

MEEG 331 Incompressible Fluids Laboratory

Date Experiment Performed: 3

25,2908

Submission Date: Quote 9,2008

Objective: To test the theory of hydrostatics for force and pressure center on a submerged plane surface.

Background: This experiment is designed to illustrate hydrostatic pressure distributions and hydrostatic forces on plane surfaces.

Hydrostatic pressure distributions- in static fluids pressure varies only with vertical distances and
is independent of the shape of the container. The pressure is the same at all points on a given
horizontal plane in the fluid. The pressure increases with depth in the fluid.

 $P = pgy + P_{atm}$

Hydrostatic forces on plane surfaces- the fluid pressure acts normal to the surface of an object
and is positive in compression. Integration of the pressure over a submerged surface yields the
hydrostatic pressure force acting on the submerged surface. The resultant moment about a
specific point can be obtained from the calculated force and the center of pressure.

 $F_h = yh_{CG}A$

Equipment:

Torroid device- The torroid device consisted of a level, balance, weight hanger,. The balance was made up of the torroid, which was balanced so that the face of the torroid was vertical with no water present, and an area for mass to counter the moment caused by the hydrostatic force on the vertical face of the torroid.

Precision depth measuring device- A device that enabled us to take measurements of the height of the water, within a tenth of a millimeter.

Symbols Definitions: p = density g = gravitational constant y = vertical distance below the free surface.

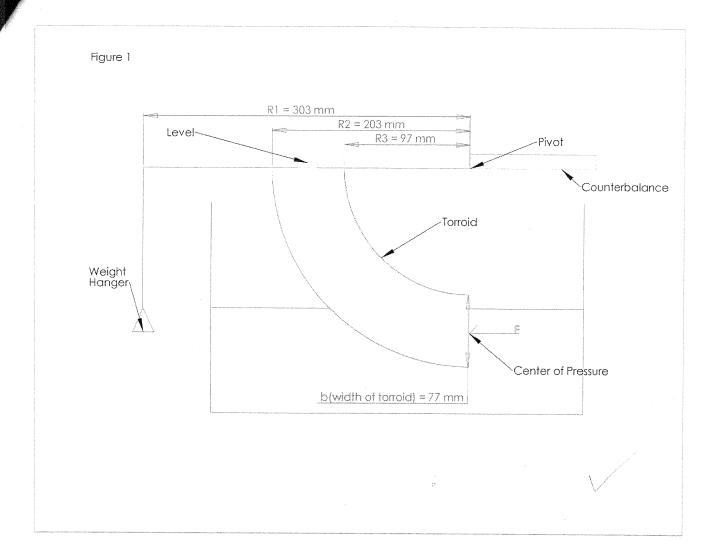
Fh = horizontal force on the plane. y = gamma = pg

 $\ensuremath{h_{\text{CG}}}\xspace$ = the distance from the surface to the plate centroid.

*See Figure 1 for schematic diagram. *

Procedure:

- 1. With the tank empty, we calibrated the balance arm so that the balance arm was horizontal.
- 2. We filled the tank so that the water level was even with the top edge of the torroid.
- 3. We then added mass to the balance to level the system again. We also recorded the level of the water. This level we set to a specific height so that all other measurements would relate to this first measurement.
- 4. We then chose an amount of mass to remove from the balance and removed it. Then we leveled the system by removing water from the system.
- 5. We repeated this step for the rest of the data points. Each time we tried to choose weights in order to get equal amounts of change in the water height.



Fluid Dynamics Lab 1: Incompressible Fluids Lab

able Measured Variable Force (N) Pressure (***) Mf. (NIM) Pressure (***		Measured	Data		Calculated	Data	
Water Height Mass on Scale 6 4,734 70.67 7,598 196,0 212 4,734 70.67 7,598 130,0 212 4,734 70.67 7,657 132.0 1,85 3,663 65,73 6,657 120,0 155 3,663 65,73 6,657 120,0 155 3,663 60.00 52803 120,0 155 3,663 60.00 52803 120,0 1,240 2,310 52803 41362 94,4 70 1,275 46.77 46.75 46.75 83.1 45 ,908 22.73 46.74 16.89 71.4 25 ,277 24.93 10.042 52,4 5 ,512 24.93 10.042 52,4 5 ,512 24.93 10.042 52,6 5 ,512 24.93 10.042		Control Variable	Measured Variable	Force (N)	Center of Pressure		MWann
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52, 8 5 133 12.53 12.62	6		52	,577			57 750.
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Other Measured Data:

Water Temperature	R1	R2	R3	q
22°C	30°8m	20,3cm	9.70m	26-17-68 1-4-14-68



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	Measured Data		70		Calculated Data	Data
Measurment Number	Height of Water (mm)	Mass on Scale (g)	Calculated height of water (mm^2) (mm)	Area (mm^2)	Force (N)	Center of pressure From Free Surface (mm)
-	140.0	212	106.0	8162.0	4.234	70.67
2	136,4	200	102.4	7884.8	3.951	58 27
es.	132,6	185	98.6	7592.2	3.663	65.73
4	124.0	155	0.06	6930.0	3.052	00.09
N	112.8	120	78.8	9.2909	2.340	52.53
9	102.6	06	9.89	5282.2	1.773	45.73
7	94,4	70	60,4	4650.8	1.375	40.27
8	83.1	45	49.1	3780.7	0.908	32.73
6	71.4	25	37.4	2879.8	0.527	24.93
10	52.8	5	18.8	1447.6	0.133	12.53

Relative Error Mf Relative Error Mw

0.059648083

0.062686343 0.068220854 0.0885876 0.094422088

0.073937031

0.149599212

0.276276701

0.118130675

0.057802327

	Ω						1		1	1	1	1					
	Relative Error Mf D	0.059648083	0.057803337	0.0735307 0.057686242	0.0674442 0.068220854	0.073937031	0.0885876	0.0433765 0.094422088	0.0358245 0.118130675	0.10042 0.07429 0.0261369 0.149599212	0.01486 0.0113436 0.276276701						
	Difference between Mf and Mw	0.0799191		0.0735307	0.0674442	0.41352 0.35658 0.0569392	0.0519887	0.0433765	0.0358245	0.0261369	0.0113436						
-	Mw (N*m)	0.70988 0.62996	0.5943	0.62326 0.54973	0.52803 0.46059	0.35658	0.31943 0.26744	0.20801		0.07429	0.01486						
	Mf (N*m)	0.70988	0.66722	0.62326	0.52803	0.41352	0.31943	0.25138	0.16954 0.13372	0.10042	0.0262						
	Center of pressure From Free Surface (mm)	70.67	68.27	65.73	00.09	52.53	45.73	40.27	32.73	24.93	12.53	>					
	Force (N)	4.234	3.951	3.663	3.052	2.340	1.773	1.375	0.908	0.527	0.133			998 kg/m^3	7.27		
	Area (mm^2)	8162.0	7884.8	7592.2	6930.0	9.7909	5282.2	4650.8	3780.7	2879.8	1447.6	_ i	Other Data	998 kg/m^	1000		
	Calculated height of water (mm)	106.0	102.4	98.6	90.0	78.8	68.6	60.4	49.1	37.4	18.8	>		Water Density Gravity			
	Mass on Scale (g)	212	200	185	155	120	06	70	45	25	5		22	303.0	203.0	97.0	0.77
	Height of Water (mm)	140.0	136.4	132.6	124.0	112.8	102.6	94.4	83.1	71.4	52.8	Other Measured Data	Water Temperature	R1	R2	R3	
				1	1	1	i	1	1	1	1						

	$y = 0.9094x - 0.0174$ $R^2 = 0.9996$				——— Linear (Data)		
Mf vs Mw							The state of the s
0,7	0.6	0.5	(X 0.4	A 0.3	0.2	0.1	*

8.0

2.0

9.0

0.5

0.3

0.2

0.1

Mf (N*m) 0.4

height of water 22-123-ho+ho=hw h= 140mm Area wh => 6. ha Fora Force

Painc A = painc (Rs 1/12/2016)

Pay ((122-123-150+h)/2)(12-123-150+h)(6) unit conversion from mamm F= PO(((t2-t2-100+1)/2)/1000)((12-t2-ho+h)(6))/1000) Center of Prossuce Nop hc+ bhw3 100 (R2-123-hoth) + 60(R2-123-no+h)? 2 (R) (R2-123-to-n) 16p = (R2-R3-ho-to) +(R2-R3-ho-to) 10p = 4(R2-R3-h0+b) => 2(R2-R3-h0+h)

MF = F x Ff = (no-no) = (R2-nw + ycp) F unit conversion from m=mm => (R2-nw+/cq)F Mw = FxFw

Mw = tz,mg

unit conversion from m = mm

Mw = Z, (m) 9

Difference between MF+MW MF-MW = BM

Error

· croors are unknown > M = X + Y

(DM) sup = DX + DY

MENTERM

Colodive arror:

$$\left(\frac{DM}{M}\right)_{SMS} = \frac{X+Y}{X+Y} = \frac{X}{X+Y} \left(\frac{X}{X}\right) + \frac{X+Y}{X+Y} \left(\frac{DX}{X}\right)$$

ME = XI+AX

MW = BI+DA

DR1 = DR2 = DR3 = Ob = t.5m

maggo <= mmo. == na

(1.5)

Discussion and Error Analysis

- There is a hydrostatic pressure force acting on the circular surface of the torroid. The equivalent force (equivalent to the distributed pressure loading on the surface) will act in a direction perpendicular to the curved surface of the torroid at the location through which it acts. By definition, the center of pressure will lie on this equivalent force's line of action. Geometrically, the curved surface of the torroid is an arc on which all the points are the same, constant radial distance from the hinge on which the torroid is mounted, similar to a circle. If the resultant force line from the hydrostatic pressure is normal to the surface of the torroid, it is also normal to a tangent line at the edge of the circle. Tangent lines of a circle always intersect radial lines extending to the point of tangency at a right angle. This means that the hydrostatic pressure force acting on the curved surface is coincident with the line extending from the hinge to the point where the equivalent hydrostatic pressure force acts. This means that the moment arm of this hydrostatic pressure force on the curved surface is zero, and therefore no moment is generated by the pressure force on the curved surface.
- One of the major sources of error is the inherent limitation of the measuring devices we used.
 For instance, the leveling bubble is a qualitative measurement of the angle of elevation relative to the direction of gravity. It is not certain that each trial found the same exact point of balance with only the use of that bubble level. We also used tools like rulers to measure the dimensions of the water level and the geometric properties of the torroid apparatus. Since these errors will cause variations in an unknown "direction" (ie positive or negative) they fall into the category of random error.
 - \circ The device used to measure the height of the water allowed us to accurately measure to one tenth of a millimeter. Therefore Δh = 0.05 mm.
 - The device used to measure the geometric properties of the system was accurate to the millimeter, therefore $\Delta x = 0.5$ mm.