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SELF BALANCING MECHANISM FOR UNDER WATER CRANE LOADING AND GRIPPING SYSTEM

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Abstract – *The Objective of this paper is to design a underwater mechanism which can increase stability of submerged bodies in any liquid medium. It is especially designed for dynamic system, taking into account the buoyancy forces and Metacenter where in the loading significantly varies and also the velocity of the body affects the condition of the system. The mechanism consists of wires which are carrying the load using the crane principle. It can also be used in the air for grasping varying sized objects and ensuring the correct position of center of gravity. Hence, the portability will become much easier in the absence of unbalanced torques and moments. The mechanism is being operated by a pulley and passing through fixed supports. The distribution of tension in the supporting wires is basically responsible for giving the stability.*

Key Words: Buoyancy, Metacenter, Metacentric height, Stability conditions of bodies, pulley, fixed support.

1.INTRODUCTION

When an object is grasped underwater, it affects the balancing of the forces resulting in unbalanced torques and moments. The Buoyancy force acts at the centre of the gravity of the displaced volume of the fluid. Based on its relative position with the centre of mass of the system, the system can either be in stable equilibrium or neutral equilibrium or unstable equilibrium. Once these moments are of high magnitude it becomes extremely difficult to transport the grasped object and can even damage the functionality of the system.

1.1 Forces acting on the Submerged Bodies

Buoyancy force (F_b): When a body is immersed completely or partially, the upward force exerted by displaced fluid on the body is called buoyancy force.

Archimedi's Principle: When a body is in equilibrium (completely or partially immersed), the buoyancy force on the body is equal to the weight (W) of the body.

$$F_b = W$$

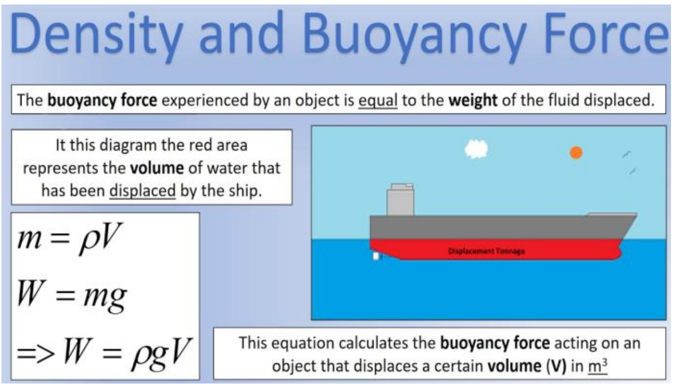

Fig 1 : Buoyancy Force vs density of fluid

Weight of the fluid displaced = weight of the body

ρ_f x g x submerged vol = ρ_b x g x volume of the body

Where, ρ_f = density of the fluid
g = acceleration due to gravity
ρ_b = density of the body

therefore, **ρ_f x submerged vol = ρ_b x volume of the body**.

Note : Buoyancy force (F_b) depends on
Type of fluid (ρ): ρ increases => F_b increases
Volume of fluid displaced :
a)ρ = constant , submerged volume increases F_b increases
b) F_b = constant => $\rho_1 h_1 = \rho_2 h_2$ i.e. if $\rho_1 > \rho_2 \Rightarrow h_2 > h_1$.

1.2 Centre of buoyancy (B)

The point of application of buoyancy force on the body is called centre of buoyancy.
'B' always acts at the "Centroid of volume of fluid displaced".
Note:
1) When body is floating at the interface of two immiscible liquids,
$W = F_{b1} + F_{b2}$.
2) Exact weight of the body can be obtained when measurement is done in atmosphere because F_b of air ≈ 0.
3) Archimedes principle at the equilibrium condition (immersed or floating) is $W = F_b$.
4) Non – Equilibrium condition, $F_{net} = | F_b - W |$.

1.3 Metacenter

The point about which the floating bodies make oscillations is called metacenter. Or the intersection of point of normal axis and the line of action of buoyancy force is called metacenter.

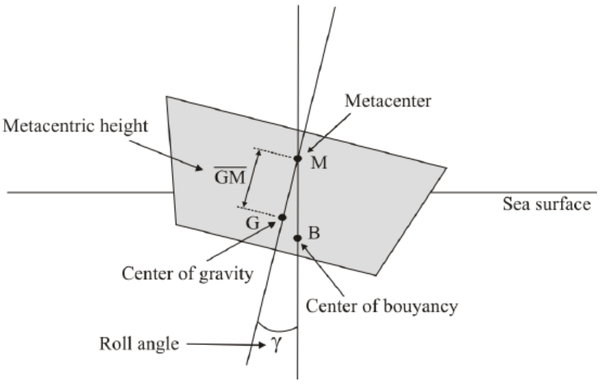

Fig 2 : Metacenter

Metacentric height (GM): It is the distance between the centre of gravity (G) and the Metacenter (M).
GM is used in design of floating bodies .

1. Analytical method for measuring GM :

Metacentric radius (BM) is the ratio of moment of inertia of top view to that of volume of fluid displaced.

$$BM_T = \frac{I_T}{\nabla} = \frac{\frac{LB^3}{12}}{LBT}$$

$$= \frac{B^2}{12T}$$

In most of the cases the failure occurs in the rolling motion, therefore moment of inertia of the top view is considered. For design point of view, least moment of inertia is considered.

GM = BM – BG

Meta-Centric Height

2. Experimental method for Meta-centric Height

$$GM = \frac{w_1 d}{W \tan\theta}$$

Here W = Weight of vessel including
G=centre of gravity og vessel
B=centre of buoyancy
w_1 =movable weight
d=distance between movable weight

2. WORKING MECHANISM

The system is stabilized vertically underwater. Initially a dead weight is attached at the bottom of the system to stabilize the self weight and small loads. It keeps the centre of buoyancy above the centre of gravity and thus resulting the system to be stable.

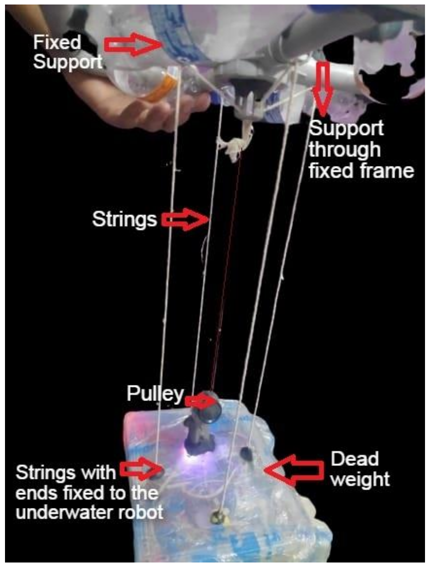

Fig 3: Working model

There is a fixed frame, which is floating above the water. This frame provides vertical support to the system. As shown in the figure, the connections are made with the string, one end of which is permanently fastened to the system and the other end passes through a hook in the fixed frame. These strings are uniformly distributed, four in this case. All the free ends of the strings are passesd through a loop and tied together. And this is connected to the pulley.

While fastening the strings on the system, their length is chosen such that the desired horizontal orientation is achieved. Hence, initially we calibrate the inclination according to our requirements.

Now when the pulley is rotated, say clockwise, the string wraps on the pulley. The effective length of the system decreases and the system moves vertically upwards. Opposite is the mechanism for moving it downwards.

To achieve stability in case of non axial loading, the system utilizes unbalanced moments and torques. Since the strings are fastened at one end and the other end of the strings are tied together at the centre of the support, at any instant the effective length between supports of the string is always constant. This results in development of varying tension in the strings and nullifying the generated moment. At any instant, the system is parallel to the calibrated position and thus transfer of materials is made easy without damaging the system.

3. ADVANTAGES AND CHALLENGES

3.1 Advantages

- Automatic balancing without the need of feedback and control systems

- Accurate and precise functioning

3.2 Challenges

- System needs to be optimized for high flow conditions.
- As the depth increases the stability decreases drastically.
- The length of strings acts as obstacles for the surroundings.

3. CONCLUSIONS

- The system is able to approximately balance the added non co-axial load.
- A small error is introduced because of shifting of the position of the tied hook knot, which effectively varies the individual length of the string between fixed supports.
- The system is further stabilized by increasing the number of parallel strings (from 4) due to better load distribution.

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