Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 34 (2012) 616 – 621

Procedia Engineering

www.elsevier.com/locate/procedia

9th Conference of the International Sports Engineering Association (ISEA)

A study of wood baseball bat breakage

Patrick Drane[a]*, James Sherwood[a], Renzo Colosimo[a], David Kretschmann[b]

[a]University of Massachusetts Lowell Baseball Research Center, One University Avenue, Lowell, MA, 01854, USA
[b]US. Forest Products Laboratory, US Forest Serice, 1 Gifford Pinchot Drive, Madison, WI, 53726, USA

Accepted 07 March 2012

Abstract

Over the span of three months in 2008, 2232 baseball bats broke while being used during Major League Baseball (MLB) games; of which 756 were classified as Multi Piece Failures (MPFs). This rate of failure motivated Major League Baseball to explore options for potential changes in the bat regulations to reduce the rate. After a study of the information that could be extracted from the 756 MPF bats, MLB implemented new bat regulations and inspection processes for both the wood billets and the final bats. Part of the study concluded that the maple bats used in 2008 were three times more likely than ash to exhibit an MPF failure phenomenon, and that high slopes of grain (SOG) of the wood were a major contributing factor to MPFs. One of the new regulations was to add a SOG indicator on the handle of each bat so that inspection would be able to easily identify the SOG of the bat both at the factory and on field. This paper will describe the test methods used, along with some results collected, in an effort to provide potential solutions to the bat breaking problem. Dynamic durability tests were performed on white ash and maple bats. Additionally, this paper presents results of a finite element model used to correlate the analytical and experimental results.

Keywords: Baseball bats; durability testing; slope of grain; density

1. Introduction

In response to the perception of an increasing number of wood bats breaking in Major League Baseball (MLB) games during the first half of the 2008 season, MLB assembled a team of wood and bat experts to study the breakage of bats. The study included video analysis, collection and analysis of broken bats from the field, testing of wood dowels, manufacturing plant visits, inspection and material testing of bats,

* Corresponding author. Tel.: 978-934-2996; fax: 978-934-4073.
E-mail address: Patrick_Drane@uml.edu.

doi:10.1016/j.proeng.2012.04.105

dynamic durability testing of bats, and finite element modeling of the bat-ball collision. This paper will focus on presenting the methodology and results utilized to study the full bats. Wood bat failure can be classified in two distinct categories; the first is a Single Piece Failure (SPF) and the second is a Multi-Piece Failure (MPF). A bat is considered an SPF when the bat cracks or splits but remains in substantially one piece, while a break is classified as a MPF when it breaks into two or more distinct pieces that are greater than 1.0 oz (28.3 g) each. In 2008, during Major League Baseball games, 2232 baseball bats broke during a three-month period; where 1476 were SPFs and 756 were MPFs [1]. Due to the high number of MPFs that occurred, Major League Baseball in cooperation with the Major League Baseball Players Association implemented changes to the Wooden Baseball Bat Specifications (WBBS) in 2008. One of the changes was for manufacturers of the baseball bats to conform to slope of grain (SOG) grading requirements. To accomplish this SOG measurement, a drop of ink is placed on the bat 12 in. (30.5 cm) from the knob. The ink travels along the grain thereby allowing for a visual measurement of SOG. An image of this ink dot is shown in Figure 1.

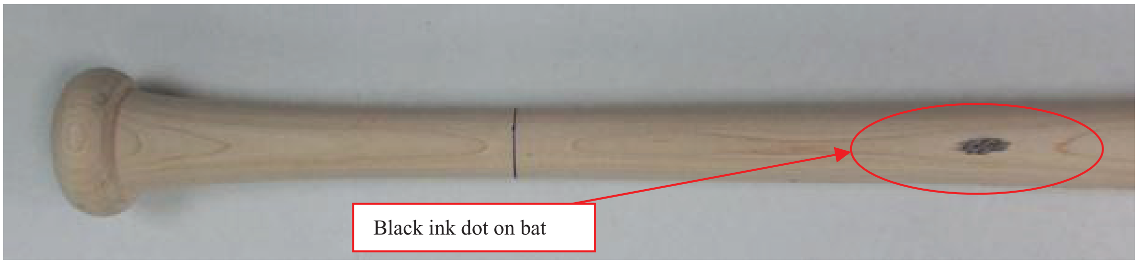


Fig. 1. Ink dot placement on a bat

There are two grain directions along the bat, the radial, which aligns with the growth rings and the tangential, which aligns with the channels that feed nutrients up the tree. The ink dot shown in Figure 1, allows the direction of the channels to be easily seen. The radial SOG and the tangential SOG for a baseball bat are the angles of the growth rings and channels with respect to the axis of the bat. The radial SOG is measured is measured on the edge-grain side, and the tangential SOG is measured on the face-grain side. Prior to 2009, the convention was for the company logo to be on the face-grain side of the bat and players would be instructed to hit "label up" or "label down" so that baseballs would primarily impact on the edge-grain side of the bat. As will be seen in this paper, this convention while appropriate for ash bats was not the correct choice for maple bats.

2. Methodology

2.1. Baseball bats selection and properties

Until the introduction of maple in the late 1990s, ash was the wood of choice for Major League bats. The bats selected for this study were common models used by MLB players and were a mix of white ash and hard maple. The initial laboratory tests, in 2008, primarily used the common models (bat shapes) of C271, C243 and I13 as are identified by Louisville Slugger (Louisville, KY, USA). Subsequent 2009 laboratory testing continued with the C271 but also used the C353 model. The C271 model is characterized by being an overall small volume bat, while the C243, I13 and C353 are all much larger volume bat shapes. Prior to being tested for durability, the dimensions (length, diameters along the axis of the bat), weight, and the tangential and radial SOGs, were measured.

2.2. Bat durability testing

The primary objective of this study was to understand the durability of wood baseball bats by identifying the phenomena that lead to MPFs. The dynamic durability testing was performed in the Automated Durability Testing System (Automated Design Corporation, Romeoville, IL) (ADC) at the UMass-Lowell Baseball Research Center (UMLBRC). The ADC system used to perform these tests is capable of firing a baseball at high speeds at a bat that is mounted in a pivoting grip which is free to swing after impact. The testing performed in 2008 studied impacts at the 9- and 10-in (22.9- and 25.4-cm) locations from the tip of barrel end of the bat. These locations were selected based on testing which showed that the impact location and location of failure were closely related and that many bat failures resulted from impacts at those locations. The 2008 study considered the relationship among SOG, edge vs. face side impacts and bat durability. The continued study in 2009 extended the relationship to include the effect of density on the rate of MPF. For these MPF tests, the 14-in (35.6-cm) location as measured from the tip of the barrel of the bat was selected. This impact location was identified through analysis of game videos as the most common location to result in a significant MPF. The 2009 testing used an initial impact velocity of 100 mph (161 km/h) and increased speed by 5-mph (8-km/h) for each subsequent impact until the bat cracked.

2.3. Finite element modeling

A finite element model was developed throughout this study to understand the relationship among bat geometry, wood species, wood density, impact location, and the impact speed to initiate failure. The wood properties used for stiffness and strength in the finite element models were determined as a function of density from the dowel testing completed at the US Forest Products Laboratory (FPL) [2]; which identified the linear relationship MOE (modulus of elasticity) as a function of density and MOR (modulus of rupture, i.e. failure stress) as a function of density.

3. Discussion/Results

3.1. SoG and bat orientation

As a result of the testing in 2008 and the associated three-month collection of broken bats, new wood regulations were introduced that limited the absolute value of SOG for a bat to be no greater than 3^o and that diffuse porous woods would have the label placed on the edge-grain side instead of the face-grain side. Bats were tested in groups of five bats with high absolute value of SOG ($>|3^o|$) and low absolute value of SOG ($<|3^o|$) and on the edge-grain and face-grain sides each. Overall, the results showed that the SOG had a significant effect on the durability of the bats and that higher SOG values reduced the velocity that would cause failure to occur. For maple, which is a diffuse porous woods, the study also showed that impacts on the face-grain side resulted in an increase of about 8% in the velocity that the bats could withstand before failure relative to edge-grain side impacts. As a result of these SOG and impact-face analyses, MLB implemented a restriction for SOG to be no greater than 3^o and that diffuse porous woods would have the label placed on the edge-grain side to encourage players to hit on the face-grain side. The first season where bats were required to comply with the new bat regulations and subjected to an inspection process to enforce compliance, the MPF rate was reduced by approximately 30%. This significant reduction was achieved by making changes to the bats that were essentially transparent to the players, i.e. no changes in bat dimensions, no change in bat weight and no changes in the choice of wood—ash or maple.

3.2. Wood density analysis

After observing the significant MPF reduction in MLB games, further research was performed to investigate other factors that could contribute to breakage phenomenon. Three conditions were considered: bat model, weight, and wood species. These tests were able to investigate the effect of density on breakage speed. Fig. 2 shows the dynamic durability test results for C271 (small volume) and C353 (large volume) models. In Fig. 2, the individual results are shown along with the group average. Each pair of results shows a significant increase in durability with increasing density. It can also be observed that the small volume C271 exhibits a higher velocity to break than the large volume C353. The observation that the maple bats tend to break at a higher velocity should not oversimplified. While the maple bats break at higher velocities for the same model and weight as the ash bats, the maple bats result in an MPF at a three times the of the ash bats, when breaking at the higher velocities.

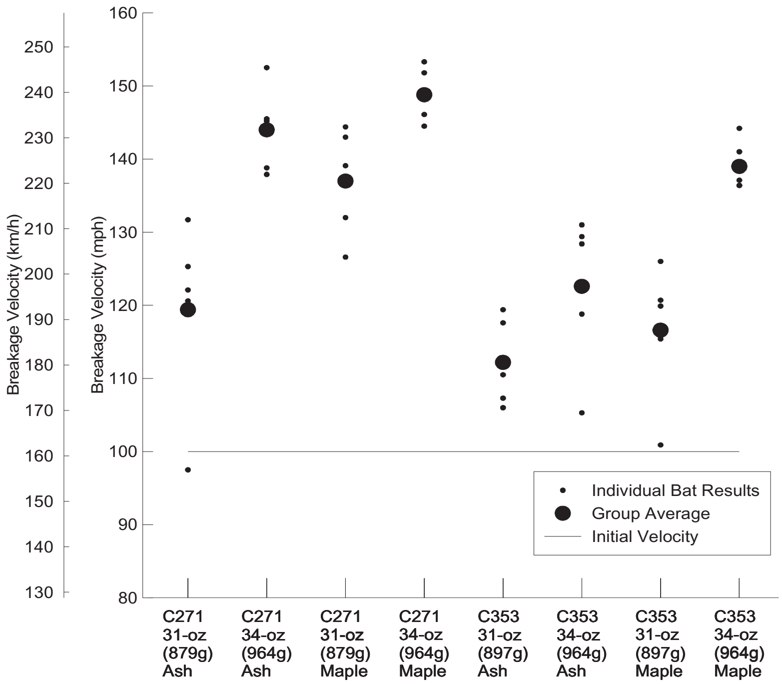
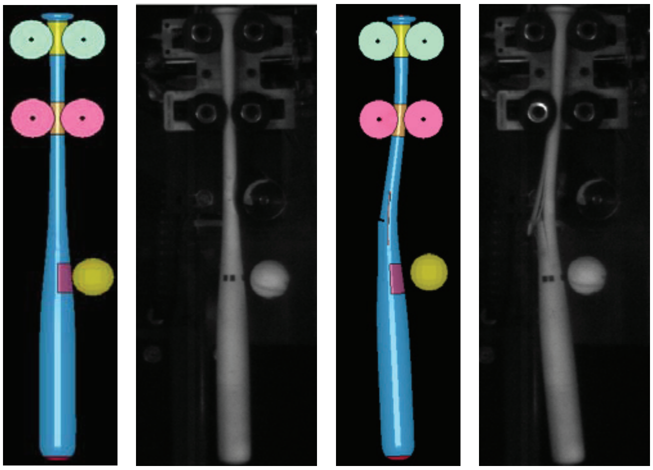


Fig. 2. Test results for dynamic testing of bat

3.3. Finite element analysis

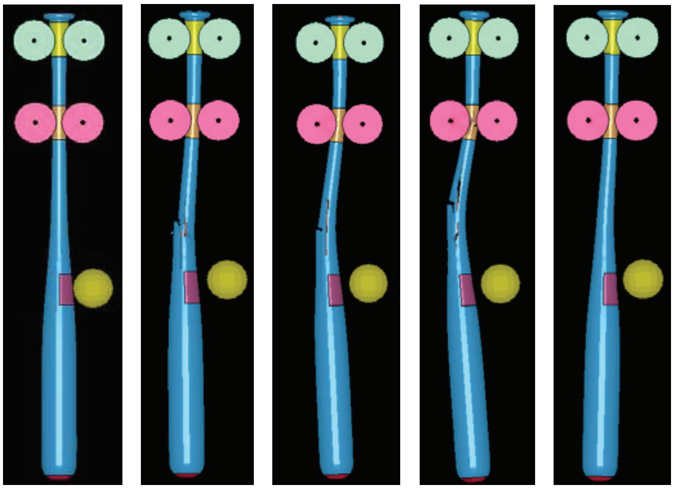
These results for density were used later in the finite element modeling of the bats. After high-speed durability testing in the ADC, it was concluded from the finite element modeling of the same bats that a strain to failure criterion showed the best correlation between lab testing and the finite element modeling.

Fig. 3 demonstrates typical failures for C353 31-oz. (879-g) maple bats in the dynamic tests and in the finite element modeling of the same. In the figure, it can be seen that the finite element model agrees very closely with the test results with respect to initiation of the crack and subsequent progression, and thus gives credibility to the modeling results. At high densities, the modeling analysis showed that the maple bats demonstrate a higher strain to failure than the ash bats and that the maple bats are also capable of withstanding higher speeds before breaking than the ash bats. At lower densities, however, the maple and ash bats have comparable strains to failure and failure speeds.



(a) (b) (c) (d)

Fig. 3. (a) Finite element model of a C353 maple bat before impact; (b) high speed image of a C353 31-oz (879-g) maple bat before impact; (c) finite element model after a 110-mph (177-km/h) collision of a C353 maple bat with 0° slope of grain; (d) high speed image after a 110-mph (177-km/h) collision of a C353 31-oz (879-g) maple bat with 0° slope of grain



(a) (b) (c) (d) (e)

Fig. 4. (a) Finite element model of a C353 31-oz (879-g) maple bat before the collision; (b) finite element model of a C353 31-oz (879-g) maple bat after a 95-mph (153-km/h) collision with a -3° slope of grain; (c) finite element model of a C353 31-oz (879-g) maple bat after a 110-mph (177-km/h) collision with a 0° slope of grain; (d) finite element model of a C353 31-oz (879-g) maple bat after a 120-mph (193-km/h) collision with a +3° slope of grain; (e) finite element model of a C353 31-oz (879-g) maple bat after a 125-mph (201-km/h) collision with a +3° slope of grain

The finite element models were used to investigate the effect of the slope of grain on the failure speed of each bat model. As the slope of grain increased from -3° to +3°, the orientation of the slope of grain with respect to the pitched ball shown in Figure 4, the break speed increased. The results showed that for the C353 model at a slope of grain of 0°, the break speed was 100 mph (161 km/h), whereas at -3°, the break speed was 95 mph (153 km/h), and at 3°, the break speed was 125 mph (201 km/h). Thus, there can even be a significant increase in durability over the currently acceptable range of SOG assuming the bat orientation is such that the SOG is positive with respect to the incoming pitch. It demonstrates that with finer refinement or targeted use of certain SOG values, a player may be able to increase the durability of his bat for inside pitches. Bat durability can potentially be increased if both left- and right-handed hitters use the wood bat with the label facing up. By using this method a batter can keep his current hitting stance, wood and weight without any changes to the WBBS.

4. Conclusion

In an effort to understand the properties that effect wood bat breakage, several durability testing and analysis projects have been performed over the past few years. These studies have shown how impact location, wood species, SOG, impact side, and wood density, influence bat durability. Some of these properties affect the velocity that will cause failure and other properties will affect if a bat breaks as an SPF or an MPF. MLB implemented new bat regulations to their WBBS for the 2009 season, including SOG limits, a change in the label orientation on the maple bats and an inspection process. Those regulations contributed to a significant reduction in MPFs during 2009 season. Further study the showed a significant relationship between density and bat durability. Bat durability increases with increasing wood density. Finite element modeling was shown to be a very useful tool to study bat durability and can reliably predict the impact speed that will cause failure, the location of failure and the type of failure.

Acknowledgements

The authors would like to acknowledge the joint Health and Safety Advisory Committee of Major League Baseball and the Major League Baseball Players Association for the financial support for this project. The authors would also like to acknowledge Dr. Carl Morris and TECO for their assistance as part of the technical team assigned to this project.

References

[1] MLB.com, MLB, MLBPA adopt recommendations of Safety and Health Advisory Committee; [Press Release] 2008. http://mlb.mlb.com/content/printer_friendly/mlb/y2008/m12/d09/c3708345.jsp.

[2] Kretschmann, D.E., Bridwell, J. J., Nelson, T. C. The Effect of Changing Slope of Grain on Ash, Maple, and Yellow Birch. Proceedings 2010 World Conference of Timber Engineering. World Conference Timber Engineering. WCTE 2010 June 20-24, 2010 Trentino, Italy. 8p.

[3] LS-DYNA Keyword User's Manual, Volume I, Version 971, Livrmore Software Technology Corporation, May 2007.