Experiment- 2

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Determining metacentric height of floting object

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1. Aim:

To measure the Metacentric height of a body floating on water.

2. Apparatus:

- Weight
- A tank with water supply.
- A floating ship which contains horizontal beam at its middle and a movable pointer on a graduated scale at the centre of horizontal beam. Also , a vertical weight scale with which we can change CG of the ship.

3. Theory:

3.1 Centre of Gravity (G):

An imaginary point in a body of matter where, for convenience in certain calculations, the total weight of the body may be thought to be concentrated.

3.2 Centre of Buoyancy (B):

When a body is immersed in fluid, an upward force is exerted by the fluid on the body. This force will be equal to the weight of the fluid displaced by the body and this force will be termed as force of buoyancy or buoyancy.
Buoyancy force will act through the centre of gravity of the displaced fluid and that point i.e. centre of gravity of the displaced fluid will be termed as centre of buoyancy.
Centre of buoyancy = Centre of gravity of the displaced fluid = Centre of gravity of the portion

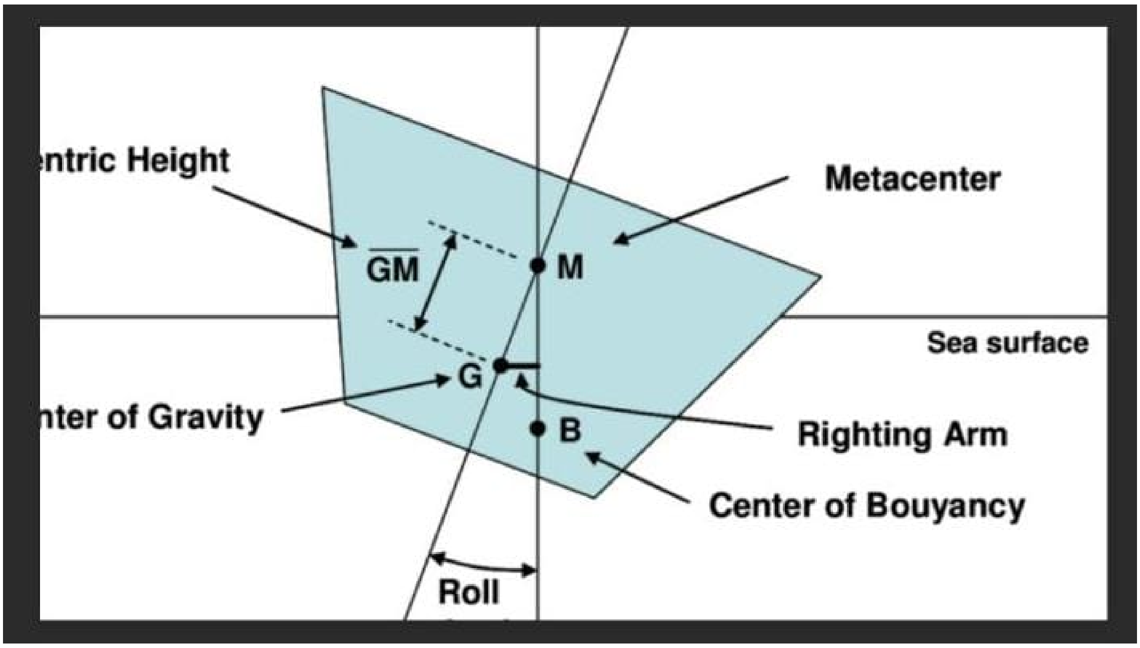

Figure 1: Caption

of the body immersed in the liquid.
The centre of buoyancy and the centre of gravity may not be along the same vertical line.When we have a force equal to the weight of the body W acting on the centre of gravity vertically downwards and an equal force acting on the centre of buoyancy vertically upwards.Now, if we displace the body by an angle the centre of buoyancy shifts but centre of gravity doesn't.This rises of the three following cases:

- If B is below G, there are three possibilities:
  - If B is to the left of G, a restoring couple is generated: Stable equilibrium.
  - If B is to the right of G, an overturning couple is generated: Unstable equilibrium.
  - If B is along the vertical line passing through G, no moment is generated: Neutral equilibrium.

  Therefore, to calculate the stability of a floating body, we define a term called the Metacentre.
- If B is above G, a restoring couple is always generated: Stable equilibrium.

3.3 Metacentre (M):

The point of intersection between an imaginary line drawn vertically through the centre of buoyancy of a floating vessel and a corresponding line through the new centre of buoyancy when the vessel is tilted.

3.4 Metacentric Height (GM):

The distance between metacentre and centre of gravity. The condition of stable equilibrium for a floating body can be expressed in terms of meta- centric height as follows:

- If $GM > 0$ (M is above G): Stable equilibrium.

- If $GM < 0$ (M is below G): Unstable equilibrium.

- If GM = 0 (M coinciding with G): Neutral equilibrium.

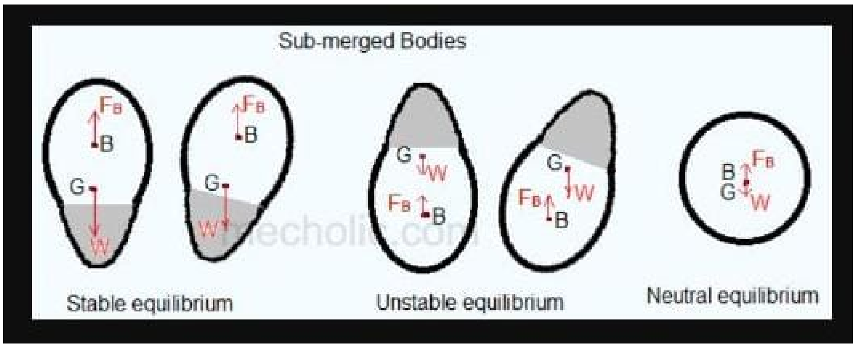

Figure 2: Conditions of stability of Submerged body

4. Procedure:

- Fill the tank with water and insert the floating body and ensure that it is in stable equilibrium.
- The horizontal sliding weight to position 'x' from the center towards left side of the vertical bar is set.
- A small angular displacement in clockwise direction is given to the model.
- The angle θ in the stable equilibrium is measured.
- The procedure is repeated by changing the distance and weight.
- GM is calculated experimentally.A relationship between angle of heel θ (x-axis) and GM (y-axis) is drawn ,then GM is obtained when equals zero.
- Calculate GM theoretically and compare model.

5. Calculation:

5.1 Experimental Calculation:

$$GM = \frac{Px}{W tan\theta}$$

where,
GM=Metacentric height
P: Weight of inclined weight (0.305 kg)
W: Total mass (1.305 kg)
x: distance of inclining weight from centre line of pontoon
θ : angle of pontoon relative to the vertical.

5.2 Theoretical Calculation:

$$GM = \frac{b^2}{12\times d} - (y - \frac{d}{2})$$

where,
b: Pontoon width (0.2m)
d: Depth of immersion (0.01864m)
y: height of CG

6. Result and Observations:

1. y=96mm

S.No.	x(in mm)	$\theta(in degrees)$	Experimental Metacentric height (in mm)
1	-60	-7	114.21
2	-50	-6	111.18
3	-40	-4.5	118.79
4	-30	-4	100.27
5	-20	-2.5	107.06
6	-10	-1	133.90
7	10	1.5	89.25
8	20	2.5	107.06
9	30	4	100.27
10	40	5	106.86
11	50	6	111.18
12	60	7	114.21

Theoretical metacentric height calculated from formula=92.15mm.

2. y=106mm

S.No.	x(in mm)	$\theta(in degrees)$	Experimental Metacentric height (in mm)
1	-50	-13	50.62
2	-40	-10.5	50.44
3	-30	-8	49.89
4	-20	-5.5	48.54
5	-10	-3	44.59
6	10	2.5	53.53
7	20	5	53.43
8	30	7.5	53.26
9	40	9.5	55.86
10	50	12.5	52.71

Theoretical metacentric height calculated from formula=82.15mm.

7. Graphs:

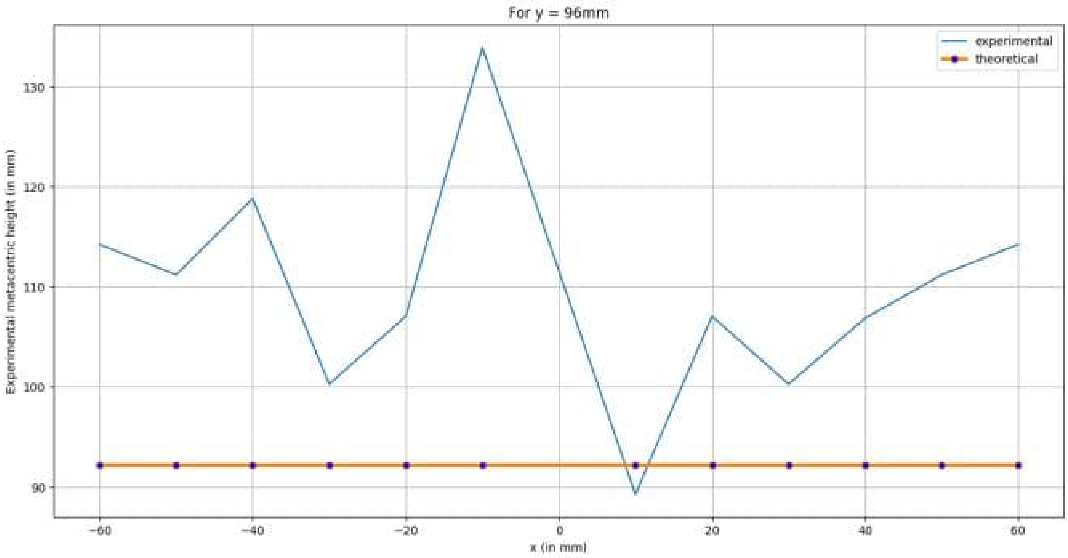

Figure 3: Aerodynamics of cars

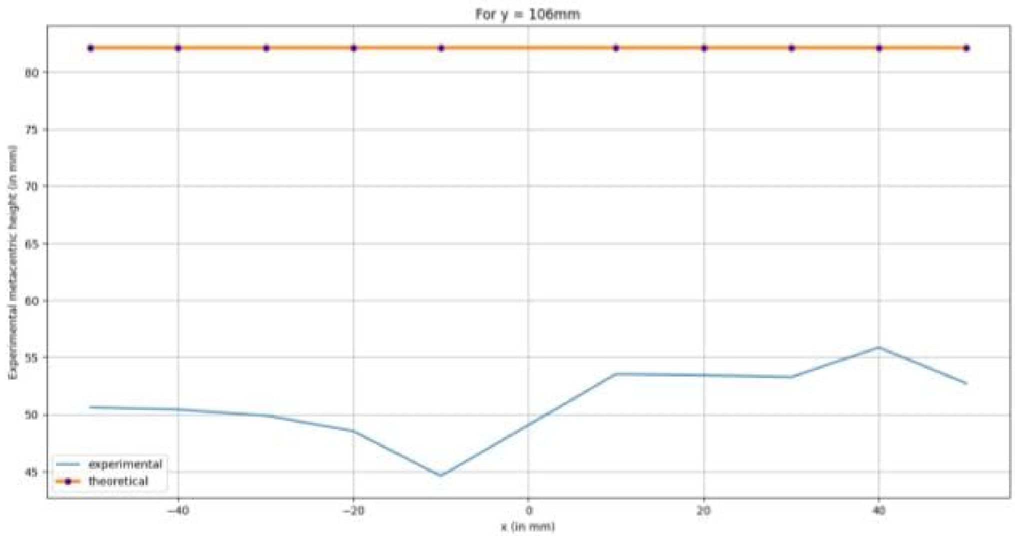

Figure 4: Aerodynamics of cars

8. Sources of Error:

The value of theoretical and experimental metacentric height is different, so there is some error in the experiment.

- Parallax errors as the body itself is in tilted position.
- Water might be present in the setup weighing it down.
- Presence of any air currents while performing this experiment may also lead to improper measurements in the degree scale.

9. Conclusion

From the above experiment we get an idea about the location of metacentric height, performed calculations to evaluate theoretically and analysed with experimental data.