
**Acoustics • Shock • Vibration • Signal Processing** **December 2001 Newsletter**

## Greetings!

Congratulations to both the New York Yankees and the Arizona Diamondbacks for giving baseball fans a thrilling seven-game World Series.

The Yankees had two miracle comeback wins in Games 4 and 5, which were decided in extra innings.

Luis Gonzalez had a single in the ninth inning of Game 7, which drove in the winning run of the game and the series for the Diamondbacks.

Diamondback pitchers Randy Johnson and Curt Schilling shared MVP honors.

As a salute to “America’s Favorite Pastime,” this newsletter presents an article on baseball bat sound and vibration.

I hope that you enjoy the article.

God bless America.

Sincerely,

Tom Irvine
Email: tomirvine@aol.com

## Feature Article



## Take Me Out To The Ball Game

*Take me out to the ball game*
*Take me out to the crowd.*
*Buy me some peanuts and Cracker Jacks*
*I don't care if I ever get back,*
*'Cause it's root, root, root*
*For the home team.*
*If they don't win it's a shame.*
*For it's one, two, three strikes*
*You're out at the old ball game.*

**Vibrationdata Announces**

**Shock & Vibration Response Spectra & Software Training Course**

## Course Benefits

This training will benefit engineers who must analyze test data, derive test specifications, and design isolation systems, with respect to shock and vibration environments.

Engineers in the aerospace, automotive, medical, petroleum, and semiconductor industries can apply the course materials to solve real-world vibration problems.

## Course Description

- The course includes viewgraph presentations as well as hands-on software training
- Each student will receive a licensed copy of MIT's EasyPlot software
- Each student will receive software programs which perform the following calculations:

  Power Spectral Density (PSD), Fast Fourier Transforms (FFT), Shock Response Spectrum (SRS), and digital filtering

- Students will receive data samples so that they can practice using the software programs
- Students are also welcome to bring their own data samples

## Dates for 2002 Courses

January 10-12, March 13-15,
April 17-19, May 15-17,
June 12-14, July 10-12,
September 10-12,
November 5-7

## Location

Mesa Commerce Center
1930 S. Alma School #B-219
Mesa, Arizona 85210

Students may also arrange for onsite training.

## For Further Information Please Contact

Tom Irvine
Course Instructor
Vibration Data
Email: tomirvine@aol.com

Voice: 480-820-6862
Fax: 240-218-4810

http://www.vibrationdata.com/

**BASEBALL BAT SOUND AND VIBRATION**

**by Tom Irvine**


Figure 1. Louisville Slugger Wooden Bat

## Introduction

A bat applies an impulse to the ball that may have a force amplitude as high as 5000 pounds with a duration of less than 1 millisecond.

This collision excites the bat's bending modes, for both aluminum and wooden bats. In addition, a hollow aluminum bat will experience excitation of its barrel modes.

The excitation of these modes affects the impulse imparted to the ball and hence the distance that the ball travels. Note that sound and vibration are forms of lost kinetic energy.

Furthermore, this excitation of vibration modes may cause the batter to experience a painful sting in his or her hands and wrists, if the ball is hit away from the "sweet spot."

Sound is also produced during the collision. A portion of this sound is generated as the bat strikes the ball. This "crack" results from the compression of the air that is abruptly squeezed between the bat and the ball. An additional portion of sound may be generated by the bat's vibration modes. This is especially true for aluminum bats, which give a distinct "ping" sound.

The acoustic signature of the collision may provide an important clue to an outfielder regarding the ball's trajectory. Baltimore Orioles outfielder Melvin Mora said, "As soon as I hear the sound of the bat, I know where the ball is going. Its all about reaction." If Mora hears a dull clunk he races in. If he hears a sharp crack, he races out.

The purpose of this article is to introduce some baseball bat sound and vibration research performed by professors. The article expands upon their research by presenting some finite element models generated by the author.

## Professors Russell's Research

Dr. Daniel A. Russell is an associate professor of applied physics at Kettering University, Flint, Michigan.

He performed a modal test on a 30-inch little league wooden bat. The bat was freely supported for this test. (Note that the batter's hands are considered to have little effect on the bending frequencies). The measured bending mode frequencies were 215 Hz, 670 Hz, and 1252 Hz.

Dr. Russell also measured the acoustic pressure generated by the collision of ball with a wooden bat and with an aluminum bat.

For the aluminum bat, distinct spectral peaks occurred at 2200 Hz and 2800 Hz. These were due to vibration modes unique to hollow cylinders. In contrast, the wooden bat had a relatively smooth acoustic spectrum.

Professor Nathan's Research

Dr. Alan M. Nathan is a professor of physics at the University of Illinois at Urbana-Champaign.

He performed both analysis and tests on a Louisville Slugger R161 wooden bat. His modal test yielded bending mode frequencies at 179 Hz, 582 Hz, and 1181 Hz, as shown in Figure 2. Furthermore, he achieved excellent agreement between his calculated frequencies and the experimental frequencies.

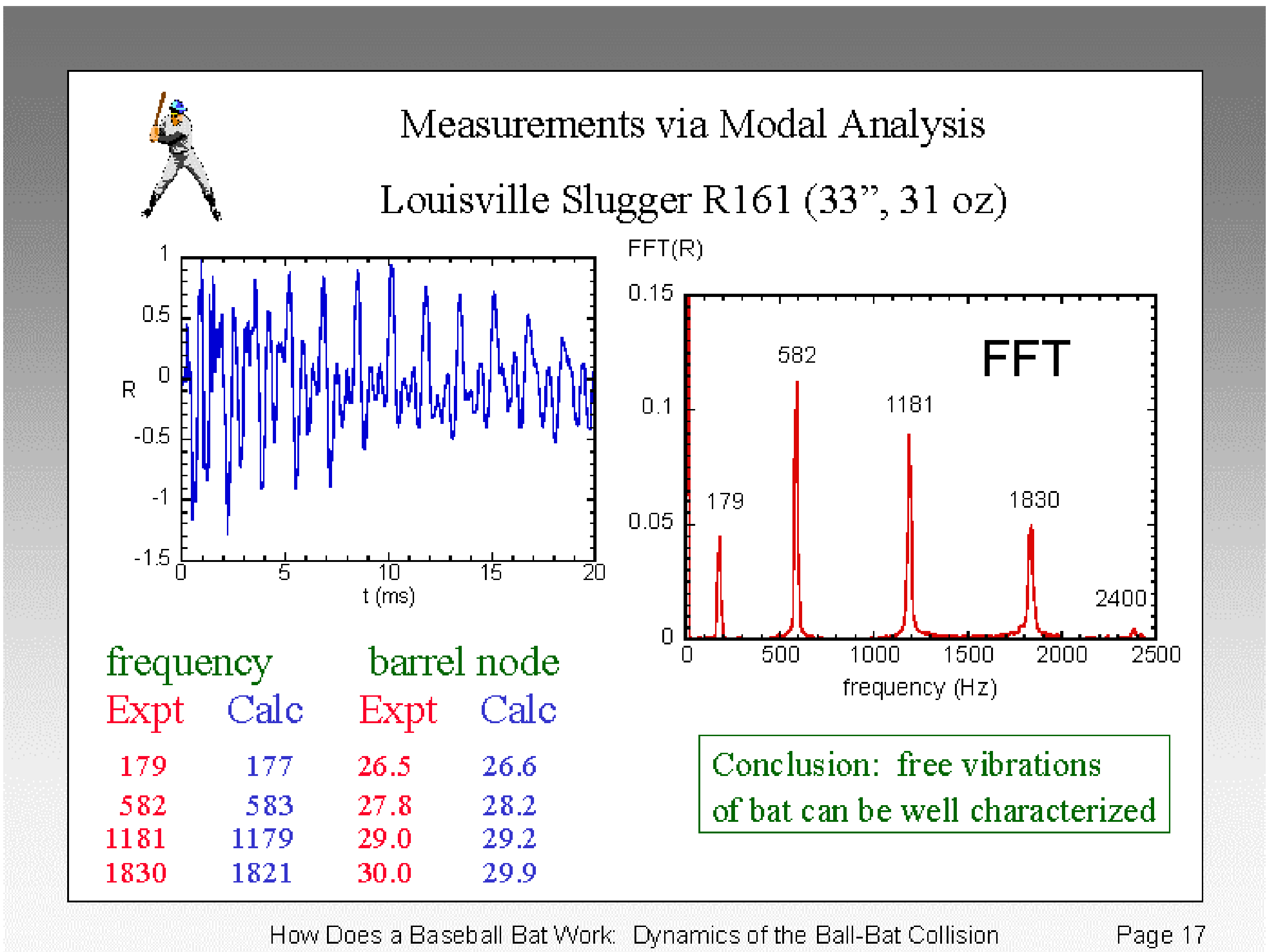


Figure 2. Dr. Nathan's Test Results for a Wooden Bat

Wooden Bat Finite Element Analysis

Consider a generic wooden bat made from ash as shown in the model in Figure 3.

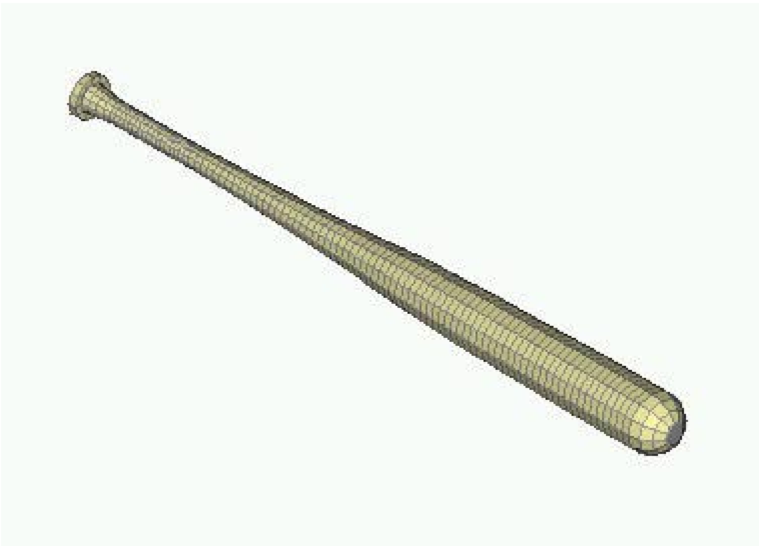

Figure 3. Wooden Baseball Bat Model

The model in Figure 3 is a finite element model, consisting of grid points and elements. The bat's dimensions and material properties are given in Table 1. The model details are summarized in Table 2.

Table 1. Wooden Bat Properties

| Parameter | Value | |
|---|---|---|
| Length | 32 | Inch |
| Maximum Diameter | 2 5/8 | Inch |
| Mass | 30.4 | Ounces |
| Elastic Modulus of Ash | 1,700,000 | Psi |
| Mass Density of Ash | 0.6 | Specific gravity (water) |

Table 2.
Wooden Bat Finite Element Model Overview

| | |
|---|---|
| Element Type | Solid |
| Grid Points | 2449 |
| Elements | 3468 |
| Software | Femap & NE/Nastran |

The first three bending frequencies and the corresponding modes shapes are shown in Figures 4 through 6, respectively. In each case, the bending mode is plotted against the undeformed model.

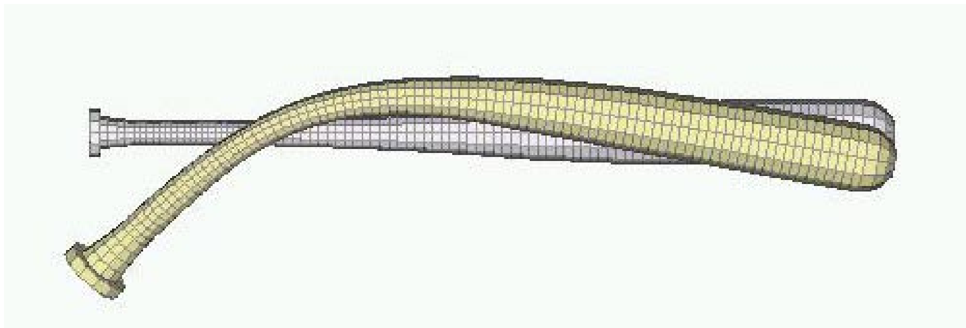

Figure 4. Wooden Bat, First Bending Mode, 204 Hz

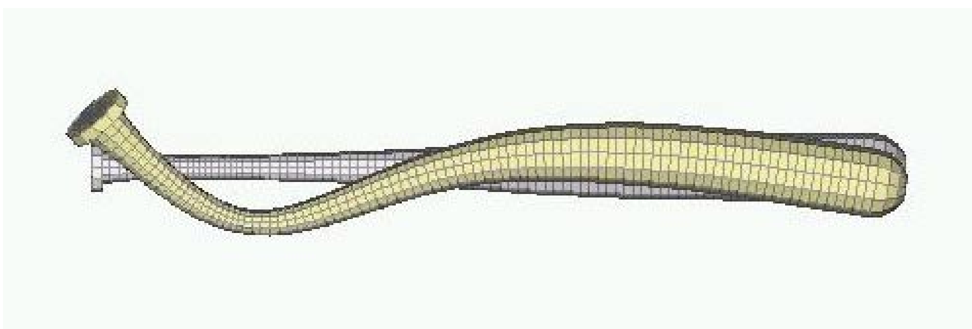

Figure 5. Wooden Bat, Second Bending Mode, 649 Hz

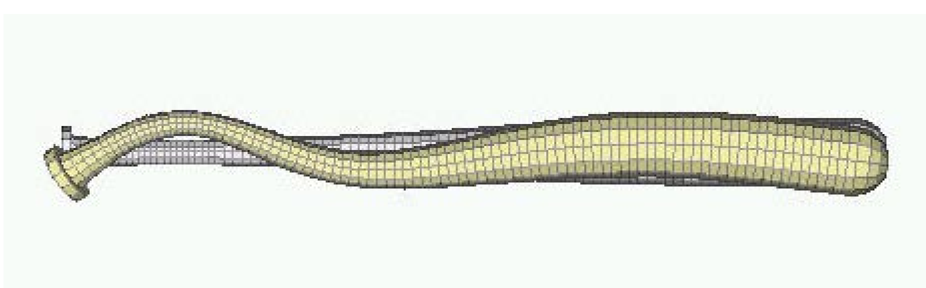

Figure 6. Wooden Bat, Third Bending Mode, 1232 Hz

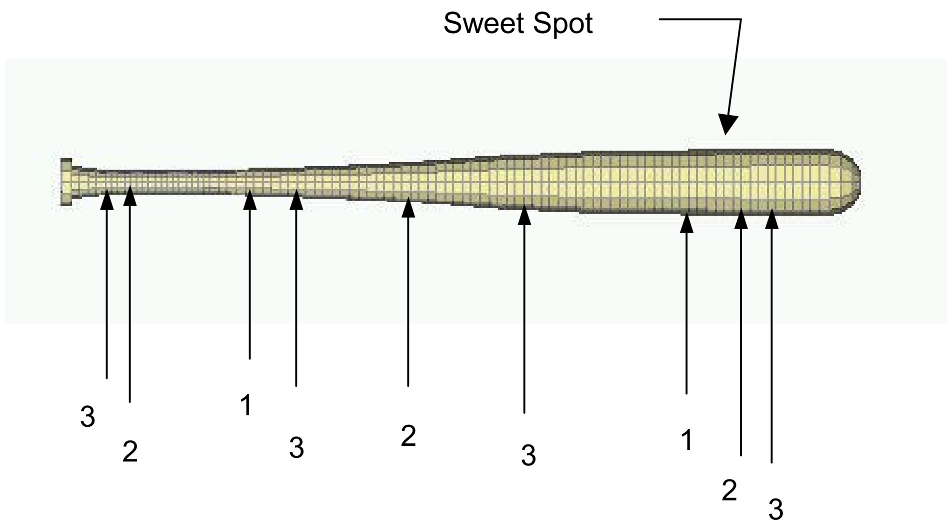


Figure 7. Location of Nodal Lines for the Three Bending Modes

The nodal lines for the three bending modes are shown in Figure 7.

The “sweet spot” is the region located between the nodal lines of the first and second modes, about six inches from the barrel end. An impact near the sweet spot will minimize the vibrational force transferred to the batter’s hands. It will also maximize the energy transferred to the ball.

Conversely, a hit away from the sweet spot will cause significant bat vibration, which is often felt as a painful sting.

<u>Aluminum Bat Finite Element Analysis</u>

An aluminum bat is stiffer than a wooden bat. An aluminum bat thus has higher natural frequencies.

The barrel of an aluminum bat is essentially a hollow cylinder. Thus, aluminum bats have several vibration modes unique to hollow cylinders, in addition to bending modes.

A finite element model of a generic aluminum bat is shown in Figure 8. The bat’s properties are shown in Table 3. The finite element model parameters are summarized in Table 4.

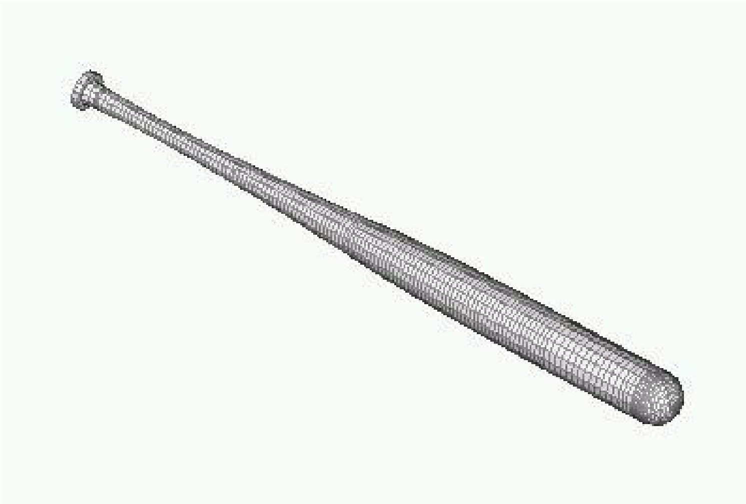

Figure 8. Aluminum Bat, FEA Model

| Table 3. Aluminum Bat Properties | | |
|---|---|---|
| Parameter | Value | |
| Length | 31 | inch |
| Wall Thickness | 0.10 | inch |
| Maximum Diameter | 2.25 | inch |
| Mass | 36.2 | ounces |
| Elastic Modulus | 10,300,000. | psi |
| Mass Density | 0.10 | lbm/in^3 |

| Table 4. Aluminum Bat Finite Element Model Overview | |
|---|---|
| Grid Points | 2091 |
| Elements | 2090 Plate<br>120 Solid<br><br>2210 Total |
| Software | Femap & NE/Nastran |

The solid elements were used for the knob.  The plate elements were used for the portion above the knob.

The aluminum bat's first bending mode is shown in Figure 9.

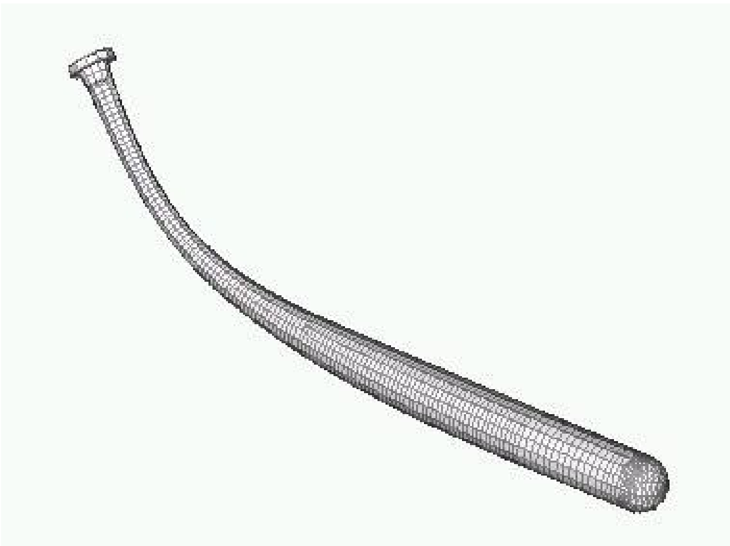

Figure 9.  Aluminum Bat, First Bending Mode, 295 Hz

The bat's second and third bending frequencies were 877 Hz and 1745 Hz, respectively.

The bat's first barrel mode is shown in Figures 10 and 11.

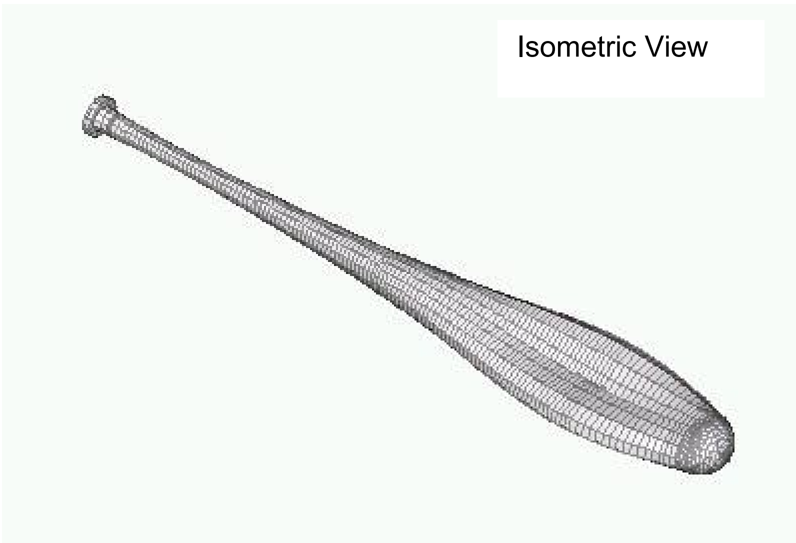


Figure 10. Aluminum Bat, First Barrel Mode, 2200 Hz, Isometric View

View From Top Looking Down, Three Snapshots

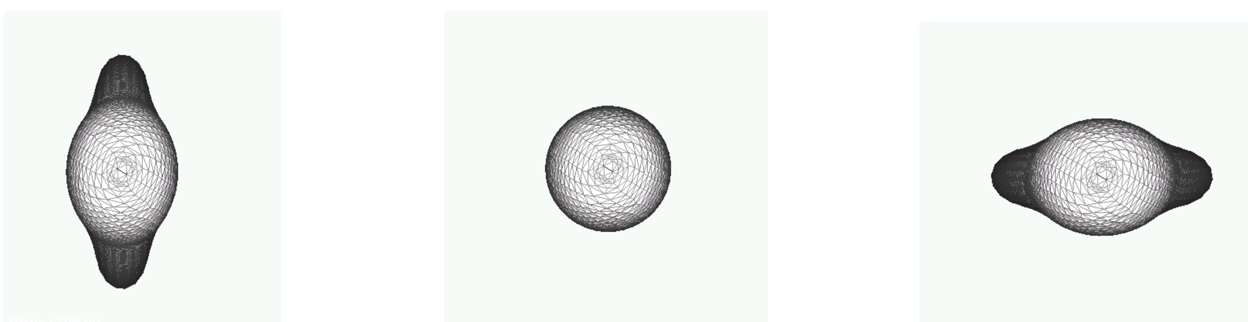

Figure 11. Aluminum Bat, First Barrel Mode, 2200 Hz

Note: the three snapshots are taken from a model with a finer element mesh.

The aluminum bat's second and third barrel modes are shown in Figures 12 and 13, respectively.

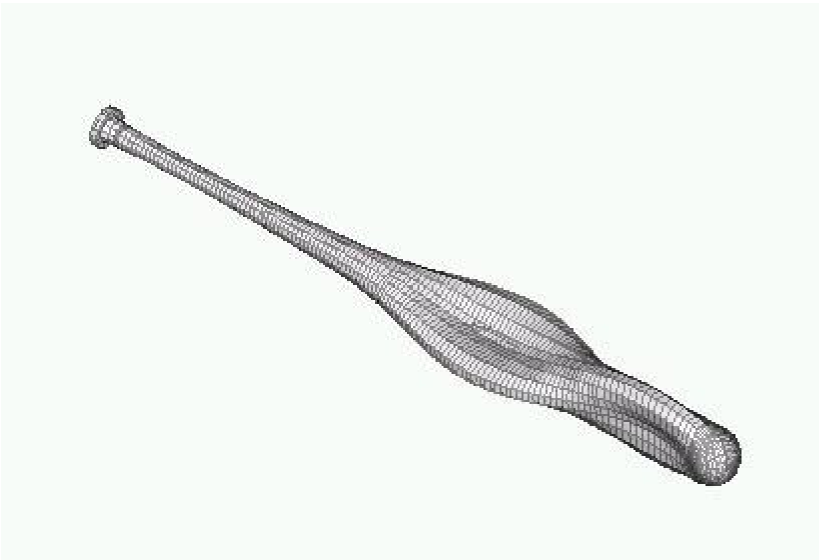

Figure 12.  Aluminum Bat, Second Barrel Mode, 2660 Hz

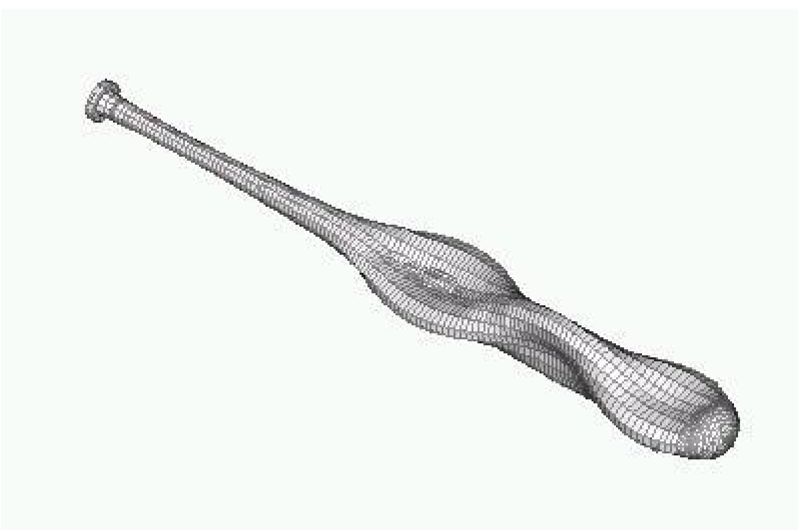

Figure 13.  Aluminum Bat, Third Barrel Mode, 3410 Hz

Acoustic Characteristics

For both aluminum and wooden bats, the bending frequencies do not tend to produce distinct sound tones. On the other hand, the barrel modes of aluminum bats generate very distinct sound tones.

A characteristic of aluminum bats is that the hollow cylinder modes tend to be excited in a similar manner regardless of how the ball is hit by the bat. In other words, the same “ping” sound tends to be generated. This ping sound so dominates the acoustic output that it obscures other acoustic characteristics. Thus, aluminum bats fail to produce important trajectory clues to outfielders.

Again, wooden bats tend to generate relatively smooth acoustic spectra. The acoustic spectrum is dominated by the collision of the ball and bat, rather than by the bat’s vibration response. Nevertheless, the quality of the hit shapes the acoustic spectral energy. This energy may be shifted downward in frequency producing a “clunk” if the ball is hit away from the bat’s sweet spot. The energy is more broadband generating a “crack” if the ball is hit near the sweet spot. The sound quality provides important clues to an outfielder, who may need to run as far as 100 feet to catch a fly ball.

Links

Dr. Nathan’s research: http://www.npl.uiuc.edu/~a-nathan/pob/sack_lunch/index.htm

Dr. Russell’s research: http://www.gmi.edu/~drussell/Demos/bats/bats.html