A Study on the Development of Auto Pilot Device at Shallow Water for the Docking of Fishing Boat

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Abstract

Generally a ship in a port or canal is guided by tugboat(s), while the ship engine(s) and steering mechanism idle. The shortcomings of this method are insufficient in course keeping ability, danger of collision with waterside structures, time-consuming preparation for tugging, as well as the need to maintain tugboats. A new technology for ship guiding, based on the physical principle of interaction of a solid body with aerated liquids has been developed [1]. Model tests were carried out for the verification of system at slow speed by engine operating conditions and with an idle steering. The developed device has been proved to keep the ship on course safely.

Key words: guiding ships(도선), narrow channels(협수로), auto pilot system(자동차도선시스템), hydrodynamic pressure(유체압력)

INTRODUCTION

When air is discharged into water through a perforated pipe, a zone of aerated liquid is created. Because of bubble buoyancy, the air bubbles, discharged into the water through a perforated pipe, aspire to the surface forming a ridge as shown in Fig. 1.

On the surface the air bubbles burst into the atmosphere, while entrained water is moving away from aerated zone. The bottom layer of water, and so-me of the upper layer of water, move into the aerated zone to replenish the entrained water. In the process two eddy rollers are formed, and makes pressure deviation.

1—seabed, 2—perforated pipe, 3—aerated zone, 4—free surface of the water, 5—eddy motion of the water

Fig. 1. Mechanism of interaction of aerated zone with a layer of liquid.

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Between the two perforated pipes two symmetrical eddy rollers are formed.

Fig. 2. Hydrodynamic Pressure on a ship's hull when it moves between two eddy rollers.

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

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. 3. Explanation of course keeping.

The kinetic energy of water movement transforms into(potential energy of) hydrodynamic pressure on the ship's hull when it moves between the two eddy rollers, as shown in

Fig. 2.

If the ship stays on course, the pressure on both sides is balanced. But the ship deviates from its course as shown in Fig. 3, the pressure on the side closer to the eddy roller rises, while it decreases on the opposite side.

In order for the ship not to deviate, the speed of ship must not be greater than the acceleration of gravity on the curvilinear course.

If the air is discharged in front of the water side structure, it protects the ship from bumping as shown in Fig. 4.

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 water.

Fig. 4. Air bubble protects the ship from bumping into water side structures.

MODEL TEST

For verification of this new technology model tests were performed in the experimental facilities of the Chosun university. This test was configured to simulate the control of ships motion in an actual harbor area. Following simulations were performed with an idle steering and under windy conditions.

1. To keep a straight course.
2. To keep a curvilinear course.
3. To pass a narrow harbor area.
This test was performed in an experimental tank (Length × Beam × Depth = 7.5 m × 3 m × 0.35 m) at Chosun University, which can simulate a narrow and crowded harbor. A model ship (Length × Beam = 0.88 m × 0.2 m) with a motor, propeller, remote control system, and power supply was used.

Fig. 5 shows a typical section of the perforated pipe used. The pipe is 1" diameter with 1.6 mm holes apart 30 mm set.

![Fig. 5. Typical section of perforated pipe.](image)

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

The diameter of the hole, d, the distance between holes, l and the total length of the pipe, L, were considered using the following formula.

\[(l + d)n = L\]  \hspace{1cm} (1)

Where \( l \) is the 30 mm, \( d \) is the 1.6 mm.

The number of perforated holes of the pipe \( n \) was determined as follows.

By equation (1), the number of perforated holes, \( n \), was

\[n = \frac{L}{l + d}\]  \hspace{1cm} (2)

The following expression (3) for a perforated pipe must be satisfied.

\[\frac{\pi}{4} D^2 \geq n \frac{\pi}{4} d^2\]  \hspace{1cm} (3)

where \( D \) is 25 m/m

Equation (3) shows that the cross-section area of pipe must be greater than total area of perforated holes.

Then, the minimum distance between holes was shown below.

\[\frac{L}{l + d} d < D^2\]  \hspace{1cm} (4)
\[L d^2 < D^2(l + d)\]
\[L d^2 - D^2 d < D^2 l\]
\[L \frac{d^2}{D^2} - d < l\]
\[d \left( \frac{L d}{D^2} - 1 \right)\]  \hspace{1cm} (5)

Total air discharge from the holes, \( G \) was determined by equation (6).

\[G = \rho_a V_a \frac{\pi}{4} D^2\]  \hspace{1cm} (6)

Where \( \rho_a \) is 10–3 g/cm³.

The estimated total pressure from the water column above the pipe can be presented by a well-known formula as below [2].

\[\therefore P_g = \rho_w g h\]  \hspace{1cm} (7)

Where \( \rho_w \) is 1 g/cm³, \( g \) is the 0.98 × 10⁻² cm/s², and \( h \) is 35 cm. As the water depth was 35 cm in the tank, \( P_k = 3.43 \times 10^{-5} \) Pₐ.

Therefore, it shows that the pressure drop by the water column above the pipes does not affect the air discharge because of 1.96 × 10⁻³ > \( P_a \) > 1.47 × 10⁻³ Pₐ and \( P_a \gg P_k \approx 3.43 \times 10^{-5} \) Pₐ.

The water velocity distribution of the surface current generated by the air flow (\( P_a = 1.96 \times 10^{-3} \) Pₐ) through the perforated pipes are presented in Fig. 6 and Fig. 7.
Fig. 6. Water velocity distribution at 1m distance from center line of tank.

Fig. 6 and 7 show that the water velocity is 0 on the wall, and at the points of y values are -22.5, 0 and +22.5cm. Where y is width from the center of the course to the wall.

It also shows that if the ship model in the track is located between -22.5 and +22.5cm of perforated pipes, it moves with safe motion.

Fig. 7. Water velocity distribution at 2m distance from center line of tank.

Fig. 8 shows an experimental setup for the test. It simulates curvilinear courses of about 7m distance for the ship model by a track of perforated pipe. It also simulate the narrow harbor, waterside structures and pier.

The unit includes a flow meter with air consumption of about G=30–50 l/s, a pressure gauge for up to $2.94 \times 10^{-3}$ Pa and valves regulating airflow in each position. And the speed of model in straight course is 0.5%, and 0.3% in curved course.

The $9.8 \times 10^{-3}$ Pa air compressor accumulated air in the gas-holder keeping an average pressure of $1.96 \times 10^{-3} > P_a > 1.47 \times 10^{-3}$ Pa.

Air from the gas-holder came into the perforated pipes through the hoses and generates aerated flow accompanied by eddy structures, which keep the ship models in the track. The airflow is controlled by valves.

On the test, after opening the gas holder, air discharge from the pipe and air bubbles burst on the water surface making two eddy rollers. Model ship was safely and smoothly maneuvered with good course keeping between two eddy rollers as shown in Fig. 9, 10, 11.

Fig. 8. Plan of water tank for the test.

Fig. 9. Model ship smoothly guiding between two eddy rollers. (Position A).
(2) If it is adopted in the serious foggy areas, specially between close islands, safety of operation even under bad the weather conditions will be increased.

요 약

해저에 설치된 파이프에서 분출되는 기포에 의해 형성된 강한 수평압력분포를 이용하여 선박을 신속하고 정밀하게 유도, 정박시키는 도선시스템으로 항구, 항수로, 해협 등과 같이 복잡한 수상, 수중 장애 물 지역에서 선박을 신속하고 정밀하게 유도함과 동시에 혼소한 부두에 안전하게 선박을 정박시키기 위하여 본 도선 시스템을 고안하였다.

REFERENCE

A. Benilov, and I. Sheynin. November 1999
Application of new technolog for guiding of ships through narrow channels and near waterside structures including mooring.

Douglas C. Giangoul, 1998 General Physics, Chung mun gak.

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