Designation: F2845 – 14

Standard Test Method for
Measuring the Dynamic Stiffness (DS) and Cylindrical Coefficient of Restitution (CCOR) of Baseballs and Softballs[1]

This standard is issued under the fixed designation F2845; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This procedure describes a method of measuring the dynamic stiffness (DS) and cylindrical coefficient of restitution (CCOR) of baseballs and softballs providing similar impact forces and ball deformation as are observed in a bat-ball collision.

1.2 This procedure is for a ball that is intended for the game of baseball or softball.

1.3 The test method is based on ball speed measurements before and after impact with a cylindrical test surface and the impact force between the ball and impacted surface.

1.4 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.

1.5 *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]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *baseball or softball, n*—any ball defined by the rules for the game of baseball or softball, respectively.

3.1.2 *cylindrical coefficient of restitution (CCOR), n*—the ratio of the rebound to incoming speed of a ball impacting a solid rigid cylinder.

3.1.3 *dynamic stiffness (DS), n*—a normalized measure of the ball impact force having units of stiffness (lb/in. or kN/m). It is obtained by dividing the square of the peak force between the ball and impact surface by the ball mass and the square of the incoming ball speed.

4. Summary of Test Method

4.1 A load cell or array of load cells is mounted between a cylindrical solid steel impact surface and a rigid wall. The ball speed is measured before and after impact with the impact surface and the force is measured throughout the impact event.

5. Significance and Use

5.1 1 The ball dynamic stiffness is a measure of a ball's hardness. Its measurement is conducted to represent bat-ball impact forces. It is normalized by the ball weight and speed to minimize the influence of manufacturing and test variations from the measure.

5.2 The cylindrical coefficient of restitution is a ball property of relative velocity change caused by impact with a cylindrical surface.

5.3 This test method compares the performance of baseballs and softballs after impact with a cylindrical test surface.

5.4 Sports associations can use DS and CCOR measurements in specifications for official baseballs and softballs.

6. Apparatus

6.1 *Strike Plate:*

6.1.1 *Load Cell*—A device capable of measuring force up to 10 kip (45 kN) within ±1 %. The peak load-cell reading after ball impact due to oscillation shall not exceed 5 % of the measured peak impact force.

6.1.2 *Impact Surface*—A 4 ± 0.1-in. (102 ± 2-mm) long solid steel half cylinder. For softballs, the diameter of the half

---

[1] This test method is under the jurisdiction of ASTM Committee F08 on Sports Equipment, Playing Surfaces, and Facilities and is the direct responsibility of Subcommittee F08.26 on Baseball and Softball Equipment.

Current edition approved March 1, 2014. Published March 2014. Originally approved in 2010. Last previous edition approved in 2011 as F2845 – 11. DOI: 10.1520/F2845-14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

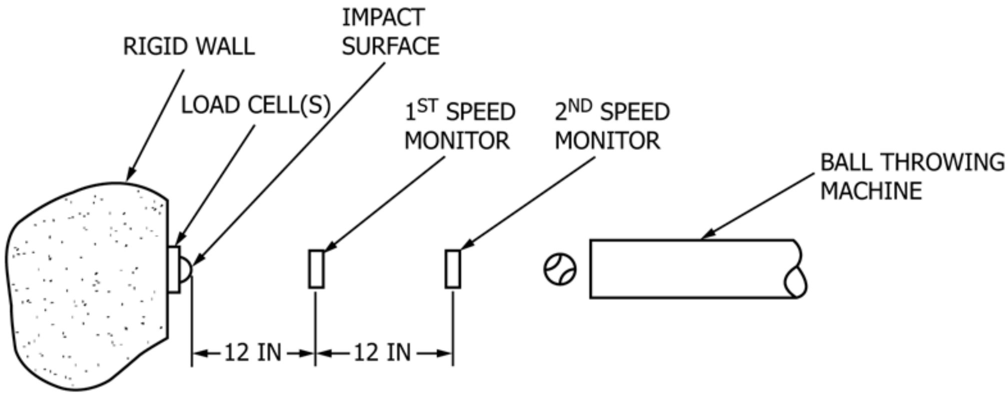

FIG. 1 Test Apparatus

cylinder is 2.25 ± 0.01 in. (57.2 ± 0.3 mm). For baseballs the diameter of the half cylinder is 2.62 ± 0.01 in. (66.7 ± 0.3 mm).

6.1.3 *Mounting*—The load cell and impact surface shall be secured to a massive rigid wall and fastened sufficiently secure to prevent movement during ball impact. Thread-locking liquids help prevent fasteners from coming loose and reduce load-cell oscillations.

6.2 *Ball Throwing Device*—A ball throwing device capable of delivering the ball through the electronic speed monitor within ±1 mph (±0.5 m/s) of the desired speed. Balls shall be oriented to impact the strike surface between the stitches.

6.3 *Electronic Speed Monitors*[3]—An electronic ball-speed measuring system consisting of two vertical light screens mounted 12 ± 0.03 in. (305 ± 0.8 mm) apart, and a photoelectric sensor located at each screen that triggers a timing device on ball passage to measure the time for the ball to traverse the distance between the two vertical planes before and after impact with the strike plate. Accuracy shall be ±0.1 mph (±0.05 m/s).

6.4 *Data Acquisition*—The signal from the load cell shall be sampled at a frequency of at least 100 kHz while it is in contact with the ball.

7. Preparation of Apparatus

7.1 Mount the cylindrical impact surface and load cell on a rigid wall. Verify all fasteners are tightened according to laboratory procedure to minimize load-cell oscillation.

7.2 Position the speed monitors so that the first speed monitor (light screen) is 12 ± 0.1 in. (305 ± 3 mm) from the strike plate (see Fig. 1).

8. Calibration and Standardization

8.1 *Ball Speed Gate*—The distance between the sensors of the speed gates should be measured and recorded. The timers used for speed measurements should be calibrated on at least a yearly basis.

8.2 *Load Cells*—The load cells used to measure the impact force should be calibrated on at least a yearly basis.

9. Conditioning

9.1 *Ball Conditioning and Test-Room Conditioning:*

9.1.1 Test balls shall be stored in an environmentally controlled space for at least 14 days immediately before testing.

9.1.2 Temperature is to be maintained at 72 ± 4°F (22 ± 2°C).

9.1.3 Relative humidity (RH) is to be maintained between 40 and 60 %.

9.1.4 Temperature and relative humidity are to be measured and recorded hourly within 0.5°F (0.3°C) and 2 % RH over conditioning and test durations.

10. Procedure

10.1 Set the ball throwing device to 95 mph (42.5 m/s) for softballs and 115 mph (51.4 m/s) for baseballs. Results from inbound speeds exceeding ±1 mph (±0.5 m/s) of the target speed will not be used.

10.2 Record the inbound speed, rebound speed, force-time data and peak impact force.

10.3 A minimum 1-min rest period is required between each shot. A non-contact temperature sensor shall be used to verify the ball temperature remains within the specified test-room temperature range.

10.4 The ball shall be rotated after each impact among its four ears or surfaces with maximum spacing between the stitches.

10.5 Verify proper alignment by observing the rebound path of the ball after impact. The ball rebound angle after impact with the impact surface should be within ±5° of the inbound ball path.

10.6 Compare the impulse from the ball speed and impact force.

10.6.1 Calculate the impulse from the impact force by:

$$L_F = \int_{t_0}^{t_1} F(t)dt \tag{1}$$

where:

L_F = force impulse (area under the force-time curve), lb-s (N-s),

[3] The sole source of supply of the apparatus (IBeam Sensor or equivalent) known to the committee at this time is Automated Design Corporation, 1404 Joliet Road, Suite B, Romeoville, IL 60446, http://www.automateddesign.com/. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

$F(t)$ = force measurement during impact, lb (N),
t_0 = time when $F(t)$ exceeds 20 lb (89 N) (s), and
t_1 = time after the peak force is reached when $F(t)$ is less than 20 lb (89 N) (s).

10.6.2 Calculate the impulse from the ball speeds by:

$$L_S = \frac{m}{c_L}(V+S) \quad (2)$$

where:

L_S = speed impulse, lb-s (N-s),
m = ball mass, oz (g),
V = incoming speed, mph (m/s),
S = outgoing ball speed, mph (m/s), and
c_L = unit conversion factor, 350.99 US (1000 SI).[4]

10.6.3 Calculate the impulse ratio by:

$$K = \frac{L_S}{L_F} \quad (3)$$

where:

K = impulse ratio,
L_S = speed impulse, lb-s (N-s), and
L_F = force impulse, lb-s (N-s).

10.7 The speeds and forces from the six valid impacts for each ball are averaged to determine the DS and CCOR for a ball.

10.7.1 For an impact to be valid the ball inbound speed and rebound trajectory must be within the allowable respective tolerance for speed and trajectory and the impulse ratio must fall between 0.9 and 1.1.

10.7.2 For a ball test result to be valid, the standard deviation of the six impulse ratios of a ball must be less than 0.02.

10.7.3 For cases of excessive invalid hits due to the impulse ratio requirements, check light-gate and load-cell calibrations and ball-weight measurement.

10.7.4 Formula:

$$DS = \frac{c_S}{6m}\sum_{i=1}^{6}\left(K_i\frac{F_i}{V_i}\right)^2 \quad (4)$$

$$CCOR = \frac{1}{6}\sum_{i=1}^{6}\frac{S_i}{V_i} \quad (5)$$

where:

DS = dynamic stiffness, lb/in (kN/m),
$CCOR$ = cylindrical coefficient of restitution,
V_i = incoming ball speed of the i^{th} test, mph (m/s),
S_i = outgoing ball speed of the i^{th} test, mph (m/s),
F_i = peak impact force of the i^{th} test, lb (N),
m = ball mass, oz (g), and
c_S = unit conversion factor - 19.943 US (1 SI).[5]

11. Report

11.1 Report the following information:

11.1.1 Name of test facility and test operator,

11.1.2 Test date,

11.1.3 Hourly measurements of test conditions including:

11.1.3.1 Relative humidity and temperature of the ball-conditioning and test-room environments,

11.1.3.2 Number of days ball was in conditioning environment.

11.1.4 Test equipment used for this method.

11.1.5 Test ball information including weight, circumference, model and manufacturer.

11.1.6 For each impact (including invalid impacts) ball inbound speed, rebound speed, CCOR, peak force and DS.

11.1.7 Any important observations including but not exclusively, damage to the ball, unusual noises or vibrations and the number of invalid impacts for each ball.

11.1.8 Respective calibration dates for load cells and velocity timers.

12. Precision and Bias[6]

12.1 The precision of this test method is based on an interlaboratory study conducted in 2009. Five laboratories participated in this study. Each of the labs was asked to report three replicate test results for eighteen different balls (nine sets of two). After completing their measurements on the first set, the laboratories sent their nine balls to a second laboratory for another round of testing (Round 2). Every "test result" reported represents a single determination or measurement. Practice E691 was followed for the design and analysis of the data.

12.1.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "r" value for that material; "r" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

12.1.1.1 Repeatability limits are listed in Tables 1-3.

12.1.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "R" value for that material; "R" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

12.1.2.1 Reproducibility limits are listed in Tables 1-3.

12.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

12.1.4 Any judgment in accordance with statements 12.1.1 and 12.1.2 would have an approximate 95 % probability of being correct.

12.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

12.3 The precision statement was determined through statistical examination of 1080 results, from five laboratories, on nine sets of ball samples. To judge the equivalency of two test results, it is recommended to choose a sample material closest in characteristics to the test material.

[4] The conversion factor is found from (16 oz/lb)(32.174 ft/s^2)(1 mi/5280 ft)(3600 s/hr) = 350.99 (oz/lb s)(mi/hr) US or (1000 g/kg) = 1000 SI.

[5] The conversion factor is found from (16 oz/lb)(386.088 in/s^2)(1 mi/63360 in)^2 (3600 s/hr)^2 = 19.943 (oz/in lb)(mi/hr)^2 US or (1000 g/kg)(1 kN/1000 N) = 1 SI.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: F08-1010.

TABLE 1 Dynamic Stiffness (lb/in.)

Sample	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Ball 1 Round 1	6943.2	243.2	425.4	680.9	1191.2
Ball 1 Round 2	6744.3	114.1	433.1	319.6	1212.8
Ball 2 Round 1	6783.4	117.3	317.8	328.5	889.8
Ball 2 Round 2	6554.0	113.8	314.0	318.7	879.3
Ball 3 Round 1	8190.8	135.1	499.5	378.3	1398.5
Ball 3 Round 2	8117.6	233.2	626.1	652.9	1753.1
Ball 4 Round 1	7186.5	115.1	332.8	322.1	931.8
Ball 4 Round 2	7080.3	203.2	356.4	569.0	997.9
Ball 5 Round 1	8539.3	166.5	609.2	466.3	1705.8
Ball 5 Round 2	8356.7	205.2	650.9	574.6	1822.5
Ball 6 Round 1	8111.8	128.3	568.5	359.2	1591.9
Ball 6 Round 2	8254.4	329.7	526.8	923.3	1475.1
Ball 7 Round 1	8025.8	146.2	575.5	409.3	1611.3
Ball 7 Round 2	7870.2	353.8	582.4	990.8	1630.9
Ball 8 Round 1	7778.4	114.5	583.8	320.6	1634.6
Ball 8 Round 2	7738.9	421.0	627.5	1178.9	1757.0
Ball 9 Round 1	7419.5	122.6	582.9	343.2	1632.1
Ball 9 Round 2	7064.9	159.5	348.0	446.5	974.4

TABLE 2 Mass (ounces)

Sample	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Ball 1 Round 1	4.9641	0.0068	0.0262	0.0191	0.0734
Ball 1 Round 2	4.9539	0.0018	0.0240	0.0052	0.0673
Ball 2 Round 1	4.9080	0.0090	0.0231	0.0251	0.0646
Ball 2 Round 2	4.9067	0.0032	0.0295	0.0090	0.0825
Ball 3 Round 1	5.2238	0.0062	0.0264	0.0174	0.0739
Ball 3 Round 2	5.2254	0.0030	0.0354	0.0083	0.0991
Ball 4 Round 1	5.1245	0.0089	0.0356	0.0250	0.0996
Ball 4 Round 2	5.1196	0.0032	0.0349	0.0089	0.0977
Ball 5 Round 1	5.2575	0.0069	0.0303	0.0193	0.0849
Ball 5 Round 2	5.2505	0.0019	0.0165	0.0053	0.0463
Ball 6 Round 1	5.1193	0.0461	0.0462	0.1291	0.1294
Ball 6 Round 2	5.1161	0.0027	0.0202	0.0077	0.0564
Ball 7 Round 1	5.0294	0.0048	0.0491	0.0133	0.1376
Ball 7 Round 2	5.0402	0.0032	0.0456	0.0089	0.1276
Ball 8 Round 1	5.1135	0.0056	0.0437	0.0157	0.1223
Ball 8 Round 2	5.1052	0.0039	0.0205	0.0108	0.0574
Ball 9 Round 1	5.1613	0.0058	0.0392	0.0161	0.1097
Ball 9 Round 2	5.1467	0.0107	0.0220	0.0300	0.0616

13. Keywords

13.1 ball elasticity; ball hardness; baseball; cylindrical coefficient of restitution; dynamic stiffness; softball

TABLE 3 Average CCOR

Sample	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	s_R	r	R
Ball 1 Round 1	0.56180	0.00803	0.00832	0.02248	0.02330
Ball 1 Round 2	0.56839	0.00319	0.00529	0.00894	0.01481
Ball 2 Round 1	0.56537	0.00678	0.00702	0.01900	0.01966
Ball 2 Round 2	0.56750	0.00353	0.00572	0.00988	0.01600
Ball 3 Round 1	0.56910	0.00588	0.00721	0.01647	0.02018
Ball 3 Round 2	0.57366	0.00323	0.00507	0.00905	0.01420
Ball 4 Round 1	0.56421	0.00661	0.00777	0.01852	0.02175
Ball 4 Round 2	0.56987	0.00261	0.00763	0.00730	0.02137
Ball 5 Round 1	0.57032	0.00694	0.00916	0.01942	0.02566
Ball 5 Round 2	0.57746	0.00344	0.00726	0.00964	0.02033
Ball 6 Round 1	0.56981	0.00603	0.00687	0.01690	0.01923
Ball 6 Round 2	0.57402	0.00556	0.00698	0.01558	0.01954
Ball 7 Round 1	0.57228	0.00681	0.00964	0.01907	0.02700
Ball 7 Round 2	0.57465	0.00400	0.00722	0.01121	0.02023
Ball 8 Round 1	0.56619	0.00689	0.00830	0.01930	0.02324
Ball 8 Round 2	0.57174	0.00461	0.00720	0.01292	0.02016
Ball 9 Round 1	0.56455	0.00650	0.01051	0.01820	0.02942
Ball 9 Round 2	0.57306	0.00747	0.00843	0.02091	0.02360