October 18, 2017

Initial Velocity (IV) Test Replacement

1   Rationale of Equipment and Method Change

The Rules of Golf Appendix III, Rule 5, refers to the Initial Velocity Standard ("IV is tested according to TPX3007 "Initial Velocity Test Procedure", revision 1.0.0). This procedure requires the use of the Illinois Tool Works Impact Reaction Tester (referred to as "ITW" or "IV Machine"), a specialized device first put into use in the 1960's.

In October 2017, The R&A will begin conformance testing of golf balls produced by manufacturers having operating headquarters outside of the United States and Mexico. This will mark a change from the previous state, in which the USGA performed all golf ball conformance testing.

It has been a significant challenge for golf ball manufacturers to replicate the ITW device. The R&A and USGA believe that, with The R&A beginning ball conformance testing, a perfect opportunity has been presented to develop an alternative method that alleviates many of the challenges of testing golf balls for conformance to Appendix III, Rule 5. This was initially communicated in the May 11, 2015 Notice to Golf Ball Manufacturers ("Equipment Research – Area of Interest Changes to Golf Ball Testing Equipment").

The following constraints were imposed in developing an alternative test:

a.   This shall not constitute a change to the Rules, specifically to Appendix III, Rule 5.
b.   Accordingly, the alternative test shall reproduce the results of the existing method, in accordance with the Rule.

2   Description of Test Equipment and Method Change

2.1   Existing Test

The full test using the ITW consists of the following steps (screening steps may apply):

a.   At an impact speed of 143.8 ft/s, measure the post-impact velocity of a golf ball from four impacts for each ball.
b.   Calculate IV from the average from the four measurements.
c.   For each golf ball, compare the IV to the 250 ft/s limit plus a maximum tolerance of 2% (255 ft/s)
d.   In a sample of 24 golf balls, if four or more initial velocities exceed 255 ft/s, then the sample is deemed to be nonconforming.

2.2   New Test

The new test consists of the following steps:

    a. Propel a golf ball at a fixed, rigid barrier (see Appendix I, new test protocol).
        i. Calculate the coefficient of restitution and time of contact between the ball and barrier at an impact speed of 143.8 ft/s.
        ii. Calculate the IV from the coefficient of restitution and contact time (see Appendix I, new test protocol).
    b. For each golf ball, compare the IV to the 250 ft/s limit plus a maximum tolerance of 2% (255 ft/s)
    c. In a sample of 24 golf balls, if four or more initial velocities exceed 255 ft/s, then the sample is deemed to be nonconforming.

3   Appropriateness of Equipment and Method Change

Given the manner in which conformance determination according to Appendix III, Rule 5 is made, three conditions exist for a test method replacement to be considered like-for-like (that is, a golf ball submission has the same probability of being found conforming or nonconforming with either test). First, the replacement test calculation of IV must be linear and unbiased when compared with the ITW result. Second, the distribution of IVs within a given sample should be similar between the two tests. Finally, the gage of the new test should be no greater than the existing test.

The results shown below reflect the outcomes of testing according to Appendix I (new test protocol) and Appendix II (new test procedure) as compared to the existing test process.

3.1   Bias and Linearity

Trials were conducted using sixty-four types of golf balls, encompassing representative ranges of coefficient of restitution, contact time, and IV for golf balls submitted for conformance testing. These trials showed that this test agrees with the ITW IV with an R^2 of 0.99 (Figure 3-1), leading to a prediction interval of 0.35 ft/s at 99% (comparable with the gage of the existing test).
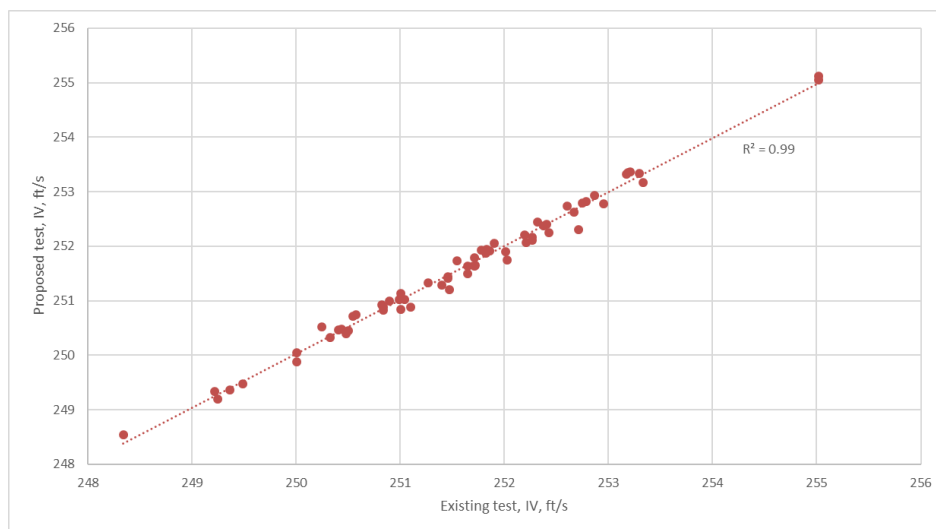

Figure 3-1: Comparison of the Initial Velocity (IV) as determined through two measurement processes.

3.2   IV distribution

Examining the variation within samples has shown that standard deviations resulting from tests with the ITW and the new method had distributions that were not distinguishable, satisfying the second condition (Figure 3-2).
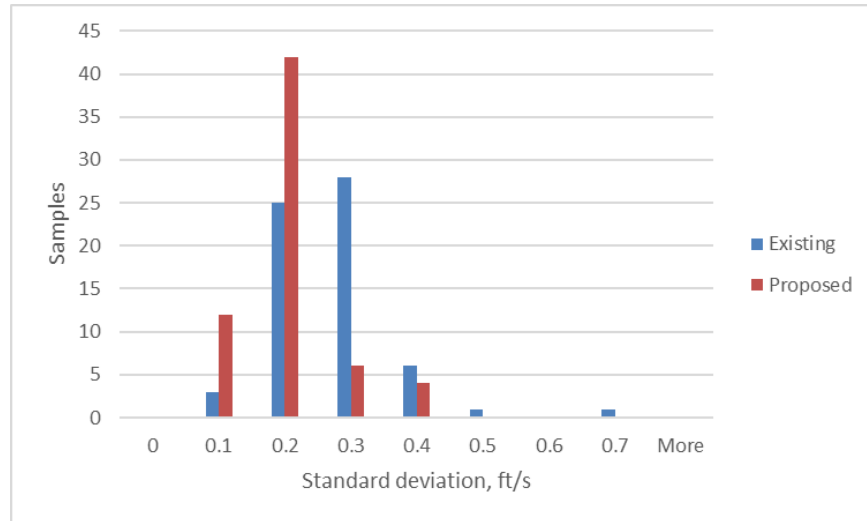

Figure 3-2: Comparison of the standard deviations of samples tested using the two processes.

3.3   Test Gage

A Gage R&R study was conducted to ensure that the repeatability and reproducibility were consistent between the new and existing tests. Five ball types were tested by three operators each over three randomized trials. The resulting gage was +/- 0.289 at 99% confidence, which compares favorably the established ITW gage (+/- 0.293).

4   Implementation Plan

This testing method will be used for balls provided for the October 2017 submission deadline which are intended to be listed in the December 2017 Conforming Golf Ball List.

Appendix I: New Test Protocol

Test Protocol for Golf Ball Initial Velocity

Scope

This protocol describes the method used to test golf balls for conformance to the Rules of Golf, Appendix III, Rule 5, as administered by the United States Golf Association (USGA) and R&A Rules, Ltd., (The R&A).

Test Requirements

Scope

Golf balls shall be maintained at 75° F +/- 1° F (23.9° C +/- 0.6° C) for a minimum of three hours prior to testing.

    a. For a given sample, each golf ball shall impact an effectively rigid, fixed barrier.

        i. The barrier shall be set such that the surface normal is inclined at an angle of 5° from the inbound path of the golf ball.
        ii. The ball should be propelled in such a way as not to induce significant spin.

    b. The rebound velocity of the ball shall be measured at distance beginning no less than 7 inches, and no more than 9 inches from the impact target. The gauge distance for velocity measurement should be no more than 18 inches.

    c. The time of contact between the ball and the barrier shall be measured.

    d. The IV of the golf ball (ft/s) shall be calculated according the following:

$$IV = 136.8 + 136.3\,e + 0.019\,t_c$$

Where e is the coefficient of restitution, and t_c is the contact time in microseconds at an impact speed of 143.8 ft/s.

    e. The pre-impact speeds for the test should enable accurate interpolation at the target speed of 143.8 ft/s.

        i. To this end, each golf ball may be tested over a range of speeds, such that:

            a) The impact speeds should not be different from 143.8 ft/s by more than 15 ft/s.

            b) Sufficient measurements are made at speeds above and below the nominal speed as to allow for linear correction to 143.8 ft/s.

    f. The IV of each of 24 balls comprising a sample shall be reported.

The USGA and The R&A reserve the right to employ valid screening methods as appropriate.

Interpretation

For each golf ball, the IV shall be compared to the 250 ft/s limit plus a maximum tolerance of 2% (255 ft/s). In a sample of 24 golf balls, if four or more initial velocities exceed 255 ft/s, then the sample shall be ruled nonconforming to Appendix III, Rule 5.

Appendix II: New Test Procedure

Apparatus

The Hye PTM3 is used to conduct Initial Velocity testing following the new procedure. The PTM3 machine meets the requirements outlined in Appendix I. The machine comprises an air cannon that launches golf balls vertically at a rigid target plate oriented at 5 degrees to horizontal. Ballistic screens are positioned 7 inches from the target plate, with 12 inches of gauge distance to measure both inbound and outbound velocity. This plate is instrumented with a force transducer to enable the measurement of contact time.

Vendor

Hye Precision Products is a Custom Tool and Automation design specialist based in Perry, GA, USA.

Procedure

a. Use the Hye PTM3.
b. Test each ball at four speeds, two each above and below 143.8. The following nominal speeds should be used:
    1. 150 ft/s
    2. 147 ft/s
    3. 139 ft/s
    4. 136 ft/s
c. Record the coefficient of restitution as the post-impact ball speed divided by the pre-impact ball speed.
d. From the force-time history, record the contact time (in microseconds) as the time at which the impact force (using a 12 kHz low-pass filter) crosses 5% of the peak force falling minus the time at which it crosses 5% of the peak force rising.
e. With the results of four impacts recorded, linearly interpolate the coefficient of restitution and contact time to 143.8 ft/s and calculate the Pearson correlation coefficient.
    i. If the Pearson correlation coefficient for coefficient of restitution as a function of impact speed is less than 0.9, review the data for unusual results. Re-test the golf ball if necessary.
    ii. If the contact time range for four impacts exceeds 11µs, review the data for unusual results. Re-test the golf ball if necessary.
f. For each ball, calculate the Initial Velocity according to the following:

$$IV = 136.8 + 136.3\ e + 0.019\ t_c$$

g. Report the results for golf balls in accordance with Test Protocol for Golf Ball Initial Velocity.

Note that this procedure may change at any time, subject to notice to manufacturers.