# Studies of the Torpedo Bat

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## Introduction

The baseball world was taken by surprise on March 29, 2025, when the New York Yankees hit nine home runs in a single game, a team record. Moreover, many of these home runs were hit using a new-fangled bat which has since been dubbed the "torpedo" bat because of its unusual shape compared to a more conventional bat, as shown in Figure 1.


Figure 1: Two of the bats used in the present study: a standard bat (top) and torpedo bat (bottom).

A typical bat is composed of a thin handle and knob where the bat is held, a larger diameter barrel where contact with the ball is made, and a tapered region connecting the two. For a standard bat, the barrel is approximately 10 inches long and has a diameter that gradually increases towards the end. The sweet spot of the bat, defined as the location along the barrel resulting in the best performance, is typically about 5-6 inches from the barrel tip. The essential idea of the torpedo bat is to remove wood from the barrel tip, where the performance is low, and add wood in the vicinity of the sweet spot, where the performance is high. This results in a barrel that has a larger diameter near the sweet spot and tapers to a smaller diameter near the tip (giving rise to the "torpedo" moniker) without adding weight to the bat.

There are two generic schemes for moving mass from the barrel tip to the sweet spot. On the one hand, moving the mass of the bat closer to the hands results in a reduction in the moment of inertia (MOI) of the bat about the hands, commonly referred to as the "swing weight", possibly leading to a greater swing speed. Moreover, the bat will be "quicker,"

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meaning that the batter can accelerate it from its initial position into the hitting zone more quickly, allowing the batter to wait a bit longer before committing to swing. Furthermore, the bat will be more maneuvrable, making it easier for the batter to alter the swing once it has begun, as more information is gathered on the pitch location. A quicker bat is a definite advantage for the batter, likely resulting in the batter making good contact with the ball more often.

An alternate scheme is to take advantage of the mass being closer to the hands by increasing the diameter of the bat at the sweet spot, perhaps to the maximum allowable diameter of 2.61 inches, keeping the MOI unchanged. The advantage comes not from better quickness but from a larger hitting surface.

These advantages focus on the batter's swing. But are there advantages to the torpedo bat that are intrinsic to the bat itself? An early on-line article that seeks to address this question via computer simulations can be found in reference [1]. The present research program is, to our knowledge, the first to address these questions experimentally.

**Methods**

Four maple bats were specially constructed for this study, two standard and two torpedo, with profiles shown in Figure 2 and inertial properties given in Table 1. Both pairs of bats are exact duplicates of an actual standard bat (S154 and S155) used by a specific MLB player in 2024 and a new torpedo bat (T153 and T156) used by the same player in 2025. The standard and torpedo bats have very different profiles in the barrel region but are nearly identical further from the barrel tip than 15 inches. Despite the different shapes, the bats have similar inertial properties (length, weight, and moment of inertia), as shown in Table 1, resulting in the expectation that the bats will feel nearly the same when held or swung by the batter. Therefore, it is expected that any difference in performance among the bats will be due to differences in the ball-bat coefficient of restitution (BBCOR). The quantity ($1\text{-}BBCOR^2$) is the fraction of initial kinetic energy in the center of mass frame that is dissipated in the collision, so that a larger BBCOR results in less energy loss and therefore better performance. While there is considerable energy dissipated in the ball, the bat also contributes, primarily from the excitation of bending vibrations from the ball-bat collision. Since the bending vibrations are expected to depend on the shape profile of the bat, one can anticipate that the dependence of BBCOR on impact location will be different for the two types of bats.

Accordingly, the following measurements consisted of two distinct parts:

- Modal analysis to determine for each bat the frequencies and mode shapes for the lowest six vibrational modes. The experimental method is described in [2].

- High-speed ball-bat impacts to measure the BBCOR as a function of impact location along the barrel, using the technique described in [3]. These measurements were

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performed by firing a baseball from an air cannon at 100 mph onto a stationary bat that was free to pivot about an axis six inches from the knob end. Ordinarily the laboratory ball speed correlates to the relative bat-ball speed in play, which for MLB is around 160 mph. A lower speed was used here to ensure the wood bats did not break from impacts away from the sweet spot. Light gates were used to measure the speed of the incoming and rebounding ball, from which the BBCOR could be determined.

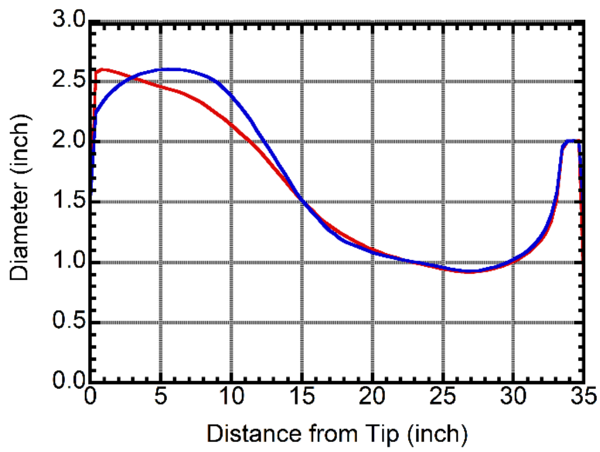


Figure 2 Diameter profiles of the standard (red) and torpedo (blue) bats.

Table 1. Inertial properties of the four bats used in the current study. The MOI is with respect to a point on the handle of the bat six inches from the knob end.[3] Also shown are the frequencies of the lowest four bending modes and the location relative to the barrel tip of the nodes closest to the barrel tip.

| **Type & ID** | **L (inch)** | **W (oz)** | **MOI (oz-in$^2$)** | **Frequencies (Hz)** | **Barrel Nodes (inches)** |
|---|---|---|---|---|---|
| Standard, S154 | 35.2 | 33.9 | 13354 | 115, 441, 945, 1542 | 6.9, 5.4, 4.0, 3.9 |
| Standard, S155 | 35.1 | 34.0 | 13302 | 116, 441, 950, 1540 | 7.0, 5.5, 4.1, 3.9 |
| Torpedo, T153 | 35.2 | 34.0 | 13117 | 116, 449, 1005, 1636 | 7.4, 5.6, 4.9, 4.7 |
| Torpedo, T156 | 35.1 | 34.5 | 13527 | 124, 476, 1060, 1718 | 6.8, 5.8, 4.4, 4.2 |

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## Results

The frequencies of the lowest four modes from the modal analysis, Table 1, show a typical non-harmonic progression, with the torpedo bat having progressively greater frequencies than its standard counterpart. The two Standard bats and the T153 Torpedo bats have nearly the same frequencies of the two lowest modes, whereas Torpedo bat T156 has slightly higher frequencies. The squared amplitudes of the lowest four modal shapes in the vicinity of the barrel are shown in Figure 3; these determine, in part, the energy transferred to each mode from the ball-bat collision [4].

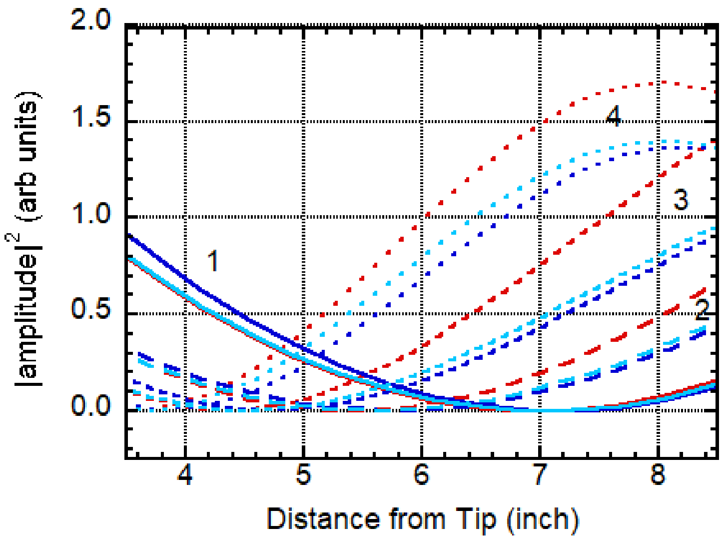


Figure 3 Squared amplitude of the lowest four bending modes for each of the bats, where red, dark blue, and light blue are for the combined S154 and S155 (they are essentially identical), T153, and T156, respectively. Modes 1, 2, 3, and 4 are shown as the solid, long-dashed, short-dashed, and dotted curves, respectively.

The BBCOR measurements are shown in Figure 4. The data are highly reproducible with variation from mean values having a standard deviation of 0.0038 for 288 total measurements among the four bats. Each point represents an average of at least six measurements and has a standard error in the range 0.001-0.002. The two Standard bats perform essentially identically, with differences between them small compared to differences with the Torpedo bats. The curves are parabolic fits to the data. The data in Figure 4 represent the primary result of this research.

## Discussion

The general features of the BBCOR data look as expected [3,4], with the peak BBCOR occurring at the location that minimizes vibrations in the bat, between the nodes of the lowest two modes (see Table 1 and Figure 3). All four bats have a similar parabolic shape with identical peak values primarily determined by the properties of the ball. If the bats were rigid bodies, the BBCOR would be independent of impact location, so the falloff from the peak value is due entirely to the excitation of bending vibrations in the bat. The BBCOR values for the two Standard bats are essentially identical, as would be expected based on their identical shape profile and very similar inertial and vibrational properties (Table 1). The same is not true of

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the two Torpedo bats, despite having identical shape profiles. The natural variation of the wood apparently results in their having different inertial and vibrational properties, giving rise to differences in their BBCOR values.

One of the striking features of Figure 4 is that T153 is virtually identical to the Standard bats, except shifted toward the tip by 0.6 inches. The same is not true of T156. This point is further emphasized in Figure 5, which shows the Standard bat (S154 and S155 averaged together) and each Torpedo bat, where the latter have been shifted by -0.6 inches. The Standard bats and T153 overlap perfectly, whereas T156 does not. Indeed, the range of impact locations for which the BBCOR exceeds 0.5 is identical for the two Standard and the T153 bats (2.4 inches) but is greater for T156 (2.7 inches). In effect, the "sweet spot" is wider for T156 than for the other bats, as predicted earlier in [1] using computer simulations.

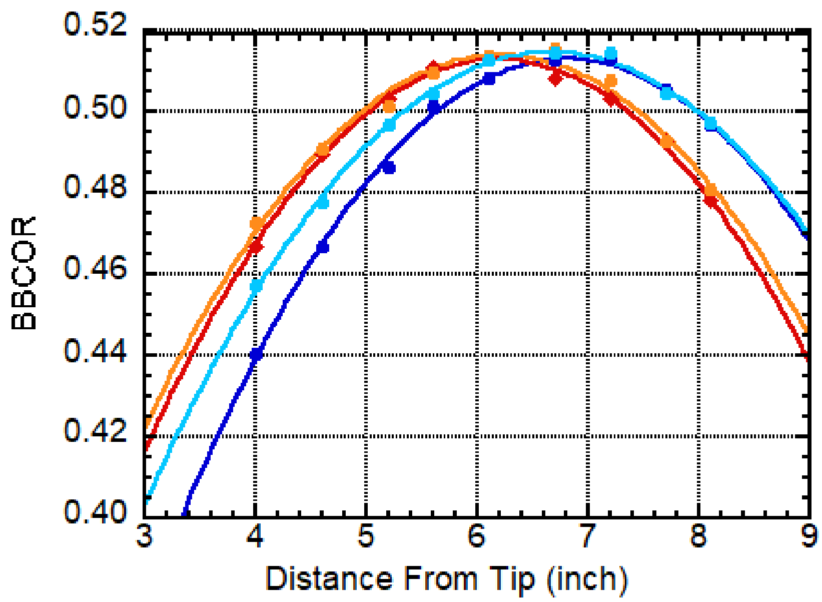


Figure 4 Comparison of BBCOR among the four bats, with S154 in red, S155 in orange, T153 in dark blue, and T156 in light blue. The curves are parabolic fits to the data.

To estimate how these bats would perform in the field, a model [5] is used to extrapolate the experimental BBCOR values to higher speed (150-165 mph) along with an assumed pitch speed and a model for bat speed [3] to predict so-called exit velocities (EV), the initial speed of the batted ball, as a function of impact location. The results are shown in Figure 6. Recall that a high EV is characteristic of a well-hit ball and one that most likely leads to a good outcome for the batter. T156 has an advantage over the other bats, with a greater peak EV and a wider sweet spot. While such an advantage might appear small, it is not uncommon for important games to be won or lost by small margins.

**Summary and Conclusions**

The research reported here investigates how the mass distribution of a bat affects its performance, specifically the BBCOR. It was shown that moving mass from the barrel tip

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towards the hands does indeed affect the BBCOR by shifting its peak away from the tip, resulting in a definite advantage for batters who prefer to make contact closer to the hands. It was also shown that variability in wood can lead to differences in performance, even for bats having the same shape profile. While all the bats tested had essentially the same peak value of the BBCOR, one of the bats had a broader range over which the BBCOR was large, effectively implying a wider sweet spot, a definite advantage for a batter. The underlying reason for this result is currently being studied with computer simulations, with the goal of interpreting the present results in the context of the frequencies (Table 1) and shapes (Figure 3) of the bending modes. It will be interesting to do similar studies, both experimental and computational, on bats with other shape profiles.

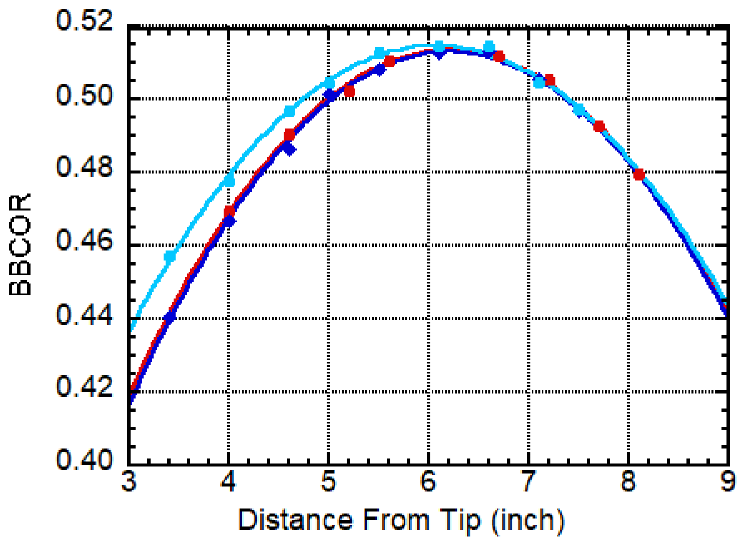


Figure 5 Same as Figure 4, except that the two Standard bats (red) have been combined and the two Torpedo bats, T153 and T156 (dark blue and light blue, respectively), have been shifted -0.6 inches.

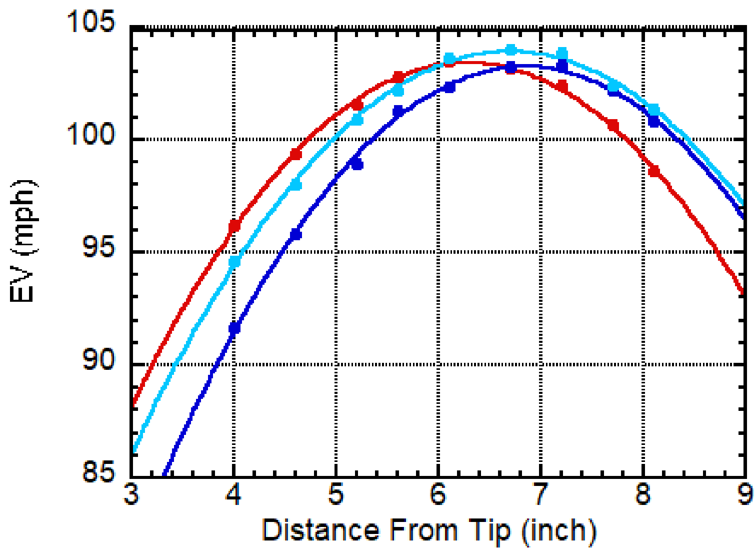


Figure 6 Calculated exit velocity (EV) simulating standard game conditions, with red, light blue, and dark blue corresponding to the combined Standard bats, T153, and T156, respectively.

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## References

1. Nathan, A (2025) The physics of the torpedo bat. FanGraphs. blogs.fangraphs.com/the-physics-of-the-torpedo-bat/. Accessed 29 September 2025.

2. Russell, DA (2018) Acoustics of ping-pong: Vibroacoustic analysis of table tennis rackets and balls. J. Sports Sci., 36: 2644-2652 (2018). doi.org/0.1080/02640414.2018.1462578 .

3. Smith, L. (2008) Progress in measuring the performance of baseball and softball bats. *Sports Technology*, *1*(6), 291–299. https://doi.org/10.1080/19346182.2008.9648486.

4. Nathan, AM (2000) Dynamics of the baseball-bat collision. *American Journal of Physis, 68(11): 979-990.* https://doi.org/10.1119/1.1286119.

5. Smith, L.V., Nathan, A.M. & Duris, J.G. A determination of the dynamic response of softballs. Sports Eng 12, 163–169 (2010). https://doi.org/10.1007/s12283-010-0041-4

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