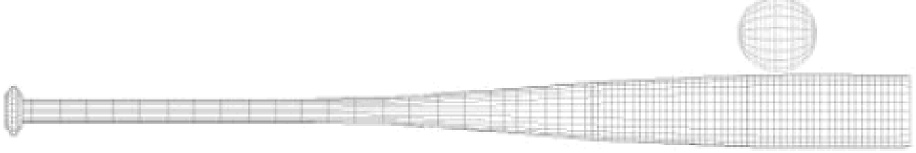


Fig. 10 Profile of the aluminum bat model

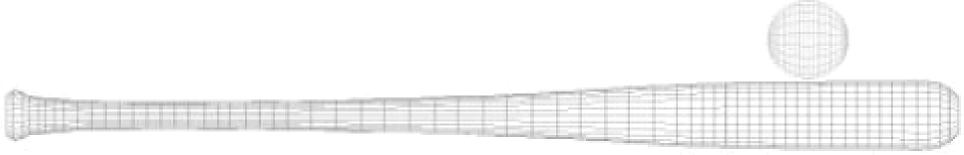
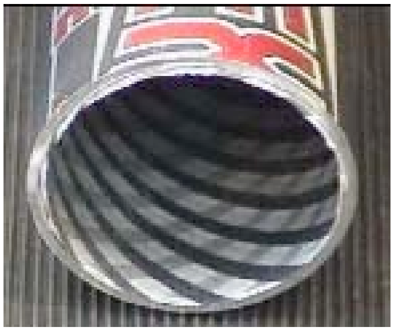
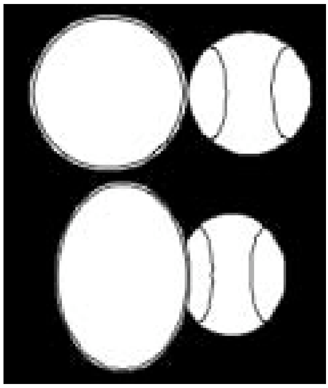


Fig. 11 Profile of the wood bat model

[9]

As one might expect from the pictures, the weight distribution is different. The center of gravity (balance point) for the aluminum bat is 12.63 inches from the knob while the center of gravity for the wooden bat is only 11.25 inches away.[10] Because an aluminum bat is often lighter and weighted towards the barrel, it does not resist momentum as much (i.e. has a lower moment of inertia) and is easier to swing faster. The NCAA regulations provide a minimum MOI, but these values are still lower than the MOI for wooden bats. Other advantages for aluminum bats include more elastic materials and the hollow inside, which creates a trampoline effect:





[11]

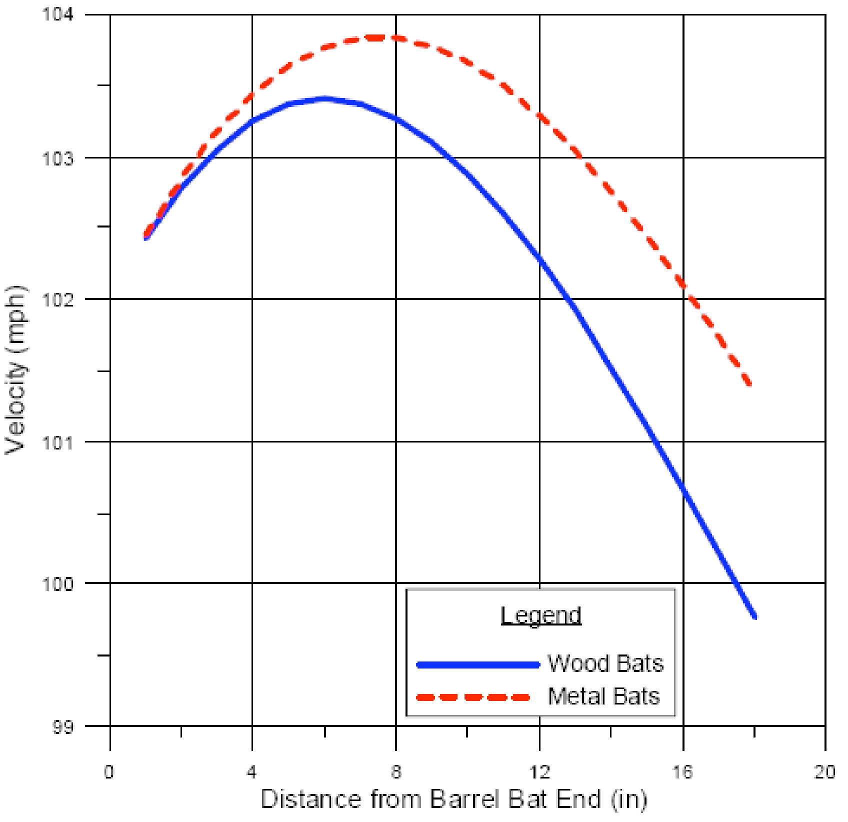
The above pictures show a cut hollow aluminum bat and an illustration of the hoop (bending) deformation during impact. Timothy Mustone describes how all of these differences create an advantage for aluminum:

> “When the ball impacts the bat…the barrel elastically deforms and becomes oval in shape, storing energy from the collision. When the material springs back to its original shape, the stored energy in the bat is returned to the ball, propelling off of the bat at a faster rate than if using a wood bat. Within this global hoop [bending]-deformation mode in hollow metal bats is a phenomenon known as the trampoline effect. This trampoline

> effect is a local deformation in the bat at the point of impact that also stores energy during contact with the ball and then returns it to the ball as the bat returns to its original shape. The trampoline effect also causes the baseball to deform less, which is significant because the baseball is not a good energy storage device. When impacted with the solid wood bats, the baseball deforms more, thus dissipating some of the collision energy…By using newer metal alloys that have higher yield-strength, the trampoline effect can increase the exit velocity of a baseball."[12]

The NCAA aims to equalize these advantages through the BESR (Ball Exit Speed Ratio) test. This test is performed by simulating a 70 mph pitch hitting a bat 6 inches from the end of the barrel being swung at 66 mph; the ball cannot exceed 97 mph (the speed of a wooden bat's BESR) coming off of the bat.[13] So if the requirements for wood and aluminum bats are the same, why is there still a difference in aluminum and wood after a bat is BESR certified? There are several faults with the BESR test. First, the speed of the ball and bat are too slow to be realistic and thus skew the resulting ratios. While the "sweet spot" may be six inches from the end of the barrel for a wooden bat, this spot is about eight inches in for most aluminum bats. Most importantly, the 66 mph swing is standardized and does not take into account MOI, which allows aluminum bats to be swung faster. BESR tests that adjusted for these faults have found baseballs to leave aluminum bats anywhere from 2-5 mph faster than wooden bats.

The following graph does a good job of summarizing the physical differences between aluminum and wood:



[14]

The first thing to note is that this particular test was performed under slightly different conditions than the previously mentioned "optimal" tests, so the difference in exit velocities are closer to a more conservative 1 mph (instead of 2 to 5). Nevertheless, one sees that no matter where the ball hits the bat, it still leaves faster with aluminum than wood. The maximum velocity (sweet spot) by position is about 6 inches from the end of barrel for wood, while it is 8 inches away for wood. Also, the graphs do not show the exact same curve. The graph for wood is steeper than metal, meaning that a batter using aluminum can hit an inside pitch (farther away from end of barrel) a lot harder than he could have with a wooden bat. A wooden bat needs to make contact in a 7-inch zone (from the 3rd to the 10th inch) to be hit hardest, above 103 mph line, while an aluminum bat has a 11-inch zone (from the 2nd to the 13th inch) that will produce the same exit velocity.

STATISTICAL HYPOTHESES

Based on the last graph in the Physical Differences section, a few qualitative observations can be made on aluminum bats. First, aluminum bats hit baseballs harder, and thus farther. Second, a batter using aluminum does not always have to make perfect "sweet spot" contact to hit the ball well; specifically, an inside pitch is easier for the batter to hit. For pitchers, a swing and miss on an unhittable pitch will stay the same no matter what the bat is made out of.

Quantitatively, one would expect the transition from aluminum to wood to decrease all major offensive statistics except for walks (since the bat does not put the ball in play, aluminum / wood bats shouldn't be a difference). A pitcher who lets the batter put the ball in play would struggle facing aluminum, but strikeouts and walks should remain consistent.

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[1] Timothy J. Mustone, "A Method to Evaluate and Predict the Performance of Baseball Bats Using Finite Elements," (2003), viewed May 3, 2007. <http://m-5.eng.uml.edu/umlbrc/Publications/Thesis-Timothy%20J%20Mustone.pdf>

[2] James A. Sherwood, Timothy J. Mustone, and Lawrence P. Fallon, "Characterizing the Performance of Baseball Bats Using Experimental and Finite Methods," (no date), viewed May 3, 2007. <http://m-5.eng.uml.edu/umlbrc/publications/Characterizing%20the%20Performance%20of%20Baseball%20Bats%20using%20Experimental%20and%20Finite%20Element%20Methods.pdf>

[3] Sherwood, Mustone, and Fallon, "Characterizing the Performance of Baseball Bats Using Experimental and Finite Methods."

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[4] "On The Warning Track," Boston Globe (April 22, 2007), viewed May 10, 2007. <http://www.boston.com/news/local/articles/2007/04/22/on_the_warning_track/>

[5] Sherwood, Mustone, and Fallon, "Characterizing the Performance of Baseball Bats Using Experimental and Finite Methods."

[6] Mustone, "A Method to Evaluate and Predict the Performance of Baseball Bats Using Finite Elements."

[7] Ibid.

[8] NCAA, "National Collegiate Athletic Association Standard for Testing Baseball Bat Performance," (October 30, 2006), viewed May 15, 2007. <http://www.ncaa.org/champadmin/baseball/bat_standards/2006_certification_protocol.pdf>

[9] Sherwood, Mustone, and Fallon, "Characterizing the Performance of Baseball Bats Using Experimental and Finite Methods."

[10] Ibid.

[11] Sherwood, Mustone, and Fallon, "Characterizing the Performance of Baseball Bats Using Experimental and Finite Methods."

[12] Mustone, "A Method to Evaluate and Predict the Performance of Baseball Bats Using Finite Elements."

[13] Alan M. Nathan, "Characterizing the Performance of Baseball Bats," (July 12, 2002), viewed May 3, 2007. <http://webusers.npl.uiuc.edu/~a-nathan/pob/AJP-Feb2003.pdf>

[14] Mustone, "A Method to Evaluate and Predict the Performance of Baseball Bats Using Finite Elements."