Birzeit university– faculty of engineering and technology

Department of mechanical engineering

Fluid Mechanic Laboratory

ENME312

Section 1

Experiment No.2

"Stability of floating body"

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Abstract

An essential aspect of studying the behaviour of floating objects in fluids is their stability, which is crucial for the functionality of applications like boats and ships. The experiment demonstrated this concept by testing the stability of a floating pontoon under various loading conditions, specifically by altering the center of gravity. This was done by applying small tilts, using a jockey weight positioned at varying locations and heights on the pontoon, and observing its response. The experiment aimed to assess the pontoon's stability and its capacity to return to equilibrium. Success was measured by calculating various parameters, including the metacentric height (GM), the height of the metacentre above the water surface (CM), and the pontoon's inertia.

Understanding and estimating these parameters is crucial for grasping the overall behaviour of floating bodies and their reactions to applied forces. This knowledge aids in predicting potential risks and in designing floating bodies with optimal stability.

The calculation showed that the value of the experimental CM was 0.11065 m, whereas the calculated theoretical value is 0.06801 m.

Objectives

- Examining the stability of floating bodies, such as ships and submarines.
- Determination of the Meta Centric height for various heights of the center of gravity.

Sample Calculations

- The relation between Y and ȳ:

  $\bar{y} = \frac{y_1}{7.21} + A$

Where:

Ȳ: The height of G above the base (m). (92mm)

Y1: The height of adjustable weight above the base(m). (345mm)

A: The constant to be determined from the first measurement.

$$A = \bar{y} - \frac{Y1}{7.21} = 92 - \frac{345}{7.21} = 44.15$$

- The immersed Volume

$$V = \frac{mass}{Density\ of\ water\ (\frac{kg}{m^3})} = \frac{2.821}{1000} = 0.002821\ m^3$$

- The height of immersion

$$H = \frac{V}{LD} = \frac{0.002821}{0.3601*0.2018} = 0.03882\ m$$

- The distance between G and C

$$\overrightarrow{CG} = \bar{y} - H$$

- The rate of change in angle

$$\frac{d\theta}{dx} = \text{Slope of the curve X vs. } \Theta$$

- The distance between G and M:

$$\overrightarrow{GM} = \left(\frac{w}{W}\right)\left(\frac{dx_1}{d\theta}\right)$$

- The experimental distance between C and M:

$$CM_{Exp} = \overrightarrow{CG} + \overrightarrow{GM}$$

- Theoretical Distance between C and M:

$$CM_{Theo} = \overrightarrow{BM} - \frac{H}{2}$$

- Moment of inertia: I = $\frac{1}{12}$LD^3

$$I= \left(\frac{1}{12} \times \frac{306.1}{1000} \times \left(\frac{201.8}{1000}\right)^3\right) = 2.46607*10^{-4}\ m^4$$ -

- The distance between B and M: (BM) = $\frac{I}{V}$

- Sample Calculation for y_1= 105 mm

$$\bar{y} = \left(\frac{105}{7.21}\right) + 44.15 = 58.71mm$$

$$CG = 58.71 - 38.83 = 19.88mm$$

$$GM = \left(\frac{0.391}{2.821}\right) \times 374.13 = 51.855mm$$

$$CM = 19.88 + 51.855 = 71.74mm$$

Results

Table(1): Experiment Data

	position of jockey weight , X_1 (mm)						
Y_1 (mm)	-45	-30	-15	0	15	30	45
105	-6.8	-4.7	-2.3	0	2.2	4.5	7
165	-	-5.5	-2.5	0	2.7	5.3	-
225	-	-6.4	-3.2	0	3.2	6.6	-
285	-	-7.8	-4.2	0	4.3	8	-
345	-	-	-5.5	0	5.5	-	-

Table (2): Calculated data

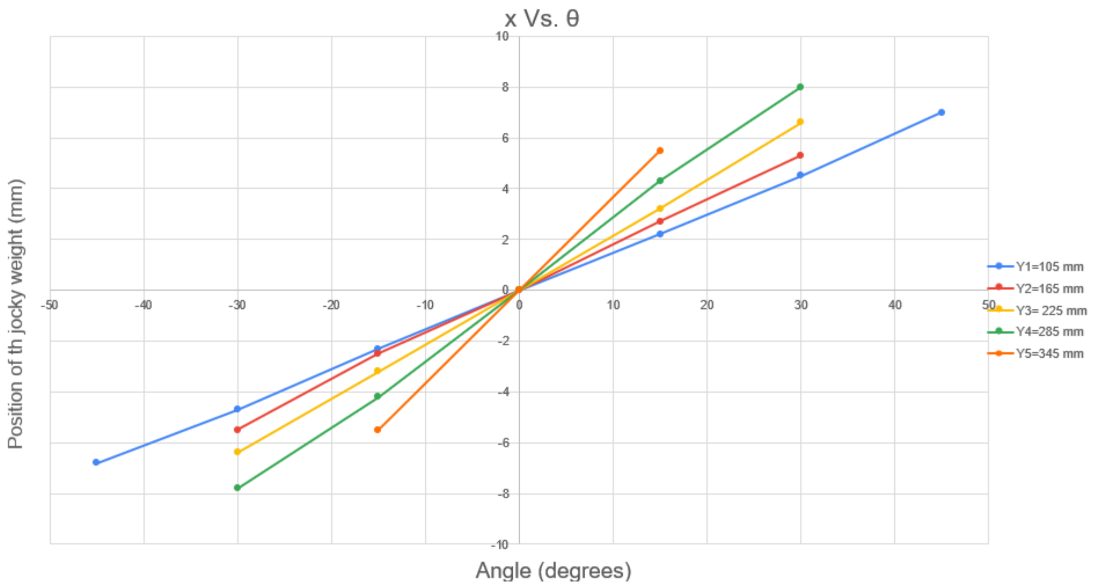
Y_1 (mm)	Ybar (mm)	CG (mm)	slope of dx/dΘ	GM(mm)	$CM_{experimental}$ (mm)	$CM_{experimental}$ (m)
105	58.713	57.132	374.1262242	51.855	108.987	0.108987
165	67.035	65.454	320.4347455	44.413	109.867	0.109867
225	75.356	73.776	265.2171949	36.760	110.536	0.110536
285	83.678	82.097	214.1217928	29.678	111.775	0.111775
345	92.000	90.419	156.2608514	21.658	112.077	0.112077
				Avarage	110.649	0.110649

Table (3): Theoretical results

I	0.000246606
H	0.0389233
BM	0.087418284
CB	0.019410146
$CM_{theoretical}$ (m)	0.068008137
$CM_{theoretical}$ (mm)	68.00813731

Table(4): Data given.

Total weight of assembly (kg)	2.821
Jockey weight (kg)	0.391
Breadth of pontoon (mm)	201.8
Length of pontoon (mm)	360.1
Approximate sin(θ) (rad)	θ
cos(θ	1



Figure(1): Jockey position (x) vs tilt angle in degrees (Ɵ) at the same graph for different jockey heights (y1).

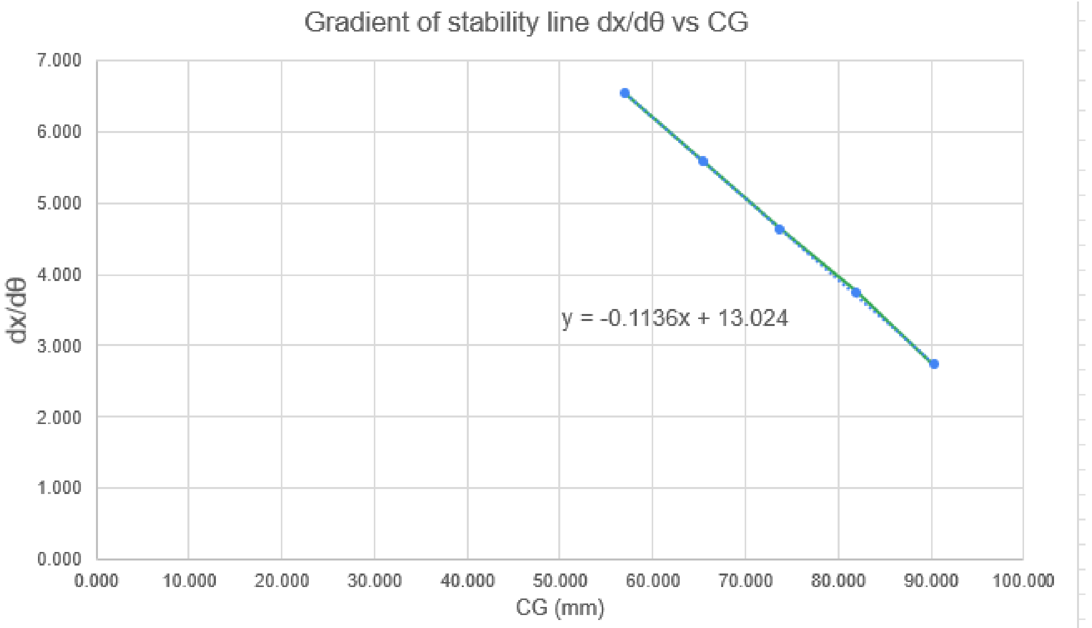


Figure (2): The gradient of stability line vs height of G above water surface

Discussion of the results

As noticed from (y), raising the height of the jockey weight results in an increase in the height of the center of gravity (G). this leads to decrease in the distance (GM), and the arrangement becomes more unstable.

A closer approximation of the linear equation can be made because there are more points to consider when the jockey weight is at its lowest height and the slope ($dx1 /d\boldsymbol{\theta}$) is at its maximum value. This is because lower jockey weight heights offer more stability, allowing for a wider range of tilt angles.

The CM values in Table 2 for the five readings are almost the same. As shown in Table 2, the average of these values was calculated to be CM average= 0.11065 m, and the theoretical value of CM was calculated to be 0.06801 m. The error in the experiment is due to an inaccurate reading due to the presence of air in the laboratory.

When the relation between the stability line ($dx/d\theta$) against the height of G was plotted in Fig 2, it can be noticed that the behavior of the trend is linear, and the relation is inversely proportional with a slope of -0.1136.

To answer the question of how the density of the liquid will affect the stability of the floating body it’s important to investigate the effect of the density of liquid on the different parameters considered in the determination of stability, such as the buoyance force, the height of metacenter, etc. when each of these parameters are studied independently on how it’s affected by the density of a liquid will help reaching a summary regarding this question.

Conclusion

The objectives of the experiment were achieved, where the stability of the pontoon was investigated through calculating the value of GM and CM at different heights of the jockey weight.

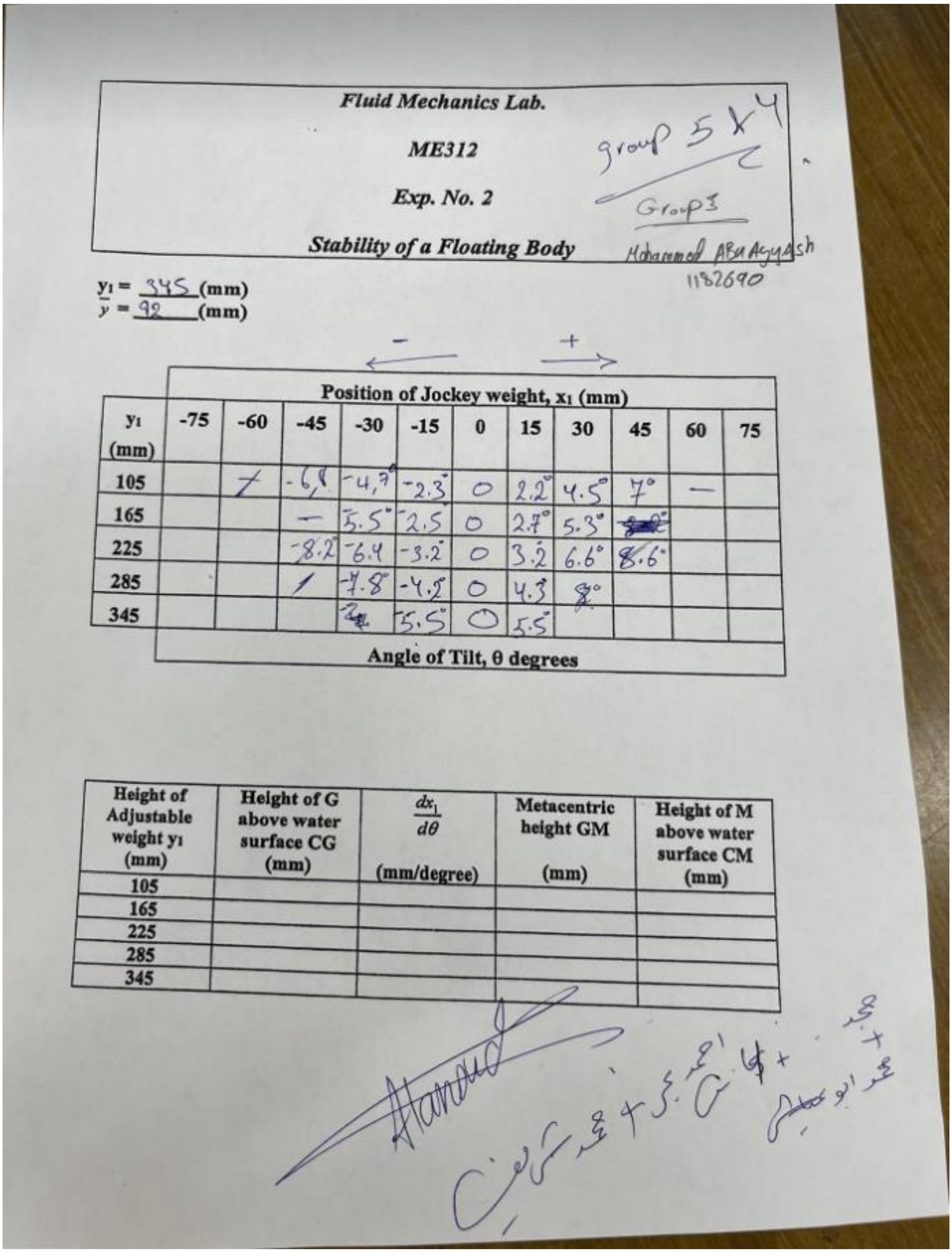
Two graphs were plotted one for the relation of the tilt angle and the jockey weight position, which was found to be linear and directly proportional, the other plotted graph was between the stability gradient and the height of G above the water level which was found to be nearly linear and inversely proportional.

Throughout the experiment the ponton is floating in the fluid (water) with changing the position of accompanying weight to the right and left for each y 1of pontoon (345,285,225,165 and105mm) the accompanying weight moved left and right about center line each move is 15mm until reached 75mm with this changing The change in tilt angle is observed. The results of this experiment can be used by designers to determine how stable bodies in water are and to determine the consequences of lowering the center of gravity (G). To restore the floating body to its stable form after it has been tilted by force, designers needed a restoring moment. During this process, the centroid of the displaced volume shifts due to a rotational disturbance, but G stays in place. Additionally, a wider body has more stability retention resistance.

References

- Fluid mechanics laboratory manual (2022, march).
- White, F. M. (1999, January 1). Fluid Mechanics.

Appendices



Fluid Mechanics Lab.

ME312

Exp. No. 2

Stability of a Floating Body

group 5 & 4

Group 3

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y_1 = 345 (mm)
$\bar{y}$ = 92 (mm)

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	Position of Jockey weight, x_1 (mm)										
y_1 (mm)	-75	-60	-45	-30	-15	0	15	30	45	60	75
105		/	-6,8	-4,7°	-2.3°	0	2.2°	4.5°	7°	—	
165			—	-5.5°	-2.5	0	2.7°	5.3°	[illegible]		
225			-8.2°	-6.4	-3.2°	0	3.2°	6.6°	8.6°		
285			/	-7.8°	-4.5°	0	4.3°	8°			
345				[illegible]	-5.5°	0	5.5°				
	Angle of Tilt, θ degrees										

Height of Adjustable weight y_1 (mm)	Height of G above water surface CG (mm)	$\frac{dx_1}{d\theta}$ (mm/degree)	Metacentric height GM (mm)	Height of M above water surface CM (mm)
105				
165				
225				
285				
345				