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THE STABILITY ANALYSIS OF HYDROFOILS BOATS

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Abstract:*The lateral and longitudinal stability of hydrofoils which have an important interstice at the speedy boats market and especially used widely at the seas without wave beyond last years is analysed in this paper. The stability of hydrofoils especially for Surface Piercing types is important for the passenger and security of the cargo because of not having wet surface area when they cruise at high velocities on their foils at hard sea conditions.*

Keywords*: hidrofoils boats, lateral stability, longitudinal stability*, *Automatic Control System, the metasantric point*

Introductıon

The water resistance that frustrates the movements with the increasing speeds of the ships which cruise at the water surface and also engine powers those will provide speed enlarge in this case. The researches are directed to alterations of underwater forms and sliding type keeve forms are developed. But the navigation and the movements among the waves of those types of ships shows higher resistance according to other low speed boats and the desired goals are not be reached in this situation. So the researches are directed to keeve types those move out of the water and worked on Hovercrafts as an alternative so that to make the disadvantage of ships those cruise at the water disappear.

The hydrofoils those their lateral and longitudinal stability will be analysed are types of ships which move with principal of profile hydrodynamics and also cruising on the hydrofoil that makes the ship's keeve raise over the water by lifting force effect with the increasing speed.

There occurs a lifting force "L" on the hydrofoils as a result of cruising with a speed "V" and this lifting force varies with the square of the speed (V^2). Increasing the speed, lifting force will increase in this case and it will come to a point that lifting force will be equal to weight of the ship. The ship cruises out of the water completely on hydrofoils at this point. The water resistance of the ship will be the resistance of hydrofoils those are in the water and a decreasing value is observed according to ship's resistance.

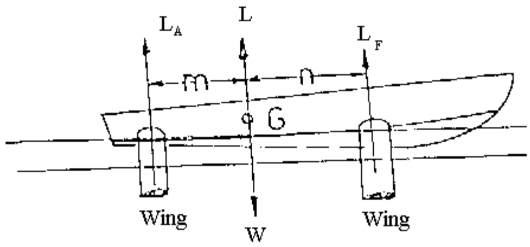

Fig. 1 The forces on the ship

The ımportance of stabılıty at hydrofoıls

Reaching very high velocity is the biggest priority of hydrofoils according to those velocities at hard conditioned seas. It is not really easy to calculate the effects to stability such as the geometry of hydrofoil profiles, free water surface, lifting force divergence on the hydrofoil, center of gravity due to the hydrofoils and etc. The most important problem of the hydrofoils is the stability because of this reason.

But it is a fact that hydrofoils have more navigation ability according to displacement ships. Because the hydrofoils are above the water surface and the waves can't effect the ship and the velocity losses decrease.

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The explaination of notations those will be used in stability of hydrofoils:

GZ - Rectyfing moment arm
W - Total weight of ship
L - Total lifting force
C_L - Lifting force coefficiency
S - Wet surface area
ρ - Massive density of water
V : Ship velocity
AR - Side ratio
b - Profile width
c - Cord lenght
GM - Lateral metasantric level
θ - Curvature angle of ship bottom
φ - Wing curvature angle
KG - Distance between centre of gravity and base line
M_{st} - Moment of stability
L_F - Lifting forces of fore wing
L_A - Lifting forces of aft wing
M - Total moment
M_F - Lift moment of fore wing
M_A - Lift moment of aft wing
M_D - Resisting forces moment of wing
M_T - Impeller thrust force moment

Lateral stability

While examining the lateral stability of hydrofoils the methods those are generally used for conventional type ships, metasantric level for begining stability and GZ curve at inclined position may be taken as criterion. The explanations for V sectioned Surface Piercing type hydrofoils at Fig. 2.

Naturally if the center of gravity is not at so high there is lateral stability at the Surface Piercing hydrofoils.

Changing the velocity or cruising among the waves the hydrofoils area changes in the water. If the lifting force is reduced because of any reason the ship sinks a little bit and the hydrofoil area that gets in to the water assures the addition lifting force which is needed.

If "b" is the sinking witdh:

$$W = L = \frac{1}{2} \cdot C_L \cdot S \cdot \rho \cdot V^2 = \text{constant} \qquad (1)$$

$$AR = \frac{b}{c} = \frac{b^2}{S} = \text{constant} \qquad (2)$$

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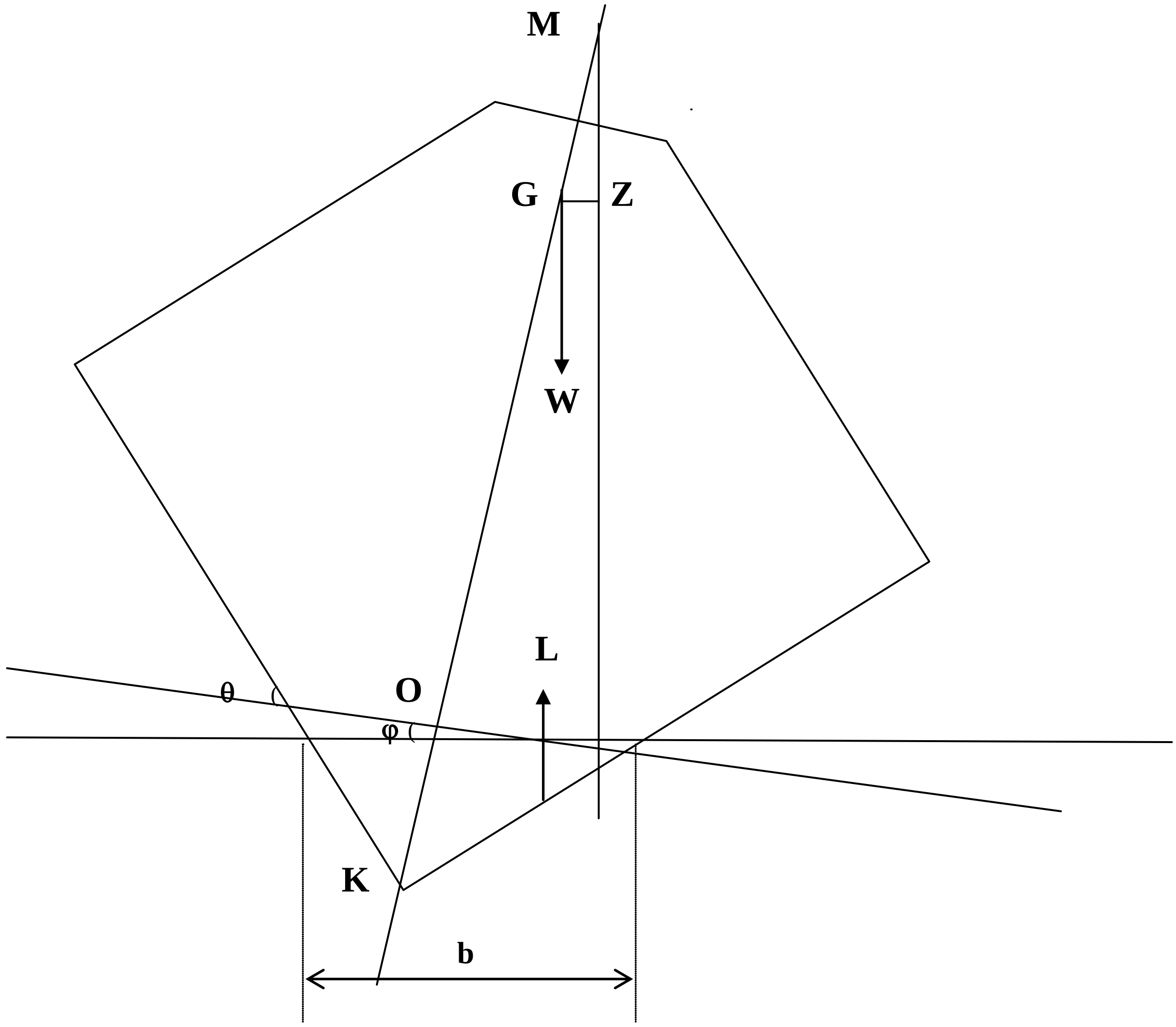

Fig.2. The stability of ships with V sectioned Surface Piercing

Begining stability,

$$GM = \left(\frac{b}{2}\sin\theta\right) - KG \quad (3)$$

Metasantric level,

$$GM_{\varphi} = \left(\frac{b\cos 2\varphi}{\sin 2\theta}\right) - KG\cos\varphi \quad (4)$$

Rectification moment arm,

$$GZ = \left(\frac{b\sin 2\varphi}{\sin 2\theta}\right) - KG\sin\varphi \quad (5)$$

Stability moment,

$$M_{st} = W \cdot GT \quad (6)$$

Stability moment at narrow angles,

$$M_{st} = W \cdot GM\sin\varphi \quad (7)$$

Sottorf, Weining and Wladimirow have been interested in and studied on the stability reducing effect of free water surface.

Enlarging the wing curvature angle, the lifting force due to the stability on the gets reduced. The most wing curvature angle is 28 and 30° [1].

The free water surface effect must be taken while calculating the approximate value of metasantric level.The metasantric point and GZ curve is calculated for each hydrofoil at ships having double hydrofoil and the resultant is defined with those. It is clear that the stability of Fully Submarged Hydrofoils is an important problem when hydrofoils are examined in two main headlines as Surface Piercing and Fully Submarged Hydrofoils. But the Fully Submarged Hydrofoil systems are better systems than the Surface Piercing Hydrofoil systems.

The ship can cruise at higher velocities among the waves with this system. But there must be an automatic control system which is working with the signals that is given by a mechanic, electronic or ultrasonic water surface tracer [2].

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Automatic Control System (ACS) controls all the movements of the moments during rising, descending and foilborne.
Beside equilifying the rolling and pitching movements the automatic control system ensures regular cruising of the ship among the waves.
The foundation of automatic control system relies on the feedback control. The height of the ship from water, the movements and the accelerations are perfected with sensors and then they are confronted with the design values. The differences are utilized by electronic control computer and gives orders to hydraulic servo actuating system at the arranging direction of ship's movements. Actuating system actuates the mechanic connections of the flaps and the ships goes on cruising at desired conditions.
Separately automatic control system percepts the waves with its sensors and makes ship cruising over the wave profile by controlling the flaps. All kind of movements like rolling and pitching are annihilated by this system. The turning of the hydrofoil is being with pitching while it is on the foils. The centrifugal force that is needed for turning is obtained from changing the lifting force as a result of the movements of flaps before. The preventing of excessive axial forces and foils raising over the water is ensured by the automatic control system which controls the flaps.
As a result the continuty of stability is not possible without automatic control system at hydrofoils. The flow chart of automatic control system is shown at Fig.3.

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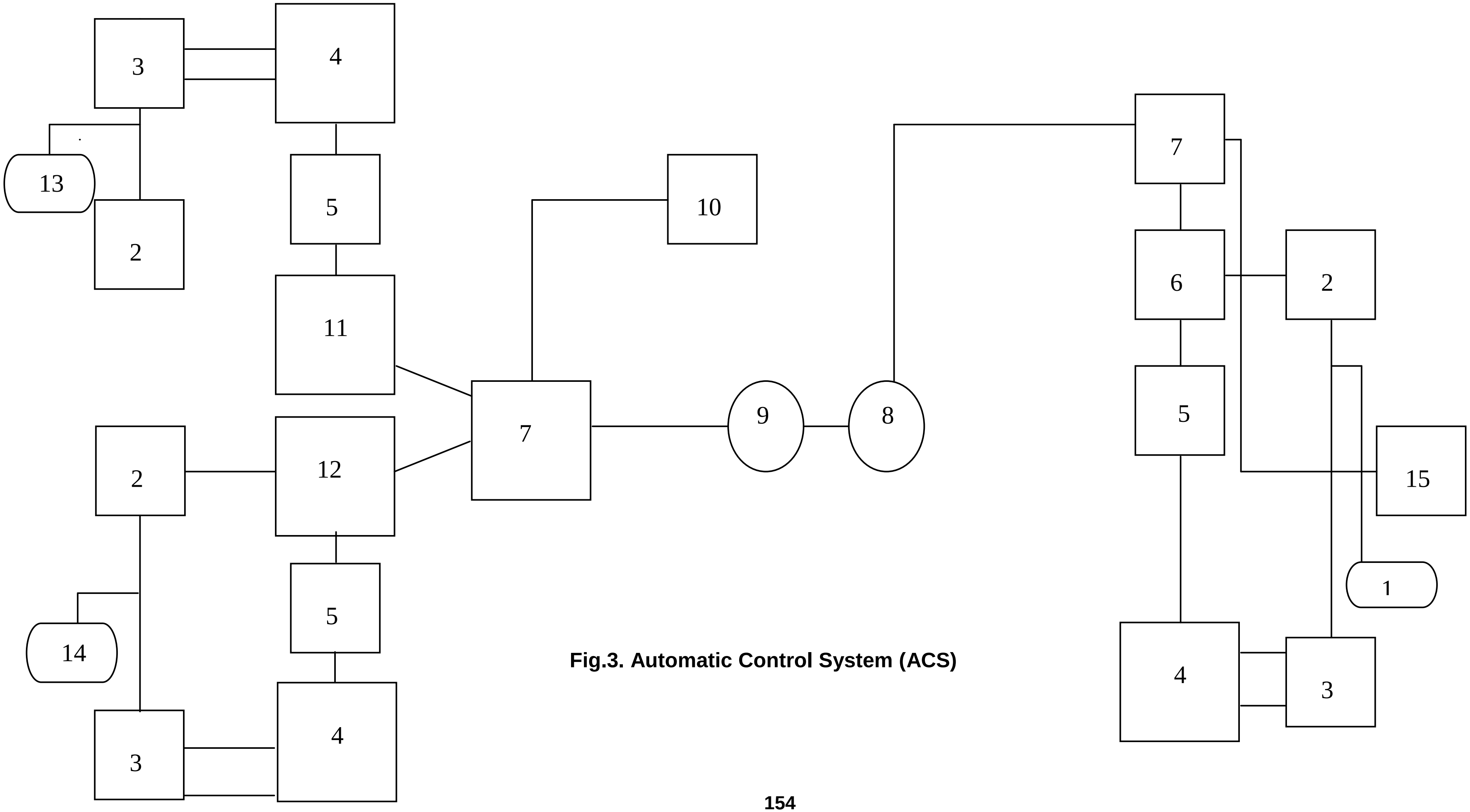

Fig.3. Automatic Control System (ACS)

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The formıng elements of automatıc control system

1. Forward flap
2. Position Feedback Transducer
3. Hydraulic Ram
4. Servo Valve
5. Flapper Control
6. Forward Control Amplifier
7. Pre-Amp and Lag Circuit
8. Pitch Gyro
9. Roll Gyro
10. Vertical Accelerameter
11. Port Control Amplifier
12. Standart Control Amplifier
13. Port Flap
14. Standart Flap
15. Height Sensor

Longitudinal stability

It is not wanted of hydrofoils making trim more than a few degrees during the cruising on the foils. The change in foil profiles angle of attack due to change of lifting force and reducing of velocity because of increasing resist is the reason of this sensivity. And so much change in angle of attack is not permitted not to get into the cavitation area because of high velocities [3].

The changing of influence point of lifting force and the dynamic effects of rolling may be neglected at longitudinal stability calculations. If the center of gravity is accepted as it is constant the longitudinal stability is connected with wings angle of attack and foil area.

Distribution of the charge on the foil affects the longitudinal stability within a big ratio.

For a ship with two transporter legs,

$$\sum L = L_A + L_F = W \tag{8}$$

Total moment,

$$\sum M = M_F - M_A - M_D + M_T = 0 \tag{9}$$

$$M_T \cong M_D \Rightarrow \sum M = M_F - M_A = nL_F - mL_A \tag{10}$$

Here n and m are the distances from center of gravity,

$$GZ = \frac{\sum M}{\sum L} = \frac{\sum M}{\sum W} \tag{11}$$

If the metasantric levels those are given from fore and aft foil profiles are different;

$$GM = \left(\frac{GM_A L_A + GM_F L_F}{L_A + L_F} \right) \tag{12}$$

Pitching depends on the relation between two profiles characteristics for short wave lenghts at the situations when the center of gravity is in the middle. The ship losses her stability when the reaction of the forward profile with waves and sinking amount is little[4].

CONCLUSION

Last years we see the hydrofoils especially the Fully Submerged types more often at maritime lines because they are being preferred for their advantages of lateral and longitudinal stabilities. Taking place at ship building industry so fast the developments of the control systems technology has been excited the stability in additional way and the minimum values
of pitching and angle of inclinasion are reached in this way. As a result reaching a quality level of cargo security and passenger comfort the hydrofoils have became a good alternative to Hovercrafts.

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