Standard Test Method for
Measuring Moment of Inertia and Center of Percussion of a Baseball or Softball Bat[1]

1. Scope

1.1 Method for determining the moment of inertia (MOI), the center of percussion (COP), and the balance point (BP) of baseball and softball bats. These physical properties are used in Test Method F1881, Test Method F1890, and Test Methods F2219.

1.2 The MOI, COP, and BP are measured in the laboratory on test equipment meeting the requirements defined in this test method.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F1881 Test Method for Measuring Baseball Bat Performance Factor (Withdrawn 2014)[3]

F1890 Test Method for Measuring Softball Bat Performance Factor

F2219 Test Methods for Measuring High-Speed Bat Performance

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *balance point (BP), n*—the distance to the center of mass measured from the knob end of the bat.

3.1.2 *center of percussion (COP), n*—also known as the center of oscillation. Forces and impacts at this location will not induce reactions at the pivot point, 6 in. (152 mm) from the knob end of the bat.

3.1.3 *cycle, n*—one complete oscillation of a pendulum supported at the pivot point, 6 in. (152 mm) from the knob end of the bat.

3.1.4 *moment of inertia (MOI), n*—also known as the mass moment of inertia, the measure of the bat's resistance to changes in its rotation rate about the pivot point, 6 in. (152 mm) from the knob end of the bat.

3.1.5 *period, n*—the time required for a pendulum to oscillate through one complete cycle.

4. Significance and Use

4.1 This test method offers a laboratory means to measure the inertial properties of bats, specifically weight, balance point, center of percussion, and MOI, in support of other test methods including the ASTM standards referenced in this document.

4.2 Use of this test method can provide sports governing bodies the means to establish rules regarding the physical properties of bats, specifically MOI.

5. Apparatus

5.1 *Bat MOI Test Apparatus:*

5.1.1 *Ruler,* suitable for measuring lengths up to 42 in. (1067 mm) to the nearest 0.03 in. (0.8 mm).

5.1.2 *Weight Scales,* suitable for measuring weight up to 48 oz (1361 g) to the nearest 0.0035 oz (0.1 g).

5.1.3 *Electronic Timer,* suitable device sufficiently accurate for measuring time to the nearest 1 μs (0.000001 s).

5.1.4 *Pendulum Stand*—A frame with a pivoting bat collar-clamp large enough to allow a bat held in a vertical position to swing freely (see Fig. 1).

5.1.5 *Bat Collar-Clamp*—A lightweight clamp or collar that can hold the weight of a bat and provide a fixed pivot location. The clamp shall be rotationally balanced and have a maximum MOI of 4 oz-in.^{2} (73 kg-mm^2) measured about the bat pivot
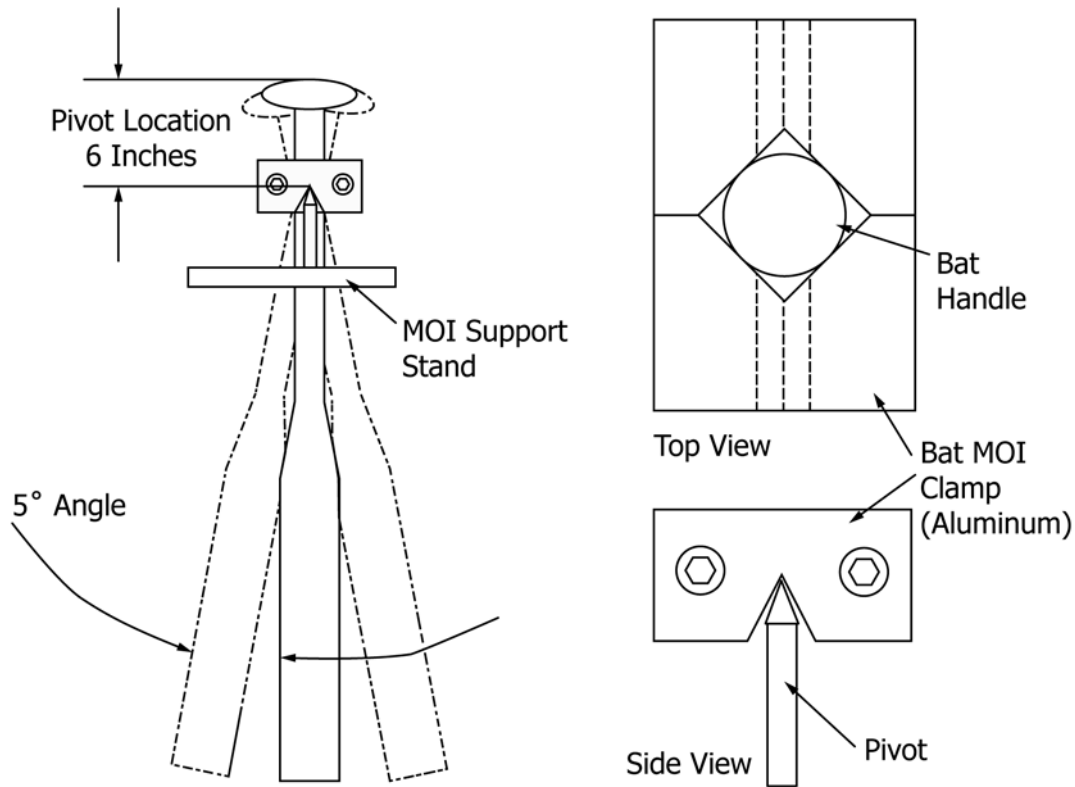
FIG. 1 MOI Fixture

location (see Fig. 1). The MOI of the clamp shall not change with the diameter of the bat being tested.

6. Calibration and Standardization

6.1 *Calibration Rod*—The calibration rod shall be 1 ± 0.01 in. (25.4 ± 0.25 mm) in diameter by 34 ± 0.1 in. (864 ± 2.5 mm) long, solid aluminum.

6.2 *Target Calibration MOI*—Measure the length and the weight of the calibration rod. Compute the target calibration rod MOI using Eq. 1:

$$I_T = W_c \left\{ \frac{L_c^2}{12} + \left(\frac{L_c}{2} - d \right)^2 \right\} + I_c \qquad (1)$$

where:
I_T = target MOI of the calibration rod, oz-in.^{2} (kg-mm^2)
W_c = measured weight of the calibration rod, oz (kg)
L_c = measured length of the calibration rod, in. (mm)
d = pivot distance (6 in. or 152 mm)
I_c = MOI of the clamp about its pivot point, oz-in.^{2} (kg-mm^2)

6.3 *Balance Point Calibration*—Following 7.1, the BP of the calibration rod shall be $L_c/2 ± 0.05$ in. (1 mm). If the BP of the calibration rod is outside the allowed range, check the calibrations of the scales and support fixture.

6.4 *Mass Moment of Inertia Calibration*—Using the measured properties of the calibration rod from 6.2 and 6.3 and following 7.2 and 7.3, the measured MOI of the calibration rod should be within ±50 oz-in.^{2} (916 kg-mm^2) of the target MOI,

I_T. If the MOI of the calibration rod is outside the allowed range, then check the clamp location and timer calibration.

7. Procedure

7.1 *Determination of BP:*

7.1.1 Measure and record the overall bat length to the nearest 0.06 in. (1.5 mm). Place the bat level on the BP fixture as shown in Fig. 2. Record the measured weights (W_6 and W_{24}) to the nearest 0.035 oz (1.0 g). Calculate the BP relative to the knob end of the bat using Eq 2:

$$BP = \frac{6 W_6 + 24 W_{24}}{W_t} \qquad (2)$$

where:
BP = BP from knob end of the bat, in. (mm)
W_6 = weight of the bat measured 6 in. (152 mm) from the knob, oz (g)
W_{24} = weight of the bat measured 24 in. (610 mm) from the knob, oz (g)
W_t = $W_6 + W_{24}$ = total weight of the bat, oz (g)

7.2 *Determination of COP:*

7.2.1 Apply the clamp to the bat handle so that the pivot location (point of the vee on underside of the clamp) is 6 ± 0.03 in. (152 ± 0.8 mm) from the knob end of the bat (see Fig. 1). Hang the bat in the stand making sure the bat hangs vertically and can swing freely about the pivots. If the bat does not hang vertically, correct by centering the bat between the pivots.
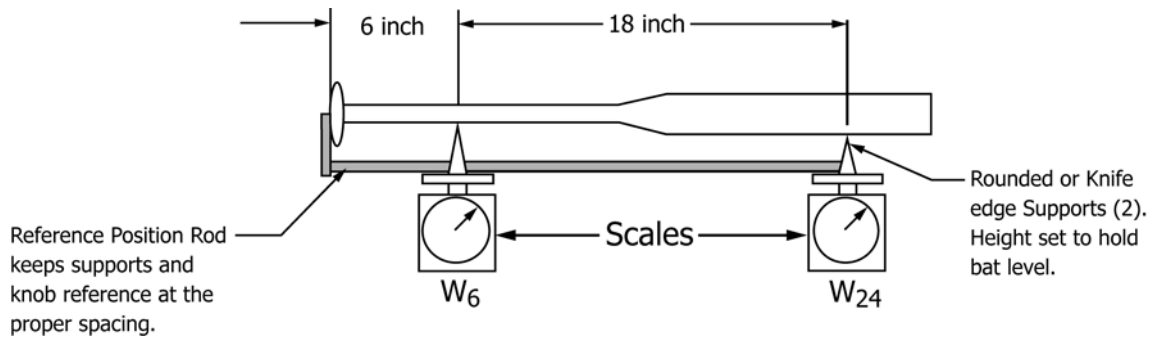
FIG. 2 Balance Point Fixture

7.2.2 Rotate the bat about the pivot to an angle of 5° from the vertical. Release the bat and allow it to swing *freely* (see Fig. 1). Allow the bat to swing through five cycles (that is, settle into simple pendulum oscillation). Start the electronic timer when bat reaches the fifth swing cycle. Stop the timer once the bat has completed 15 full cycles. The timer shall be triggered by a light beam broken by the path of the bat at the bottom of the pendulum arc. Do not use these results if the standard deviation of the last 10 period measurements is greater than 0.001 s. Determine and record the average period for the bat, T, using Eq 3:

$$T = \frac{1}{10}(p_6 + p_7 + \ldots + p_{15}) \qquad (3)$$

where:

T = average period (s), and
p_i = period of the ith oscillation (s)

7.2.3 Calculate and record the bat COP relative to the 6-in. (152-mm) pivot point location using Eq 4:

$$COP = \frac{T^2 g}{4\pi^2} \qquad (4)$$

where:

g = gravity or 386.1 in./s² (9806 mm/s²)

7.3 *Determination of MOI:*

7.3.1 Calculate and record the MOI of the bat to the nearest 1 oz-in.² (18 kg-mm²) using Eq 5:

$$I = W_t(BP - a)COP - I_c \qquad (5)$$

where:

W_t = total weight of the bat (oz or kg)
a = distance from knob end to the pivot point, a = 6 in. (152.4 mm)

8. Report

8.1 Report the following information:
8.1.1 Name of the test operator and test facility,
8.1.2 Test date,
8.1.3 Test equipment used for this test method,
8.1.4 Bat model, length, weight tested, and any other pertinent data, such as condition of the bat or modification to the bat,
8.1.5 W_6, W_{24}, and W_t,
8.1.6 Balance point,
8.1.7 Measured periods, average period, and
8.1.8 Bat COP, MOI, and MOI of bat pivot support.

9. Precision and Bias

9.1 Precision and bias evaluations have not been conducted for this test method. When such data are available, a precision and bias section will be added.

10. Keywords

10.1 balance point, BP; baseball bat; bat; center of percussion, COP; moment of inertia, MOI; softball bat