RESEARCH ARTICLE OPEN ACCESS

Understanding Force: A Fundamental Concept in Physics

Prof.Shirsath K.B.*, Jadhav Nikita*, Gundechha Nutan.*, Gawali Vaishnavi.*,Gerange Swapnil*,Jadhav Sahil*,ghule sakshi*,Gunjal Suraj*

*(Civil Engineering, ATC Chas, Ahilyanagar
Email: kavitashirsath2020@gmail.com)
** (First year students, ATC Chas, Ahilyanagar
Email: ygawande062@gmail.com)

--************************----------------------------------

Abstract:

Buoyancy and hydrostatics are important concepts in fluid mechanics and engineering applications. Archimedes' Principle states that the buoyant force acting on an immersed body is equal to the weight of the displaced fluid. However, different interpretations exist regarding how buoyancy acts on submerged bodies. This paper discusses the validity of Archimedes' Principle and explains how hydrostatic pressure and effective forces influence submerged objects such as pipes and risers. The study also highlights the relationship between buoyancy, pressure distribution, and effective tension. The results support the conclusion that buoyancy develops over the complete volume of a submerged body and not only due to pressure acting on the bottom surface.

Keywords: Buoyancy, Hydrostatics, Archimedes' Principle, Effective Force, Pressure, Fluid Mechanics

----------------------------------*************************--------------------------------

1. Introduction

Buoyancy is one of the most fundamental concepts in fluid mechanics. More than 2000 years ago, Archimedes introduced the principle that the buoyant force on a submerged object equals the weight of the displaced fluid. This principle is widely used in engineering, ship design, offshore structures, and marine mechanics.

Despite its acceptance, there are still debates regarding the exact origin of buoyancy forces. Some researchers argue that buoyancy acts only when hydrostatic pressure is applied on a flat bottom surface, while others support the classical Archimedean view that buoyancy acts throughout the submerged volume.

This paper explains the concept of buoyancy and hydrostatics using effective force theory and mechanical analysis. The study also demonstrates the importance of hydrostatic pressure in submerged pipes and cylindrical structures.

2. Archimedes' Principle

Archimedes' Principle states that the buoyant force acting on a body immersed in a fluid is equal to the weight of the fluid displaced by the body.

$Fb=\rho gV$

Where:

- Fb = Buoyant force
- ρ = Density of the fluid
- g = Acceleration due to gravity
- V = Volume of displaced fluid

This principle explains that whenever an object is partially or completely immersed in a fluid, it experiences an upward force called buoyant force, which is equal to the weight of the displaced fluid.

3. Hydrostatic Pressure

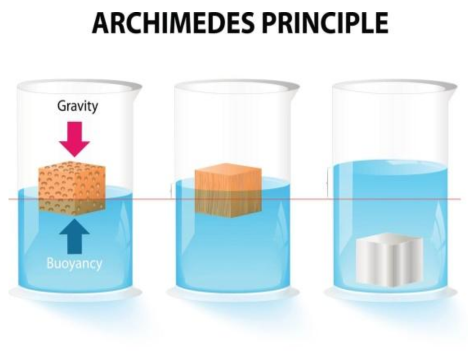
Hydrostatic pressure increases with depth because of the weight of the fluid above the object. The pressure equation is:

$P= \rho gh$

Where:

- P= Hydrostatic pressure
- ρ = Fluid density
- g = Acceleration due to gravity
- h = Depth below the fluid surface

As depth increases, the pressure acting on submerged bodies also increases.



4. Effective Tension in Submerged Pipes

For submerged pipes and risers, effective tension is influenced by hydrostatic pressure and buoyancy. The effective tension equation is:

$T_e = T_{tr} - p_i A_i + p_e A_e$

Where:

- T_e = Effective tension
- T_{tr} = True tension
- P_i = Internal pressure
- p_e = External pressure
- A_i= Internal area
- A_e = External area

This relation shows how internal and external pressures affect the stress in submerged structures.

5. Force Balance in Hydrostatics

The balance of forces in a submerged vertical pipe is represented by:

The equilibrium equation for a fluid element is given by:

$T_1 + p2A = p_1 A + w + T_2$

Where:

- T_1 = Tension at the top
- T_2 = Tension at the bottom
- p_1, p_2 = Hydrostatic pressures
- A = Cross-sectional area
- w = Weight of the fluid element

This equation represents the balance of forces acting on a fluid element in static

6. Results and Discussion

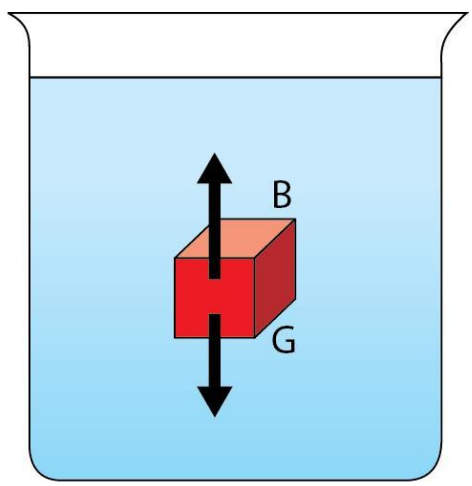
The study shows that buoyancy acts throughout the submerged body volume rather than only at the bottom surface. External hydrostatic pressure creates effective axial tension in submerged cylinders and pipes.

The analysis also confirms that:

- Buoyancy is proportional to displaced fluid volume.
- Hydrostatic pressure increases with depth.
- Effective tension is important in marine risers and offshore engineering.
- Submerged structures experience both pressure stress and buoyant force simultaneously.

The experimental observations support the full validity of Archimedes' Principle.

7. Diagram of Buoyant Force on a Submerged Object



1) Explanation of the Diagram

- B represents the Buoyant Force acting upward.
- G represents the Gravitational Force (Weight) acting downward.

When an object is placed in a fluid:

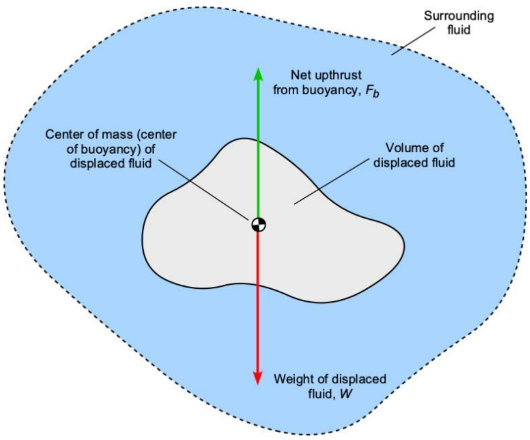
- The fluid exerts an upward force called buoyant force.
- The object's weight acts downward due to gravity.

2) Conditions

1. If B>G
   The object floats upward.
2. If B=G
   The object remains suspended in equilibrium.
3. If B<G
   The object sinks.

3) Archimedes' Principle

$F_b = \rho g V$



4) Explanation of the Diagram

- The gray object is completely immersed in the surrounding fluid.
- The fluid displaced by the object creates an upward force called buoyant force.

5) Forces Acting on the Body

- Upward Green Arrow Fb)
  Represents the buoyant force (upthrust) acting upward.
- Downward Red Arrow (W)
  Represents the weight of displaced fluid acting downward.

6) Center of Buoyancy

- The marked point represents the center of buoyancy.
- It is the center of mass of the displaced fluid.
- The buoyant force acts through this point.

Conclusion

This paper explains the importance of buoyancy and hydrostatics in fluid mechanics and offshore engineering. The study confirms that Archimedes' Principle remains fully valid and that buoyancy depends on the weight of displaced fluid.

Hydrostatic pressure produces effective forces in submerged structures, and these forces are important in the analysis of marine risers, pipelines, and floating bodies. The findings demonstrate that buoyancy acts throughout the complete submerged volume and not only due to pressure acting on a flat bottom surface.

References

1. Archimedes – Principle of Buoyancy.
2. Fluid Mechanics textbooks and engineering references.
3. Nergaard, A. *The Magic of Buoyancy and Hydrostatics – Buoyancy and Effective Forces*, Modern Applied Science, 2017.
4. Sparks, C. P. *Fundamentals of Marine Riser Mechanics*.
5. Research studies related to hydrostatic pressure and buoyancy analysis.