United States Golf Association
and
R&A Rules Limited

PROCEDURE FOR MEASURING
THE MOMENT OF INERTIA OF
GOLF CLUBHEADS

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1. Scope

1.1 This method covers the procedure for measuring the moment of inertia (MOI) of clubheads as administered by the United States Golf Association (USGA) and R&A Rules Limited (R&A).

1.2 The results of the conformance tests are used in determining conformity of the club to the Rules of Golf.

1.3 The values stated in imperial units are to be regarded as standard. The values stated in SI units are for information only.

2. Applicable Documents

2.1 USGA and R&A documents:
Rules of Golf

3. Summary of Method

3.1 Using a moment of inertia measuring instrument, the moment of inertia of clubheads is measured.

NOTE: This procedure may change and the test tolerances may be reduced as the test methods are refined.

4. Significance

4.1 This method measures the moment of inertia of wood-type clubheads to determine the conformity to the Rules of Golf.

The moment of inertia of the clubhead shall not be greater than **32.259 oz-in^2 (5900 g-cm^2)**. A maximum test tolerance of **0.547 oz-in^2 (100 g-cm^2)** is associated with this test.

Intermediate screening procedures may be used to determine clubhead conformance and increase testing efficiency.

5. Procedure for Measurement of Clubhead Moment of Inertia

The moment of inertia of the clubhead is determined using a measurement instrument which has been designed for measuring the moment of inertia of test parts having mass properties and overall dimensions similar to that of a golf clubhead.

Clubs will be tested for moment of inertia as submitted by the club manufacturer. It is expected that submissions will weigh at or near the nominal head weight for the golf club. Submitted clubheads with unusually low head weights will require additional documentation from the submitter confirming that the submitted weight is at or near the nominal head weight of the golf club as it is intended to be used.

5.0 Start the "MOI Calculation.xls" program. Select the "Data" worksheet, Figure 5.0

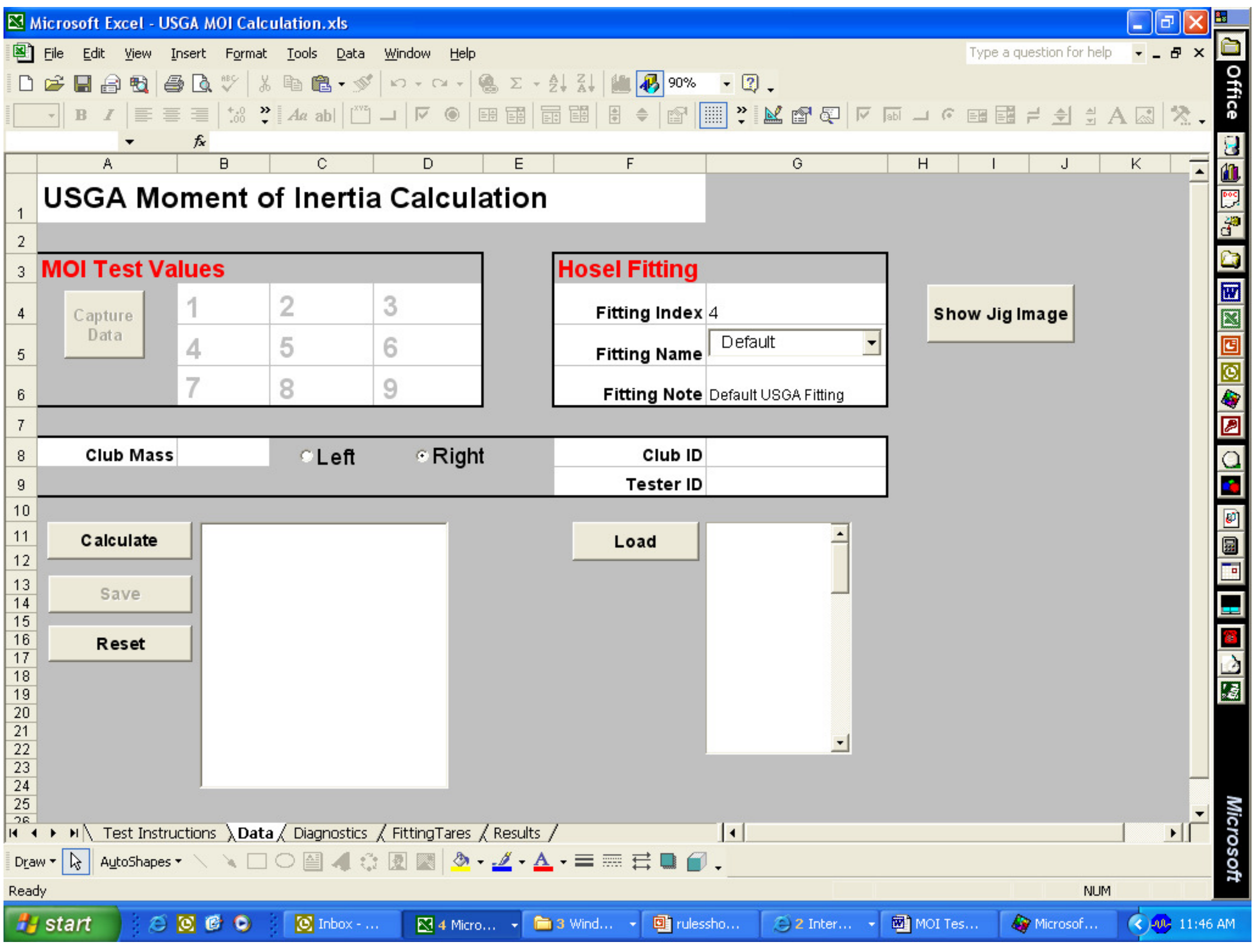


Figure 5.0–MOI Calculation.xls Program "Data" Worksheet

5.1 Attach the MOI jig plate Figure 5.1 (see Appendix A for jig plate dimensions) to the moment of inertia instrument, insuring that the plate is tight.

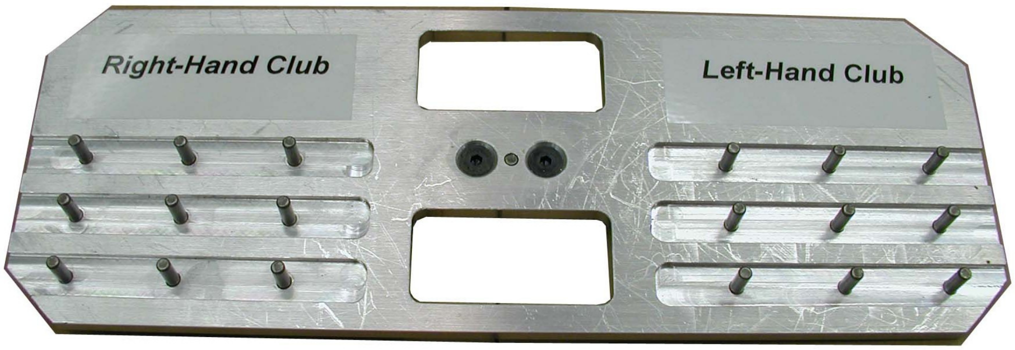


Figure 5.1 – MOI Jig Plate

5.2 With the jig plate attached, ensure that the inertia instrument and jig plate are level and tare the instrument.

5.3 Measure the mass of the clubhead and record the value in the box labeled "Club Mass" on the MOI Calculation program "Data" worksheet.

5.4 Select the "Right" or "Left" radio button as appropriate for a right or left handed clubhead.

5.5 Enter the "Club ID" and "Tester ID" in the appropriate boxes on the MOI Calculation program "Data" worksheet.

5.6 Select the appropriate hosel fitting and insert it fully into the clubhead making sure that the fitting is snug. (The hosel fitting is designed to keep the head at a prescribed lie angle of 60°. See Appendix A for hosel fitting dimensions.)

5.7 Align the face of the hosel fitting to be parallel with the middle of the clubhead.

5.8 Select the appropriate fitting name from the "Fitting Name" drop down box on the MOI Calculation program "Data" worksheet. All of the available fittings are listed in the "Fittings Tare" worksheet. If the desired fitting is not listed, a new fitting may be added using the procedure described in 5.8.1.

5.8.1 New fittings may be added to the next available row on the "Fittings Tare" worksheet. To add a new fitting, measure the moment of inertia of the fitting at each of the pins (the machine must be tared with the jig plate attached before measuring the fitting moment of inertia.) If the fitting is to be used for both right- and left-handed clubheads then the moment of inertia must be measured in both the left- and right-hand club orientations and entered as two separate fittings on the worksheet.

5.9 Mount the clubhead on the jig at pin "1". For right-handed clubheads the pins on the left side of the jig must be used. The toe of the club should point to the center of the jig, Figure 5.9.1. (The pins on the right side of the jig must be used for left-handed clubheads.)

Figure 5.9.1–Right-handed Clubhead Mounted on the MOI Jig at Pin 1

Note: Pin locations may be viewed by clicking the "Show Jig Image" button on the MOI Calculation program "Data" worksheet, Figure 5.9.2.

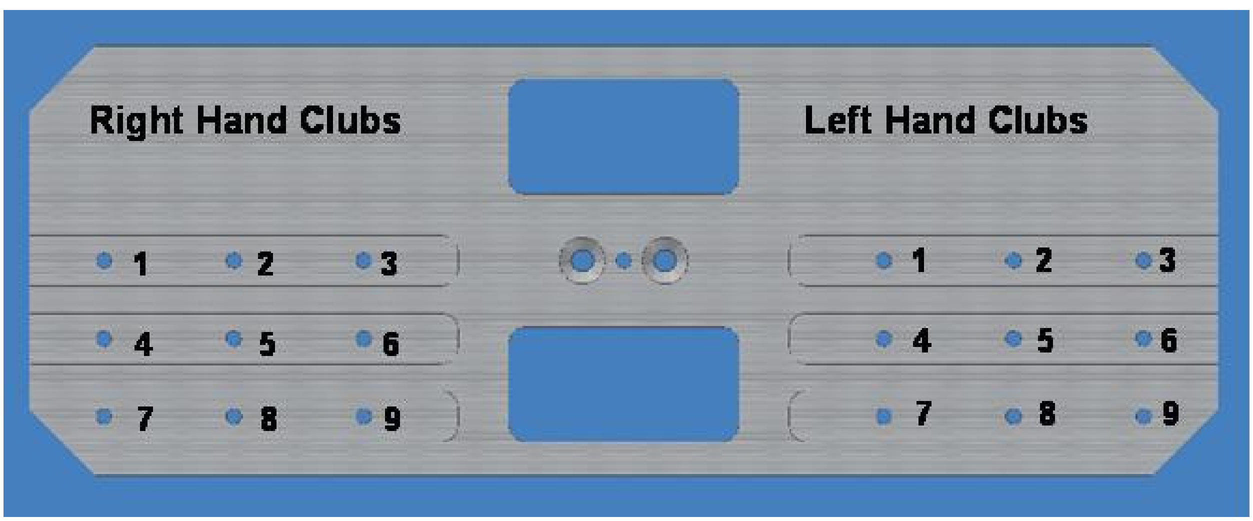


Figure 5.9.2–MOI Jig Mounting Pin Locations

5.10 With the clubhead in place, measure the moment of inertia of the clubhead at pin "1". (The instrument should be set to display the inertia measurement in g-cm^2.)

5.11 Enter the measured MOI value in the appropriate box in the "MOI Test Values" area on the MOI Calculation program "Data" worksheet.

5.12 Repeat steps 5.9 through 5.11 for pins 2 through 9 ensuring that the hosel fitting does not move while changing from pin to pin..

5.13 Once measurements at all nine pin locations have been obtained; press the “Calculate” button on the MOI Calculation program “Data” worksheet. The program will calculate the clubhead moment of inertia and display it in the output window on the MOI Calculation program “Data” worksheet (Details of the moment of inertia calculation are given in Appendix B.)

Note: Once measurements at four or more pin locations have been taken, the “Calculate” button may be pressed and an estimated value of the moment of inertia for the reduced number of pins will be calculated and displayed.

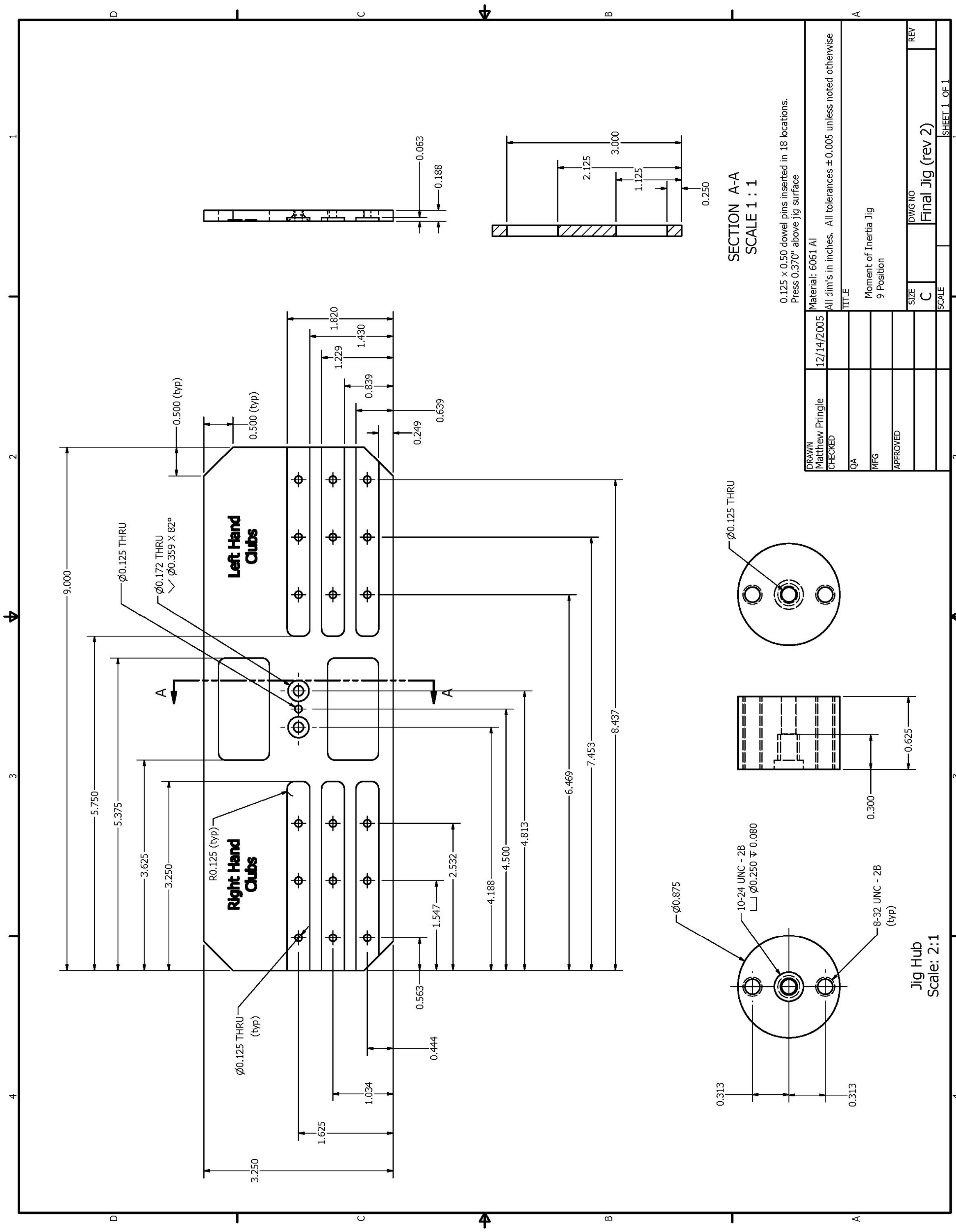
5.14 If the clubhead has moveable weights, repeat steps 5.9 through 5.13 for all possible weight configurations. The weight configuration that produces the largest moment of inertia is used for conformance determination.

6.0 Conformance Determination

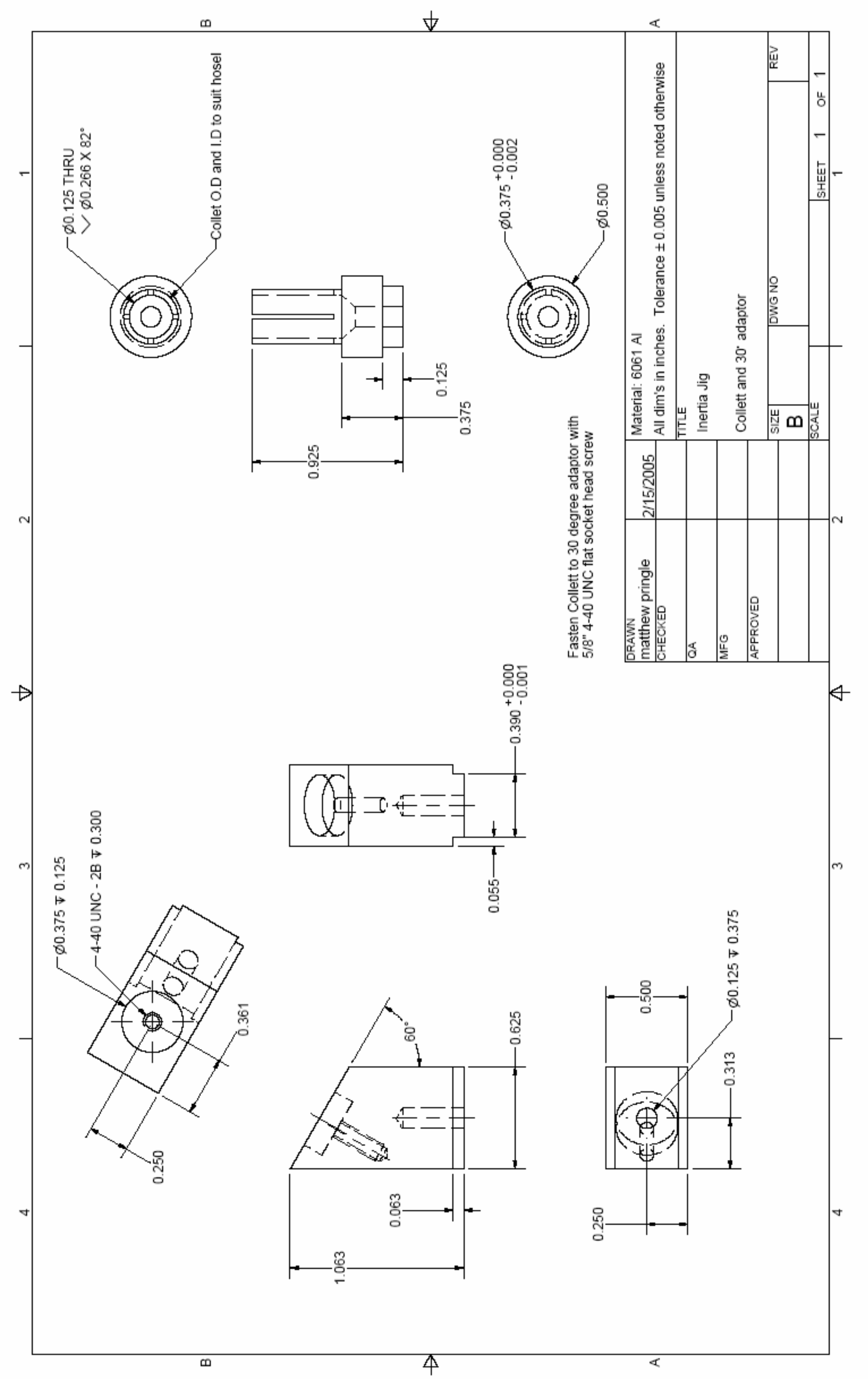
6.1 If the moment of inertia is less than or equal to **32.259 oz-in^2** plus the tolerance then the clubhead conforms to the Rules of Golf.

6.2 If the moment of inertia is greater than **32.259 oz-in^2** plus the tolerance then the test is over and the clubhead does not conform to the Rules of Golf.

Appendix A – MOI Jig Plate and Hosel Fitting Dimensions



MOI Jig Plate



MOI Hosel Fitting

Appendix B – Calculating the Mass Moment of Inertia

The mass moment of inertia of a body determines its angular acceleration when subjected to a moment. The mass moment of inertia (*I*) of a body about a particular axis is (Meriam, Kraige, 1986):

$$I = \int r^2 dm \qquad (1)$$

where *r* is the distance from the axis of rotation to an increment of mass (*dm*) measured in the plane perpendicular to the rotation axis (referred to herein as the x-y plane).

We are interested in the mass moment of inertia of a club head rotating about its center of gravity. Unfortunately, the location of the center of gravity is not known *a priori*. Therefore, our measurement procedure will have to include determining this location. If we let the mass moment of inertia about the center of gravity be $\bar{I}$, the mass moment of inertia measured about another axis will be (Meriam, Kraige, 1986):

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

where *m* is the total mass of the body and *d* is the distance from the center of gravity to the axis of rotation (again measured in the x-y plane).

Now, in the x-y plane, we will define the location of the axis of rotation as the origin of a Cartesian coordinate system. Next, we will define the location of a known point on the club in this coordinate system to be (x, y). Finally, we will define the coordinates of the center of gravity of the club head, relative to the known point to be (x_{cg}, y_{cg}). Figure 1 shows the coordinate system. Referring to this coordinate system and equation (2):

$$\bar{I} = I - md^2 = I - m\left[(x_{cg} + x)^2 + (y_{cg} + y)^2\right] \qquad (3)$$

Equation (3) cannot be solved on its own since there are three unknowns (x_{cg}, y_{cg} and $\bar{I}$). However, more than one set of measurements may be made by moving the known point (x, y) relative to the axis of rotation. Equation (3) may be generalized to, for each j^{th} measurement:

$$\bar{I} = I_j - m\left[(x_{cg} + x_j)^2 + (y_{cg} + y_j)^2\right] \qquad (4)$$

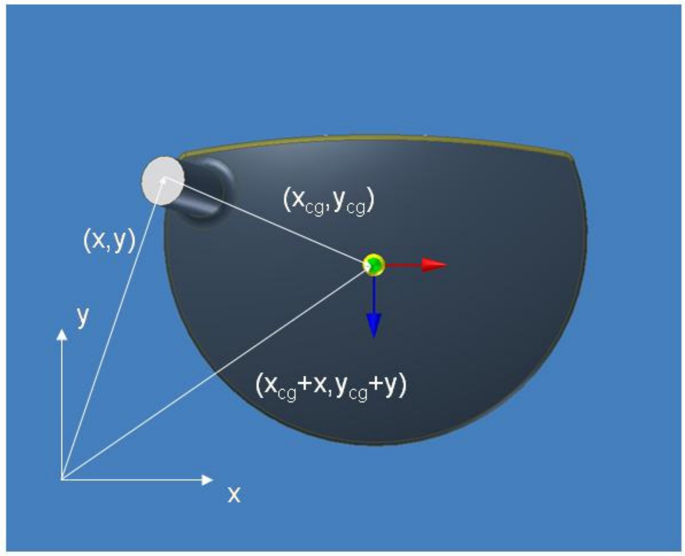


Figure 1: Inertia measurement coordinate system

Expanding and rearranging yields:

$$\frac{I_j}{m} - x_j^2 - y_j^2 = \left(\frac{\bar{I}}{m} + x_{cg}^2 + y_{cg}^2\right) + 2x_j x_{cg} + 2y_j y_{cg}\,. \qquad (5)$$

Defining $\Lambda_j = I_j / m - x_j^2 - y_j^2$, $\alpha_j = 2\, x_j$ and $\beta_j = 2\, y_j$ and by exploiting a least squares estimation of the parameters, x_{cg}, y_{cg} and $\left(\frac{\bar{I}}{m} + x_{cg}^2 + y_{cg}^2\right)$, we find that:

$$x_{cg} = \frac{\Gamma(\beta,\beta)\Gamma(\alpha,\Lambda) - \Gamma(\alpha,\beta)\Gamma(\beta,\Lambda)}{\Gamma(\alpha,\alpha)\Gamma(\beta,\beta) - \Gamma(\alpha,\beta)^2} \text{ and } y_{cg} = \frac{-\Gamma(\alpha,\beta)\Gamma(\alpha,\Lambda) + \Gamma(\alpha,\alpha)\Gamma(\beta,\Lambda)}{\Gamma(\alpha,\alpha)\Gamma(\beta,\beta) - \Gamma(\alpha,\beta)^2},$$

where we have defined the operator

$$\Gamma(a,b) = \sum_{j=1}^{N} a_j b_j - \frac{1}{N}\sum_{j=1}^{N} a_j \sum_{j=1}^{N} b_j\,.$$

Finally, from the least squares solution we find

$$\bar{I} = m\left(\frac{1}{N}\left(\sum_{j=1}^{N}\Lambda_j - x_{cg}\sum_{j=1}^{N}\alpha_j - y_{cg}\sum_{j=1}^{N}\beta_j\right) - x_{cg}^2 - y_{cg}^2\right).$$

References

J.L. Meriam, L.G. Kraige, **Dynamics 2nd Edition**

John Wiley & Sons, NY, NY, 1986