



R&A Rules Limited
and
United States Golf Association

PROTOCOL FOR MEASURING THE MOMENT OF INERTIA OF
GOLF CLUBHEADS

TPX3005

Rev. 2.0

1 December 2020

Revision	Date	Details of Revision
1.0	Jun-2005	Original published version.
2.0	1-Dec-2020	Updated references to The Equipment Rules. Reformatted step numbering and section titles to be consistent with other protocols. Eliminated requirement for use of Microsoft Excel spreadsheet and equipment specificity.

1 Scope

This protocol describes the methods used to determine the clubhead moment of inertia of woods to the Equipment Rules, Part 2, Section 4b (i), as administered by R&A Rules Ltd. (The R&A) and the United States Golf Association (USGA).

2 Test Protocol

2.1 Measurement

- a. Using a calibrated mass balance or equivalent, measure and record the mass of the clubhead.
- b. Measure the moment of inertia of the clubhead about the vertical axis of the clubhead orientated at a 60° lie angle, See Figure 1.

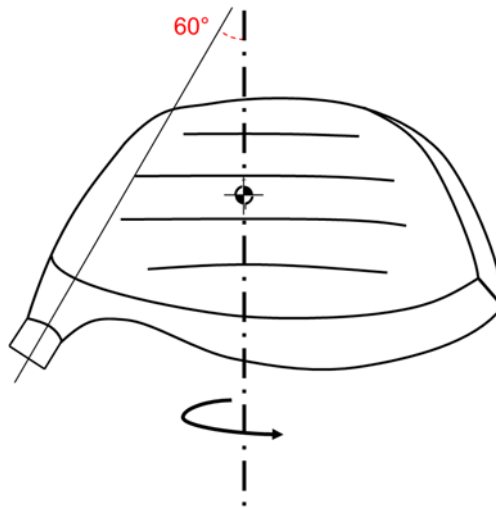


Figure 1: Clubhead mounted such that the axis of rotation is parallel to the vertical axis of the clubhead.

- i. Measure the moment of inertia about the centre of mass of the clubhead in this orientation.
- ii. If the position of the centre of mass is unknown, or if measurement of the moment of inertia is impracticable, see Appendix, 4)

3 Determination of Conformance Status

If the moment of inertia of the clubhead about its centre of mass exceeds 5,900 g-cm² plus a test tolerance, the clubhead does not conform to the Equipment Rules, Part 2, Section 4b (i).

Appropriate screening methods may be applied.

4 Appendix: Moment of Inertia Calculations, Unknown Centre of Mass

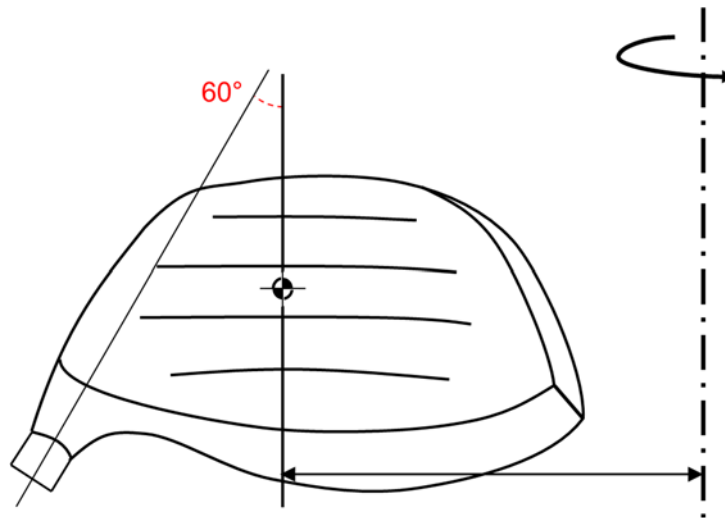


Figure 2: Measurement of the moment of inertia of a club head, unknown centre of mass.

In the case that the position of the centre of mass is unknown, or if measurement of the moment of inertia is impracticable:

- a. Measure the moment of inertia of the clubhead about the vertical axis of the clubhead orientated at a 60° lie angle, with the club at a known position.
- b. Measure the distance between the axis of rotation and a known point on the clubhead. This distance should be expressed in Cartesian coordinates on a plane normal to the axis of rotation. The origin of this plane should be the axis of rotation.
- c. Repeat the moment of inertia measurement (step a.) eight further times varying the distance between the axis of rotation and the known point on the clubhead.
 - i. Note that the orientation of the clubhead relative to the axis of rotation should be kept constant.
- d. Using the parallel axis theorem, calculate the moment of inertia of the clubhead about its centre of mass.

The parallel axis theorem may be expressed as:

$$I = \bar{I} + md^2 \quad (1)$$

where m is the total mass of the body and d is the distance from the center of mass to the axis of rotation. In a Cartesian coordinate system, this may be rearranged to show:

$$\bar{I} = I - md^2 = I - m \left[(x_{cg} + x)^2 + (y_{cg} + y)^2 \right] \quad (2)$$

This may be generalized for a collection of measurements j :

$$\bar{I} = I_j - m \left[(x_{cg} + x_j)^2 + (y_{cg} + y_j)^2 \right] \quad (3)$$

It can be shown that this may be expressed as:

$$\mathbf{f} = \mathbf{K}\mathbf{x} \quad (4)$$

where:

$$\mathbf{f} = \begin{Bmatrix} \frac{I_1}{m} - x_1^2 - y_1^2 \\ \frac{I_2}{m} - x_2^2 - y_2^2 \\ \vdots \\ \frac{I_n}{m} - x_n^2 - y_n^2 \end{Bmatrix}, \quad \mathbf{K} = \begin{bmatrix} \frac{1}{m} & x_{cg} + 2x_1 & y_{cg} + 2y_1 \\ \frac{1}{m} & x_{cg} + 2x_2 & y_{cg} + 2y_2 \\ \vdots & \vdots & \vdots \\ \frac{1}{m} & x_{cg} + 2x_n & y_{cg} + 2y_n \end{bmatrix}, \quad \mathbf{x} = \begin{Bmatrix} \bar{I} \\ x_{cg} \\ y_{cg} \end{Bmatrix}$$

For multiple points ($n > 3$), this system may be solved to arrive at a least-squares solution by use of the pseudo inverse of the K matrix:

$$\mathbf{x} = (\mathbf{K}^T \mathbf{K})^{-1} \mathbf{K}^T \mathbf{f} \quad (5)$$

An iterative solution is required such that initial guesses of x_{cg} and y_{cg} are inserted into \mathbf{K} and a solution is found with the iteration scheme converging in two iterations.