Standard Operating Procedure: SOP-BALL-13

Bowling Ball RG Device Calibration

Rev	Date	Staff Member	Purpose
3	6/8/22	D. Speranza	Added new rectangular calibration shape option
2	1-22-2014	E. Troutman	Rewrite for clarification
1	3-17-2011	J. Milligan	Reformat
Origination date: 1/27/2003	Originator:		

Purpose: To calibrate the RG swing after replacing the wire. The apparatus must be calibrated before use to determine the torsional constant. Each device will have its own constant due to differences in the wire.

Materials:

- RG Swing with timing mechanism and electric eye counter
- Solid cylinder with known dimensions or common shape with known dimensions whereby the moment of inertia can be calculated mathematically based on math models for common shapes.
- RG Swing calibration worksheet.

Procedure:

1. Determine the period of the cradle (T_C) by timing the empty cradle. The timing mechanism should be set up for determining 5 full oscillations/swings (11 sensor triggers). Document the time for the 5 full oscillations, and repeat. Then average the 10 total swings to determine $T_{c.}$

Time for 1st 5 swings = ___________sec
Time for 2nd 5 swings = ___________sec

Total = _____________sec

$\text{Tc} = \frac{Total}{10}$ Tc = _________________sec.

2. Next, select an object(s) where the Moment of Inertia can be calculated (and it will fit into the RG device). At least two known moments of inertia are required. The suggested masses are a sphere of uniform density (i.e. made of only one material) and a steel cylinder of uniform density, both weighing between 10 and 16 pounds (a steel cylinder approximately 2 1/2" dia. and 9" long will weigh around 12 pounds and a solid polyurethane sphere with the same diameter as a bowling ball will also weigh around 12 pounds). One cylinder may be used with the Moment of Inertia (I) calculated horizontally and vertically.

Accurately weigh the masses and measure the radius of the sphere and the radius and length of the cylinder. From these measurements, calculate the moment of inertia as follows:

Sphere: $I = \frac{2\,M\,R^2}{5}$

Cylinder on parallel axis (standing upright): $I = \frac{M\,R^2}{2}$

Cylinder on perpendicular axis (laying down): $I = \frac{M\,R^2}{4} + \frac{M\,L^2}{12}$

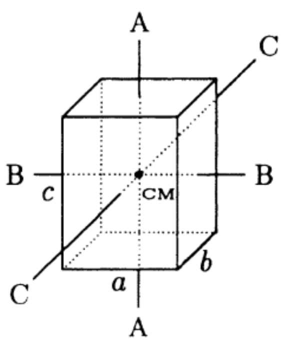
Where:

I = moment of inertia (lb*in^2)
M = mass of sphere or cylinder (lb)
R = radius of sphere or cylinder (in)
L = length of cylinder (in)

Record I here:

I_1 = _______________ lb*in^2
I_2 = _______________ lb*in^2

A different option for the calibration object is a rectangular block that can be calculated horizontally and vertically.



Rectangular Prism

$$I_{AA} = \frac{1}{12} m\left(a^2 + b^2\right)$$
$$I_{BB} = \frac{1}{12} m\left(b^2 + c^2\right)$$
$$I_{CC} = \frac{1}{12} m\left(c^2 + a^2\right)$$
$$V = abc$$

A solid aluminum block with the following dimensions works well to get Rg values that approximate the values for, both, the low and high RG balls between 14 and 16 pounds.

Aluminum block properties		
mass	15	lbs
a=	7.000	inches
b=	3.000	inches
c=	7.500	inches
Calculated values:	I	Rg
Ixx	72.5	2.198
Iyy	81.5625	2.331
Izz	131.5625	2.960

3. Determine the period with the selected objects from above. Document the time for the 5 full oscillations two times, for each object. Then average the 10 total swings to determine the period of each object.

Object 1:

Time for 1st 5 swings = ___________sec
Time for 2nd 5 swings = ___________sec

Total = _____________sec

$T_1 = \frac{Total}{10}$ T_1 = ______________ sec.

For each object, solve for the torsional constant as follows:

$K_1 = \frac{4*\pi^2*I_1}{T_1^2 - T_c^2}$ K_1 = _______________ $\frac{\text{lb}*\text{in}^2}{sec^2}$

Where:

I = moment of inertia of each mass (lb*in²)
T = period of each mass and cradle (sec)
T_c = period of the cradle (sec)

Object 2 (or object #1 rotated about a different moment of inertia axis):

Time for 1st 5 swings = ___________sec
Time for 2nd 5 swings = ___________sec

Total = _____________sec

$T_2 = \frac{Total}{10}$ T_2 = ______________ sec.

For each object, solve for the torsional constant as follows:

$K_2 = \frac{4*\pi^2*I_2}{T_2^2 - T_c^2}$ K_2 = _______________ $\frac{\text{lb}*\text{in}^2}{sec^2}$

Where:

I = moment of inertia of each mass (lb*in²)
T = period of each mass and cradle (sec)
T_c = period of the cradle (sec)

4. Determine the overall Torsional constant by averaging K_1 and K_2 as follows:

$K = \frac{(K_1+K_2)}{2}$ K = ________________ $\frac{\text{lb}*\text{in}^2}{sec^2}$

5. Determine the Moment of Inertia for the cradle as follows;

$I_c = \frac{K*T_c^2}{4*\pi^2}$ I_c = ________________ lb*in²

6. Following the above calibration, the Moment of Inertia and Radius of Gyration can now be determined of any object (bowling ball) placed in the device as follows:

$I_o = \frac{K*T_o^2}{4*\pi^2} - I_c$ ${RG_o}^2 = \frac{I_o}{M_o}$

Where:

I_o = moment of inertia of the object (lb*in²)
T_o = period of each mass and cradle (sec)
M_o = mass of the object (lb)
${RG_o}^2$ = radius of gyration squared of the object (in²)

Finally: RG_o = _____________ in.