한국해양공학회 2000년도 추계학술대회 논문집 PP. 210~215

좁은 수로나 근접한 해안구조물에서의 선박 도선에 관한 연구

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A Study about Guiding of Ships Through the Narrow Channels an(Near Waterside Structure

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KEY WORDS: Perforated pipe 구멍이 형성된 파이프, Eddy roller 와류, Kinetic energy 운동에너지, Potential energy 위치· Hydrodynamic pressure 유체동역학적 압력

ABSTRACT: Presently, one or several tugboats guide a ship in the port or canal, during the ship's engines and steering mechanism kept idle. This method has insufficient ability keeping the ship on course, danger of collision with waterside structures, tugging preparation time consuming, as well as the need expending substantial resources to acquire and maintain tugboats and associated facilities. Therefore, a new technology and system for ship's guiding to be needed and introduced instead of traditional guiding and tugging system.

1. Introduction

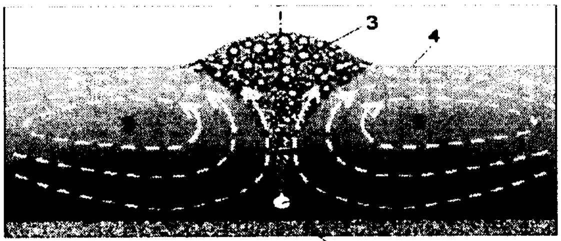
Big ships are usually guided by tugboats in the narrow waterway and crowded harbor, but they only depend on the experience of pilot for guiding them without technically developed ship's guiding equipment for the ship or data of seaway conditions, so many accidents and troubles are occurred often. There are also many people and tugboats required guiding big vessels into the harbor. Most harbors have a problem of ship's arrival and departure because it takes too many times for tugging and mooring the vessels. On the condition of fog, heavy rain and snow, it is very hard to maneuver the ship by using tugboats or guiding equipment. This weather condition restricts the vessel's in and out on time and delays the time for discharging and loading cargo.

Therefore, a new technology and system for ship's guiding to be needed and introduced instead of traditional guiding and tugging system.

2. Principles of the Ship Guiding Technology

This method is based on separation of two functions, fore-and-aft movement of the ship and keeping it on course. By using ship's engines with idle steering mechanism, fore-and-aft movement of the ship through narrow spots is executed at slow speed. A special device on the narrow spot guaranteed the ship staying on course. A description of this technique as below, which is based on a physical principal of interaction of solid body.

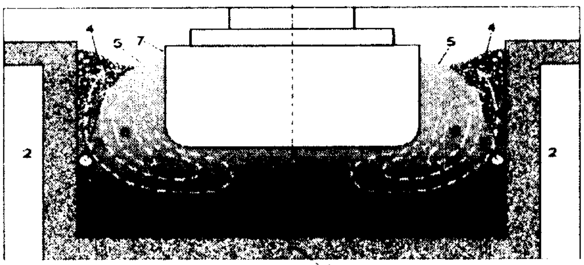
When the air is discharged into the water through a perforated pipe, aerated liquid zone is created, where the air bubbles entrain water because of bubble buoyancy as they aspire to the surface, thus forming a ridge as shown in Figure 1, General physics [2]. The air bubbles burst into the atmosphere on the surface, while entrained water is moving away from aerated zone. In the process two eddy rollers are formed as below.



1 – seabed, 2 – perforated pipe, 3 – aerated zone, 4 – free surface of the water, 5 – eddy motion of the water (arrows show direction of motion, dotted lines – lines of equal velocities).

Fig. 1

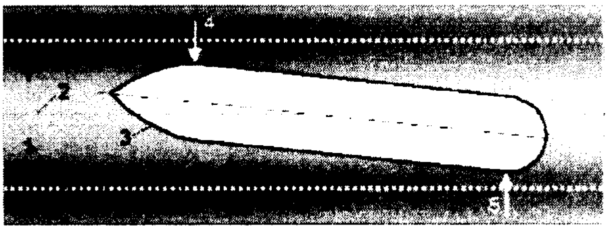
Guiding a ship from two perforated pipes, the air is discharged that are set in parallel or at a slight angle to one another at a distance slightly exceeding maximum ship width. Between the perforated pipes two symmetrical eddy rollers are formed. The kinetic energy of water movement transforms into potential energy of hydrodynamic pressure on ship's hull when ship moves between two eddy rollers, as shown on Figure 2. When this pressure increases the ship moves closer to the ridge and forms aerated zone



1 – seabed, 2 – wall, 3 – perforated pipe, 4 – aerated zone, 5 – free surface of the water, 6 – eddy motion of the water, 7 – ship hull.

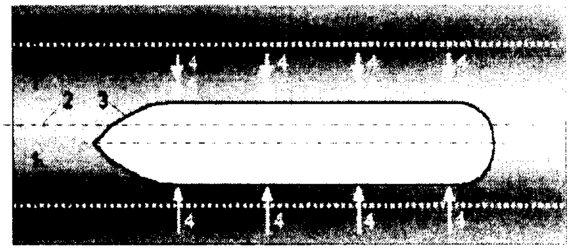
Fig. 2

When the ship stays on course, the pressure on both sides is balanced as below. If the ship deviates from its course as shown on Figure 3, the side pressure closer to eddy roller rises, while the pressure on the opposite side decreases as shown on Figure 4. In order not to deviate the ship, the speed of ship must not grater than the acceleration of gravity on the curvilinear course. This action makes the ship to stay on course. Due to increase in pressure, the reaction to deviate from the heading has greater magnitude for big ships. Therefore, piloting is dependably ensured by applying this system.



1- perforated pipe, 2- axis of the ship guiding system, 3 - ship hull, 4 - horizontal component of the resultant pressure on the right board, 5 - the horizontal component of the resultant pressure on the left board

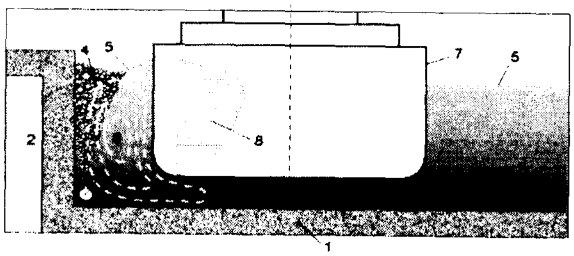
Fig. 3



1 - perforated pipe, 2- axis of the ship guiding system, 3 - ship hull, 4 - horizontal components of the resultant pressure on the ship boards, 5 - horizontal component of the resultant wind pressure on the right board

Fig. 4

The air is discharged under pressure in front of the structure when the ship moves near a waterside structure. It protects the ship from bumping to the waterside structure as shown on Figure 5. For the mooring, after the ship stops the air is cut off and lines are tie down.



1 – seabed, 2- wall, 3 – perforated pipe, 4 – aerated zone, 5 – free surface of the water, 6 – eddy motion of the water, 7 – ship hull, 8 - diagram of horizontal component of hydrodynamic pressure
The wall provides better influence of aerated zone on ship than in the open waters.

Fig. 5

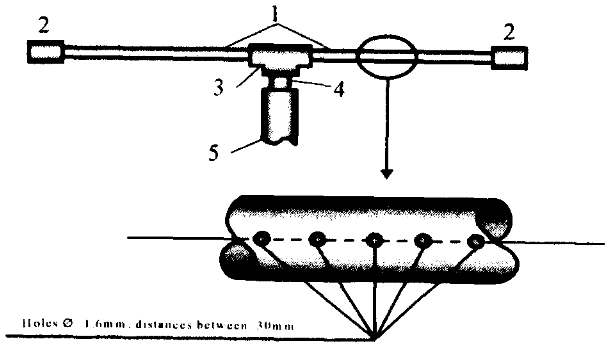
3. Model Test

For verification of the new technology, demonstration test, sponsored by the Brain Korea 21, was performed by using the Chosun university experimental facilities. This test configure ability of the new method to control ship motion at the following realistic situations in an actual harbor area.

1. To keep straight course with idle steering mechanism.
2. To keep straight course with idle steering mechanism under wind action.
3. To keep curvilinear course with idle steering mechanism.
4. To keep curvilinear course with idle steering mechanism under wind action.
5. To pass a waterside structure in a harbor's narrowness with idle steering mechanism.
6. To pass a waterside structure in a harbor's narrowness with idle steering mechanism under wind action.
7. Mooring.
8. Mooring under wind action.

This test was performed at the Chosun University and it has excellent condition, which is a tank (Length × Beam × Depth=7.5m × 3m × 0.35m). It simulates a narrow and crowded harbor. High speed planning hull type Ship model (Length × Beam=0.88m × 0.2m) has motor, propeller, remote control system, and power supply without idle steering mechanism.

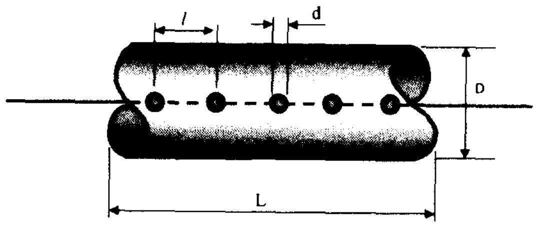
Typical section of the perforated pipe is shown in Figure 6. Estimates show the pipe diameter is 1", the diameter of holes is about 1.6mm and the distance between holes is about 30mm.



1 - Plastic pipe with inner diameter 1"
2 - End gag
3 - T-joint
4 - Socket of hose
5 - Hose with inner diameter 1"

Fig. 6

Size of hole and distance between pipes are considered as following formula.



l - Length between holes
d - Diameter of hole
D - Inner diameter of pipe
L - Length of pipe

Fig. 7

The total length of the pipe, L, may be presented as follows.

$$(l+d)n=L \quad \text{-------------------- (1)}$$

Where l is the 30 mm, d is the 1.6mm.

The number of perforated holes, n, of the pipe to be decided as follows.

By using (1), number of perforated holes, n, is

$$n=\frac{L}{l+d} \quad \text{------------------------ (2)}$$

The following expression for a perforated pipe must be satisfied:

$$\frac{\pi}{4}D^2 \geq n\frac{\pi}{4}d^2 \text{-------------------- (3)}$$

It, (3), shows that the area of pipe must be greater than total area of perforated holes.

Then, the minimum distance between holes to be as it shown below.

$$\frac{L}{l+d}d^2 < D^2 \quad \text{--------------------- (4)}$$

$$Ld^2 < D^2(l+d)$$

$$Ld^2 - D^2d < D^2 l$$

$$L\frac{d^2}{D^2} - d < l$$

$$l > d(\frac{L}{d}\frac{d^2}{D^2} - 1) = d(\frac{Ld}{D^2} - 1) \quad \text{-------- (5)}$$

Total discharge of air from perforated holes (G) to be decided as below.

$$G=\rho_a V_a \frac{\pi}{4} D^2 \quad \text{-------------------- (6)}$$

Where ρ_a is the 10^{-3} g/cm^3, and D is the 25mm.

The estimate of the contribution in total pressure by the water column above the pipe can be presented by well known form, General physics [2]. Where pressure drop by gravity(P_g) is as bellow.

$\therefore$ $P_g = \rho_w gh$--------------------- (7)

Where ρ_w is the 1 g/cm^3, g is the 0.98×10^{-2} cm/s^2, and h is the 35cm.

The water depth is 35 cm in the tank.

P_g = 0.035 kgf/cm^2

Therefore, it shows that the pressure drop by the water column above the pipes does not effect on the air discharge because of $2 > P_a > 1.5$ kgf/cm^2 and $P_a \gg P_g \fallingdotseq 0.035$kgf/cm^2.

The water velocity of the surface current generated by the air flow through the perforated pipes are presented in tables and diagrams.

Following data are decided on the pressure of P_a = 2kgf/cm^2 by using velocimeter.

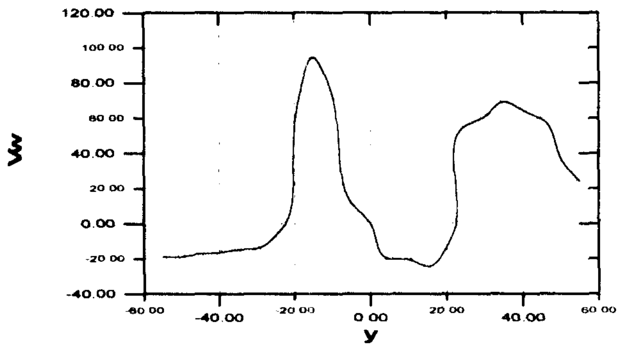


Fig. 8-1 Water velocity distribution.

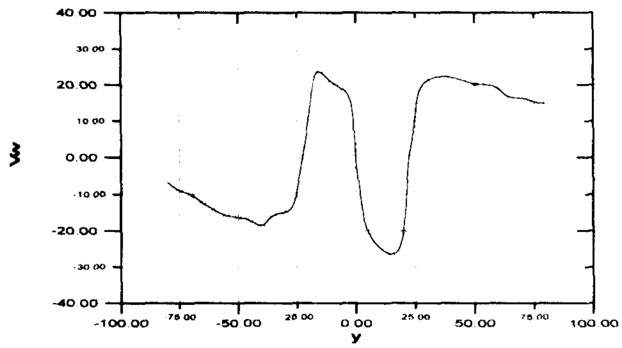


Fig. 8-2 Water velocity distribution

Figure 8-1 and 8-2 show that water velocity is 0 when it is located on the wall and y values are -22.5, 0 and +22.5cm. Where y is width from the center of course to wall.

It also shows that if the area of ship model in the voyage is located on between -22.5, 0 and +22.5cm of perforated pipes, it moves with safe motion without idle steering mechanism.

Figure 9 show an experimental setup for the test. It simulates curvilinear courses of about 7m distance for the ship model by a track of perforated pipe, imitation of harbor's narrowness, waterside structures and pier. Pair of perforated pipes are installed in the tank, the size of hole is 1.6mm distance between 30mm and the distance between the pipes are 45cm. Air compressor (10kgf/㎠), gas holder, and 3(three) valves are installed near the tank and they control the amount of air discharge to the perforated pipes.

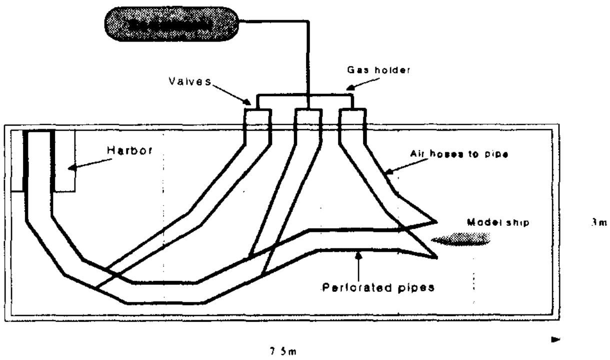


Fig. 9 Plan of water tank for the test

The unit includes a flow meter with air consumption about 30-50 l/s, a pressure gage for up to 3 kgf/cm^2 and valves regulating airflow.

The air compressor, having productivity about 10 kgf/㎠, accumulates air in the gas-holder keeping up average of 2kgf/cm^2> P > 1.5kgf/cm^2 pressure in. By the hoses the air from the gas-holder comes into the perforated pipes and finally generates bubble aerated flow accompanied by eddy structures, which keep the ship models in the track. The airflow is controlled by valves.

On the test, after open the air on gas holder, air was discharged from two perforated pipes and air bubbles bust into water surface. Two eddy rollers were formed on the surface as shown on Figure 10. An uniformed model ship was smoothly maneuvered into the straight course with safe motion as figure 11, it moved into curvilinear course as figure 12

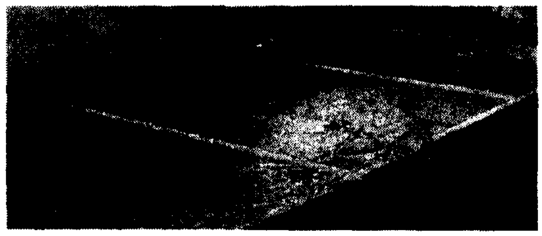


Fig. 10 Two eddy rollers are formed on the surface

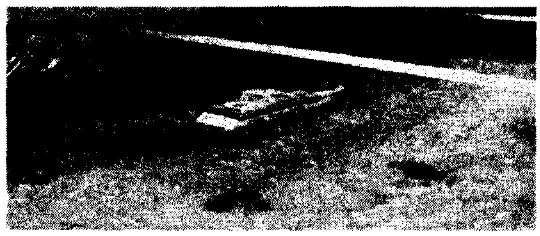


Fig. 11 Model ship smoothly guiding into the straight course without idle steering mechanism

Fig. 12 Model ship smoothly guided into the curvilinear course

4. Results

Test showed that the air created the aerated zone and two eddy rollers were formed on the surface when the air is discharged into the water from the perforated pipes as shown on figure 2, 3, and 11. When the model is located on the water surface between the perforated pipes which eddy rollers are formed, the kinetic energy of water movement transformed into potential energy of hydrodynamic pressure on ship's hull. When the ship stayed on course, the pressure was balanced on both sides during ship's idle steering mechanism.

5. Conclusion

The result and discussion can be concluded as follows:

(1). Guiding ships under conditions of the aerated flow technology can be applied as a realistic situation in an actual harbor area.
(2). It contributes to control the ship in and out and quickly berthed in the crowded harbors. It also is more effective to use in the container piers, because it guides the ship safely to the harbor without damage of expensive and dangerous cargo.
(3). If this system is installed on the dry docks in shipyards, marine and maritime police bases, it guides the ship safely and quickly to the dock, so new shipbuilding and repair would be much faster than before.
(4). This system also can be applied to foggy areas near waterside. If it is installed in the serious foggy areas between short distance islands, people could travel safely even on the bad weather conditions.
(5). Utilization of guiding system for new construction or renovation of existing facilities would provide significant improvement dependability of ship piloting, decrease required effort and time, It could be reduced capital and operational expenditures.
(6). If this system is applied in the canals, such as Panama and Suez Canal, necessary equipment of ship for canal would be reduced. Therefore, it saves money for shipbuilding.
(7). Comparison between the new and traditional technologies shows that the traditional system requires 30% to 50% higher capital and operational expenses. At the same time, the new system significantly reduces the time, required to move through the canal such as the Panama Canal, Suez Canal and harbor.

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Acknowledgements

This study was supported by research funds from Chosun University, 1999