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指導敎授　李 貴 珠

이 論文을 工學碩士學位 申請 論文으로 提出함.

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曺 墉 垣의 碩士學位 論文을 認准함

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2008年 2月　日

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CONTENTS

List of Tables

List of Figures

NOMENCLATURES

/ : Length between holes

d : Diameter of hole

D : Inner diameter of pipe

L : Length of pipe

G : Total discharge of air from perforated holes

V_a : Velocity of air

P_g : Pressure drop by gravity

P_a : Pressure of air

V_w : Velocity of water

ABSTRACT

얕은 흘수에서 두 척의 선박을 동시에 자동으로 도선하는 시스템 개발

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본 논문에서는 두 선박을 동시에 좁은 항구나 운하 또는 가까운 바다 구조물 사이를 안전하게 예인하는 시스템개발에 관한 연구가 기술되었다.

일반적으로 선박이 항구나 운하를 통과할 때는 예인선의 도움을 반드시 받으며 그동안 선박의 엔진이나 조타장치는 멈춰있다.

기존의 방법으로 선박의 코스를 유지 시키는 것은 불충분 하며 바다 구조물과의 충돌 위험 및 예인선을 준비하는데 소요되는 시간이 상당히 걸릴 뿐 아니라 상당한 비용이 요구되어 지며 또한 예인선의 유지, 숙련된 도선사 및 연관되는 시설들이 반드시 필요하다. 따라서 이러한 문제점을 개선하기 위한 새로운 선박 예인기술 및 시스템을 개발하였다.

세 개의 관통된 관으로부터 뿜어져 나오는 공기로 예인되는 두 선박은 같은 방향 또는 비스듬한 각을 가지고 거리가 있는 배의 최대 폭을 초과하는 관통된 파이프 사이를 통과한다. 이는 관통된 세 개의 파이프에서 뿜어져 나오는 대칭적인 소용돌이 웨이브를 가지는 유체에너지이다.

이와 같이 3개의 소용돌이 속에서 생긴 움직이는 활동적인 에너지가 전달되어 유체 역학적인 압력이 발생되고 두 선박이 3개의 소용돌이 웨이브를 지나갈 때 선박의 외측 선체에 전달된다.

새로운 시스템 및 기술의 확인을 위한 모형실험은 Davidson Laboratory 에 있는 수조에서 이루어졌고 모형실험 장비는 25m×25m×0.7m, 실험수조 모형은 좁은 항구를 운행하는 복잡한 항구와 유사하다.

실험에 사용된 모형선은 일반적인 화물선 타입의 모터를 가지며 프로펠러, 원격조정시스템, 전원 등, 조정성능을 제외한 모형선이 사용되었다.

실험은 아래와 같은 조건으로 수행되었다.

-조타장치 없이 직선코스 유지
-조타장치 없이 바람의 영향아래서 직선코스 유지
-조타장치 없이 곡선의 코스를 유지
-조타장치 없이 바람의 영향 아래서 곡선의 코스 유지
-조타장치 없이 항구 안에서 해상 구조물을 통과 유지
-조타장치 없이 항구 안에서 바람의 영향과 함께 해상구조물 통과 유지

이 실험에서는 Fig. 1에서 보인바와 같이 관통된 파이프를 통해서 분출된 공기가 만들어낸 포화공기구역과 분출된 공기로 만들어진 두 개의 소용돌이 웨이브를 보여준다.
실험 모형선박이 Fig. 2와 같이 관통된 파이프 사이에 있을 때 소용돌이 웨이브가 만들어지며 이는 유체역학적 에너지가 물에서 전달되어 잠제적인 에너지가 유체역학적 압력으로 변하며 Fig. 3과 같이 선체의 표면에 압력을 가해준다.
이러한 유체역학적 에너지는 Fig. 4와 같이 선박이 코스를 유지할 때 분출된 공기압력의 영향으로 배의 양쪽균형을 유지하여 모형 선박은 조타장치가 필요 없어진다.

안정적인 조건에서의 실험 모형 선박은 Fig. 22와 같이 직선 방향으로 부드럽게 통과한다. 또한 모형 선박은 Fig. 23과 같이 해양 구조물 근처를 움직이며 압축공기가 분출되어 코스 안에 있는 모형 선박은 구조물 앞에서 유체역학적 압력에 의해 구조물과 구분되어진다.
그리고 모형 선박은 곡선의 코스도 조타장치 없이 안전하게 항구 안에서 예인되어진다.

또한 모형 선박은 바람의 영향 아래서 Fig. 22와 같이 직선의 코스를 부드럽게 통과하며 분출되는 유체 역학적 압력이 구조물 앞에 작용하는 동안 Fig.24와 같이 모형선은 해양 구조물을 안전하게 통과하고 곡선의 코스를 조타장치의 영향 없이 부드럽게 예인되는 것을 알 수 있다.

따라서 새로운 선박 예인시스템에 관련된 가능성 및 선박의 안전 등이 확실하게 확인되었고 이는 실제 선박이 항구에서 예인될 수 있음을 확인해준다.

Ⅰ. Introduction and Principles of the Ship Guiding Technology

At present, Guiding of a ship in the port or canal is accomplished by the use of one or several tugboats, while the ships engines and steering mechanism kept idle. The shortcomings of this method are insufficient ability to keep the ship on course, danger of collision with waterside structures and time-consuming preparation for tugging, as well as the need to expend substantial resources to acquire and maintain tugboats and associated facilities.

Big cargo 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.

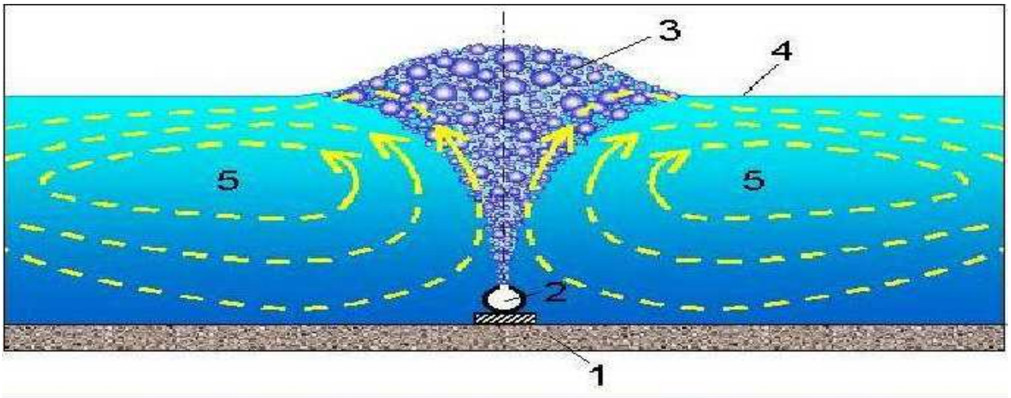
On the condition of fog, heavy rain and snow, it is very hard to maneuver the ship by using tugboats or guiding equipment. This weather condition restricts the vessel's in and out on time and delays the time for discharging and loading cargo.

The Panama Canal, a lock type canal, is 80 kilometers from deep water in the Atlantic to deep water in the Pacific. In the Canal, a ship is raised and lowered in a continuous flight of three steps and moved by using train on the side lock. It requires about 8 to 10 hours for an average ship to transit the Canal. If the time for the preparation of ship's guiding and tugging is included, it would take more than that times.

The Suez Canal is 173 kilometers long and 92 meter wide. It carries as much traffic as the Panama Canal. During 1995 through 1996, about 303 giant tankers had passed through the Canal and about 26% of oil exports go through canal. It takes about 15 hours for an average ship to pass the Canal. If the time for the preparation of ship's guiding and tugging is included, it would take more than that hours.

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

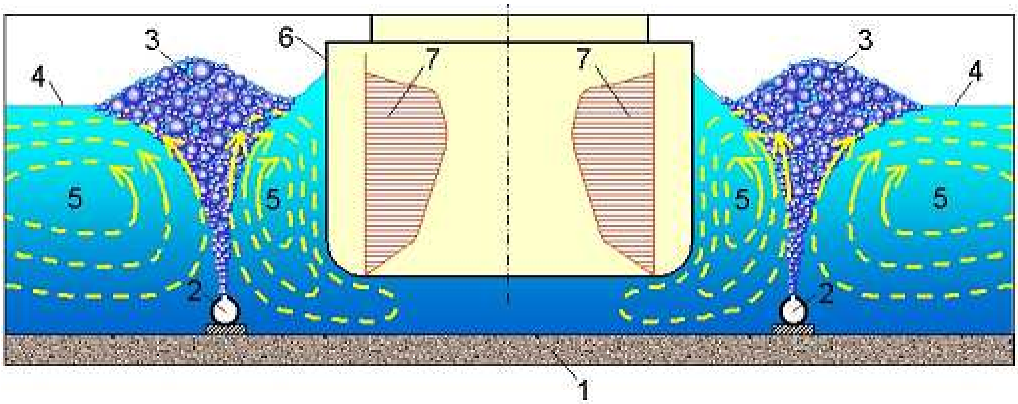
A new technology (Benilov, Sheynin 1999) for ship guiding was presented and developed in the former USSR in 1986. This method is based on separation of two functions, fore-and-aft movement of the ship and keeping it on course. By using ship's engines with idle steering mechanism, fore-and-aft movement 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.



1- Seabed 2- Perforated pipe 3- Aerated zone
4- Free surface of the water
5- Eddy motion of the water
(Arrows show direction, dotted lines- lines of equal velocities)

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

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 Fig 1, General physics. The air bubbles burst into the atmosphere on the surface, while entrained water is moving away from aerated zone. In order to replenish entrained water, the bottom layer water, and some upper layer water, move into aerated zone. In the process two eddy rollers are formed as below.



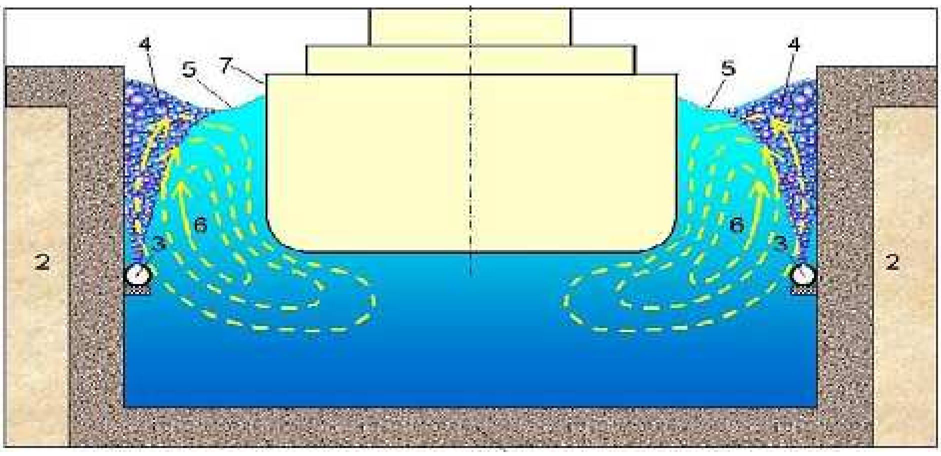
1. Seabed 2. Perforated pipes 3. Aerated zones

4. Free surface of the water

5. Eddy motion of the water   6. Ship hull

7. Diagram of horizontal component of hydrodynamic pressure

Fig. 2 Interaction mechanism between the hydrodynamic system and hull in shallow water



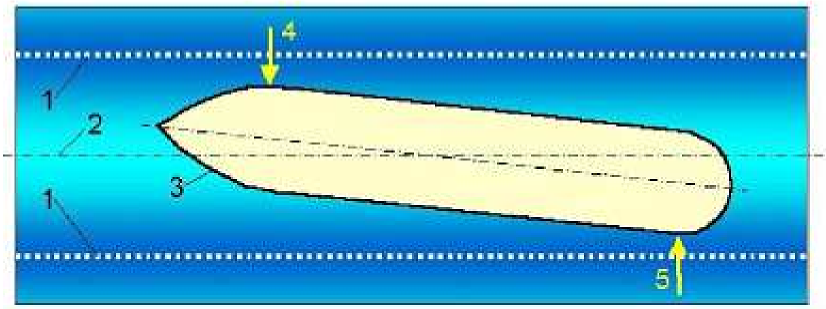
1. Seabed   2. Wall   3. Perforated pipes

4. Aerated zones   5. Free surface of the water

6. Eddy motion of the water   7.Ship hull

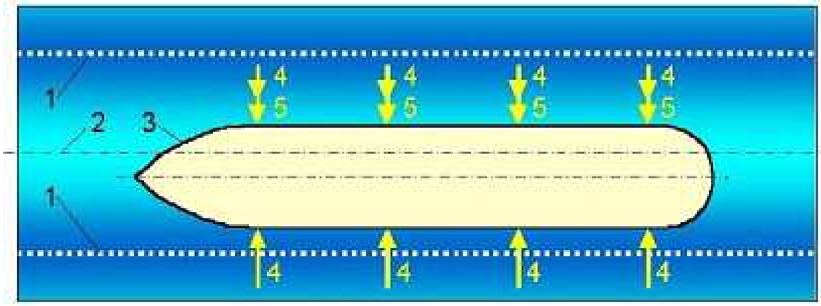
Fig. 3 Interaction mechanism between the hydrodynamic system and hull in canal

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 Fig 2 and 3. When this pressure increases the ship moves closer to the ridge and forms aerated zone.



1. Perforated pipe 2. Axis of the ship guiding system 3. Ship hull
4. Horizontal component of the resultant pressure on the starboard
5. The horizontal component of the resultant pressure on the port

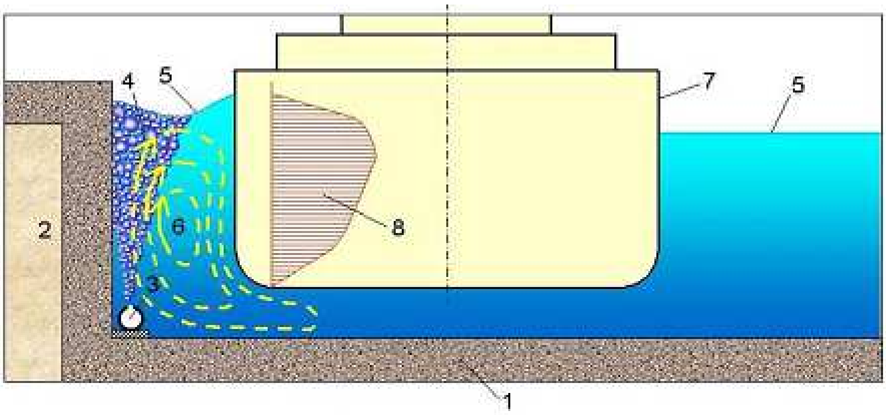
Fig. 4 The ship stays on course by the pressure on port and starboard



1. Perforated pipe 2. Axis of the ship guiding system 3. Ship hull
4. Horizontal component of the resultant pressure on the ship boards
5. The horizontal component of the resultant wind pressure
on the starboard

Fig. 5 The ship stays on course by the balanced pressure

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 Fig 4, the side pressure closer to eddy roller rises, while the pressure on the opposite side decreases as shown on Fig 5. 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. Seabed 2. Wall 3. Perforated pipes
4. Aerated zones 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 6.Interaction mechanism near waterside structure

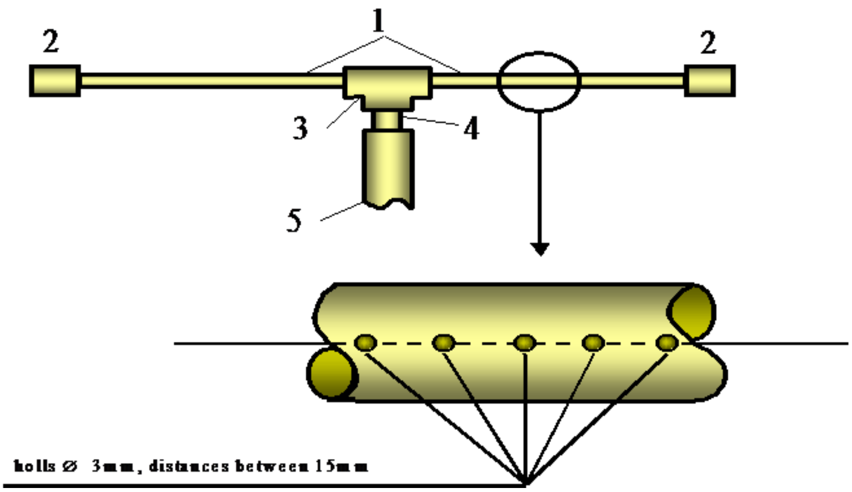
The air is discharged under pressure in front of the structure when the ship moves near a waterside structure. It protects the ship from bumping to the waterside structure as shown on Fig 6. For the mooring, after the ship stops the air is cut off and lines are tie down.

II. MODEL TEST

For verification of the new technology, demonstration test, Davidson Laboratory, was performed by using the Stevens Institute of Technology 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 Davidson Laboratory Stevens Institute of Technology, U. S. A. and it has excellent condition, which is a tank (Length × Beam × Depth = 25m × 25m × 0.7m). It simulates a narrow and crowded harbor. Common cargo vessel types ship models (Length up to 150cm and beam up to 30cm) have motor, propeller, remote control system, and power supply without idle steering mechanism.



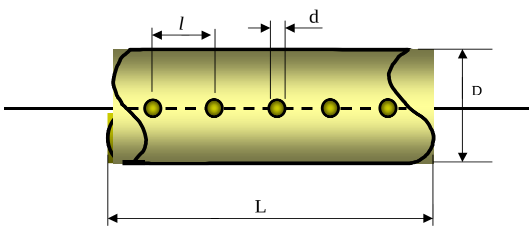
1 - Plastic pipe with inner diameter 1"   2 - End gag

3 - T-joint   4 - Socket of hose

5 - Hose with inner diameter 1"

Fig. 7 Typical Section of Perforated Pipe

Typical section of the perforated pipe is shown in Fig 7. Estimates show the pipe diameter is 1", the diameter of holes is about 3mm and the distance between holes is about 15mm.



l - Length between holes

d - Diameter of hole

D - Inner diameter of pipe

L - Length of pipe

Fig. 8 Detailed Typical Section of Perforated Pipe

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

The total length of the pipe, L, may be presented as eq.(1)

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

Where / is the 15 mm, d is the 3mm.

The number of perforated holes, n, of the pipe to be decided as eq. (2)

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

The following expression for a perforated pipe must be satisfied:

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

Eg, (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 shown in eq.(4) and (5)

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

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

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

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

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

Total discharge of air from perforated holes (G) to be decided as eq. (6)

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

Where ρ_a is the 10^{-3} g/cm^3, and D is the 35mm.

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 shown in eq.(7)

$$\therefore P_g = \rho_w g h \quad \text{--} \quad (7)$$

Where ρ_w is the 1 g/cm^3, g is the 0.98×10^{-2} cm/s^2, and h is the 75cm.

The water depth is 75 cm in the tank.

P_g = 0.075 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

$P_a \gg P_g \fallingdotseq 0.075$kgf/$cm^2$.

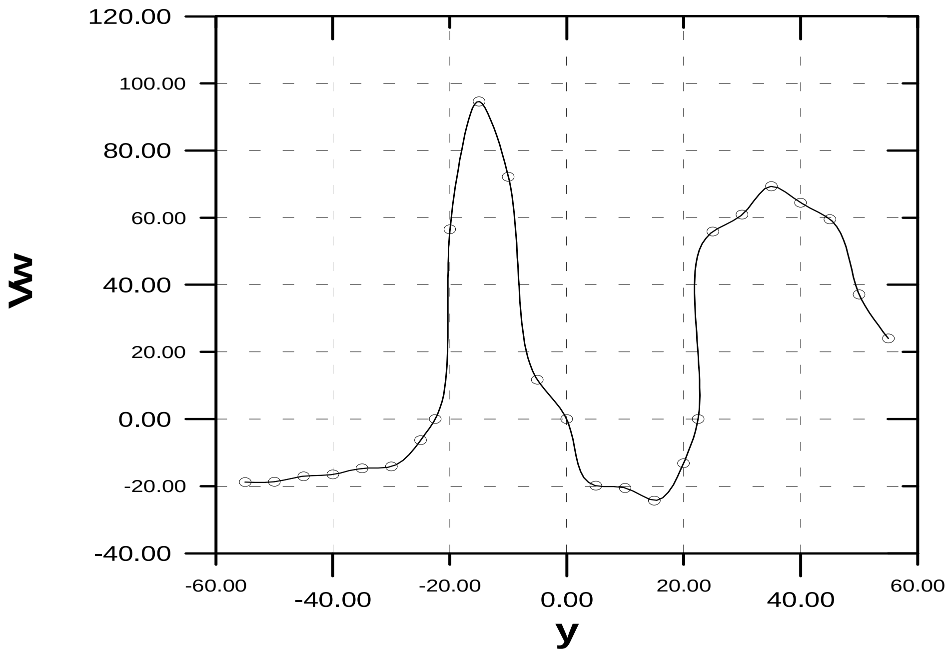


Fig. 9 Water velocity distribution at 1m distance from center line of tank

The water velocity of the surface current generated by the air flow through the perforated pipes are presented in Fig. 9, 10 and Appendix Table 1, Table 2

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

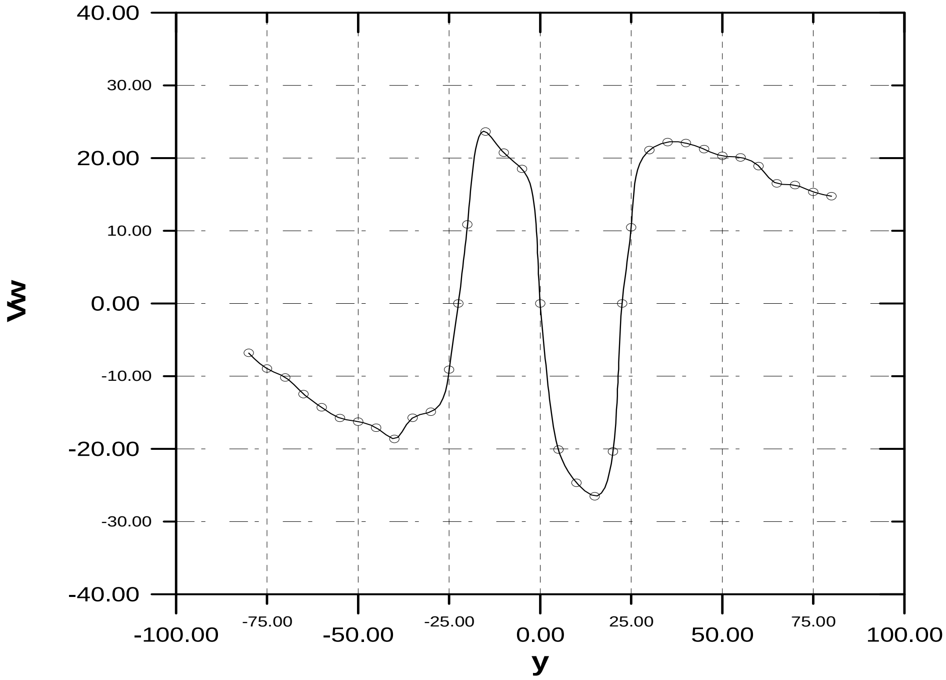
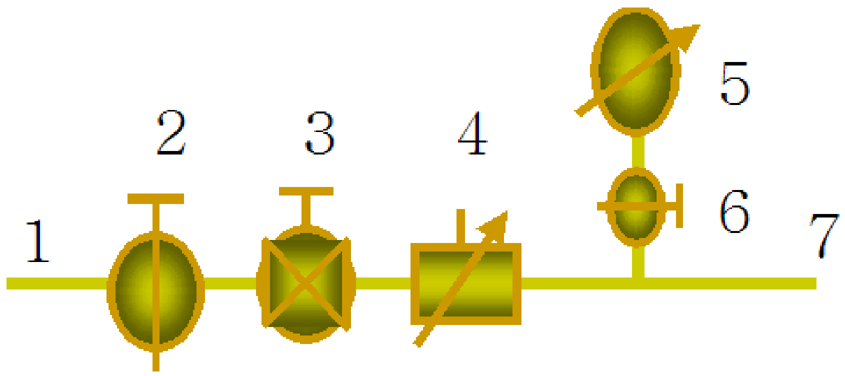


Fig. 10 Water velocity distribution at 2m distance from center line of tank

Fig. 9 and 10 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.



1 - socket of the distribution comb of ascending airway

2 - cap faucet with an opening of diameter 1",

3 - regulation faucet 1"

4 - flow-meter with air consumption up to 30-50 l/s

5 - pressure-gauge up to 3 kgf/㎠,

6 - cap faucet with an opening of diameter 1"

7 - output socket for connection with hose 1"

Fig. 11 Diagram of the regulation unit for air supply

The diagram of the airflow regulation unit is shown in Fig 11. 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/cm2> P > 1.5kgf/cm2 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.

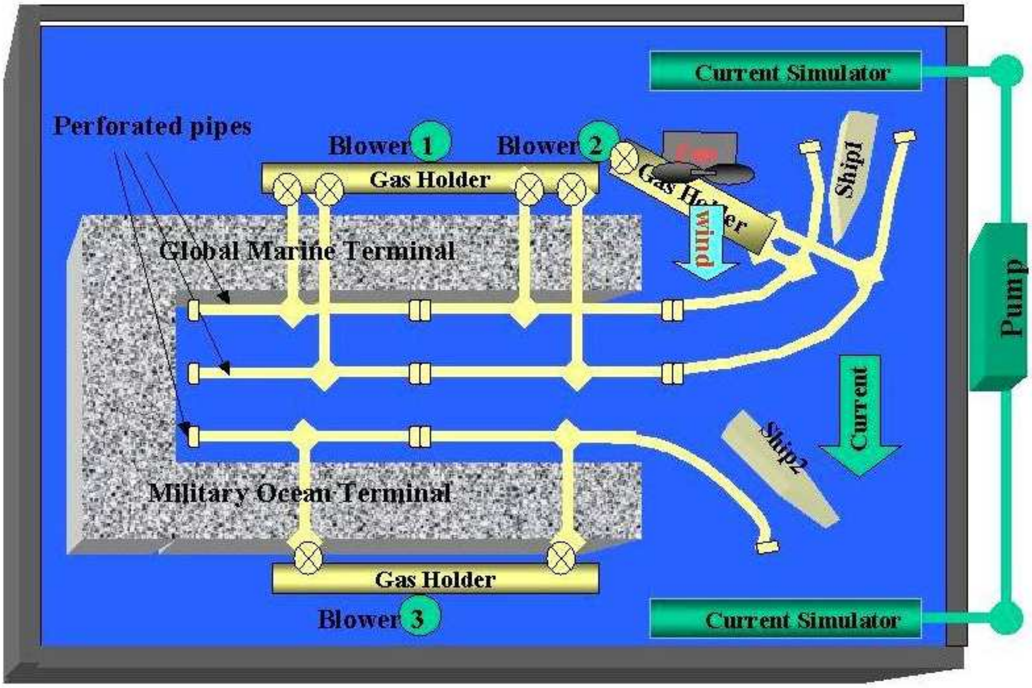


Fig. 12 Plan of water tank for the test

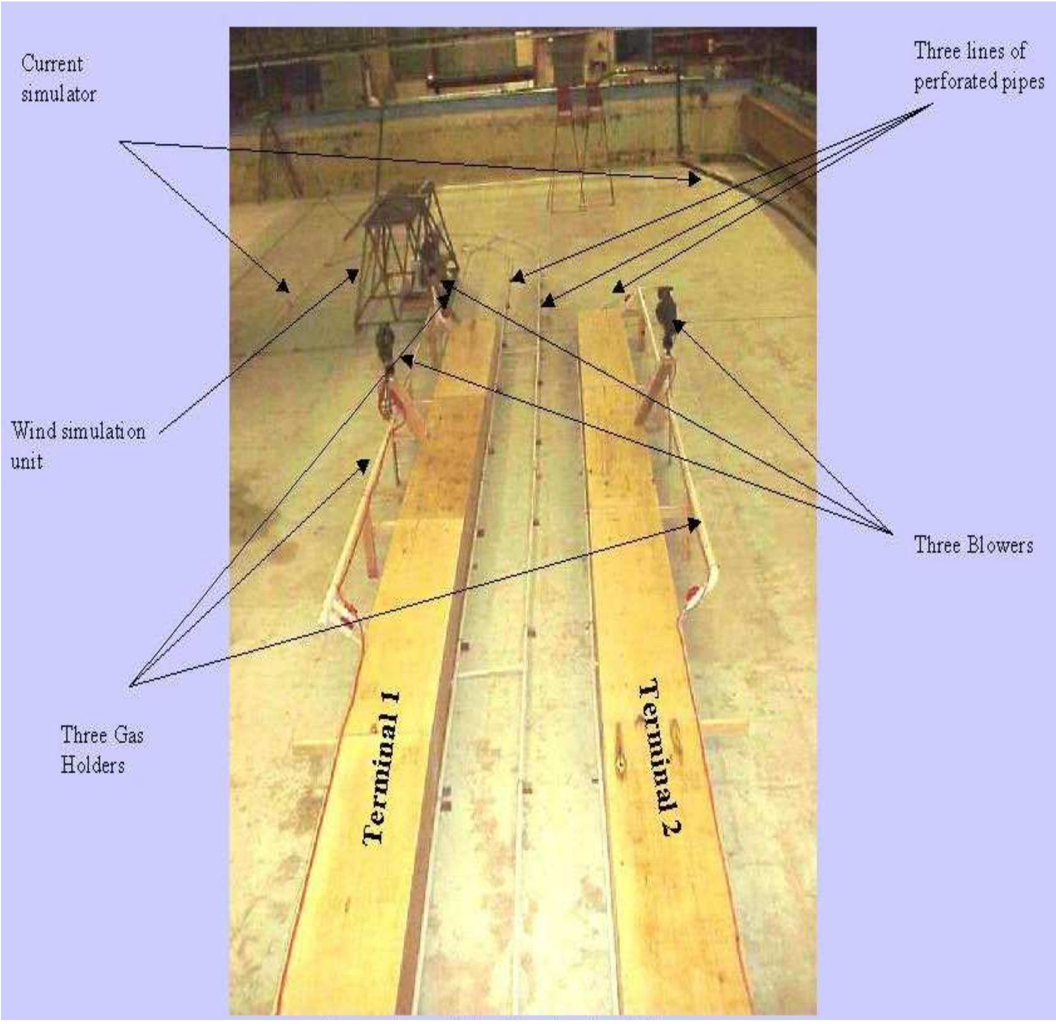


Fig. 13 Experimental setup in tanks

Fig. 12 and 13 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 3mm distance between 15mm and the distance between the pipes are 55cm.

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.

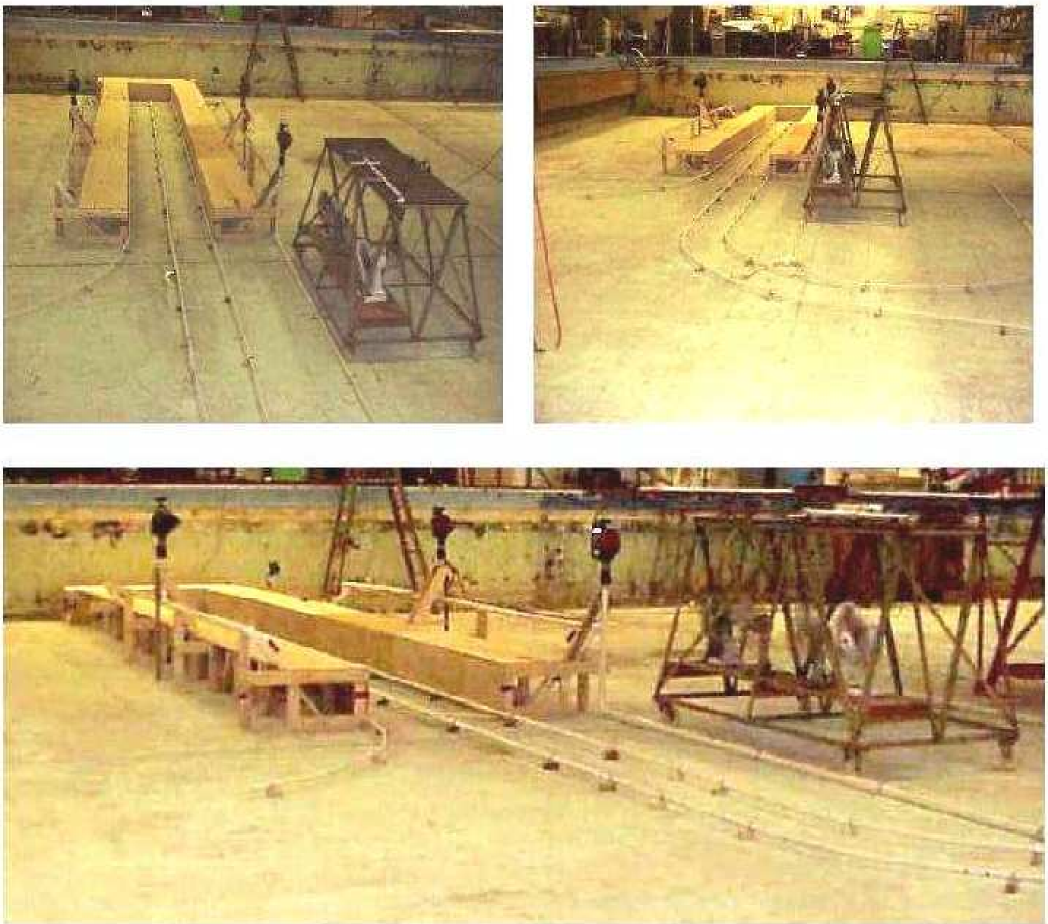


Fig. 14 Channel model and wind simulation unit with four fans

Fig.15 Components of current simulator

A fan simulates the wind action. A rotating arm in the tank allows location of the fan in any necessary for the test requirement location to carry out all the cases of wind action. For some of the cases the fan has a steady location on the tank wall as shown Fig 14 and Fig 15.

Table 1 Specification of wind-current conditions

wind z=25cm (10in) above the water surface	current z=1.2 cm (0.5in) above the tank floor	current surface 22cm(8.625'') above the tank floor
2.5 m/s (5 knots)	7cm/s (2.75 in/s)	12cm/s (4.72in/s)

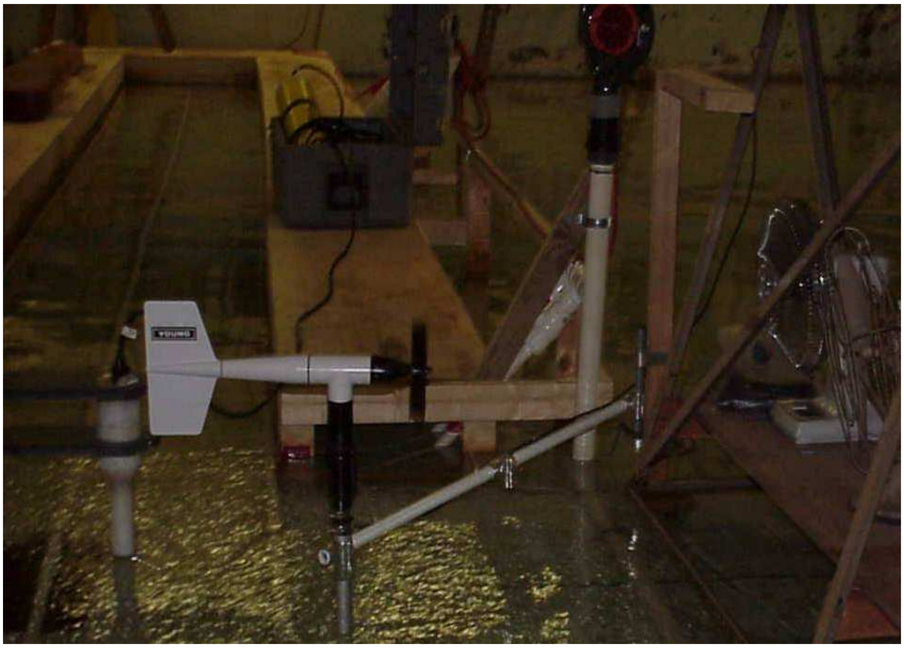


Fig. 16 Wind and current measurement unit

Table 2 Ship models specification

Model	Motor	Rudder	Remote Control	Length	Beam	Depth	Weight
M-RC	YES	NO	YES	159cm	30.5cm	12.1cm	16kg
M 1	NO	NO	NO	164cm	31.8cm	12.7cm	6.8kg
M 2	NO	NO	NO	162cm	25.4cm	12.1cm	5.7kg

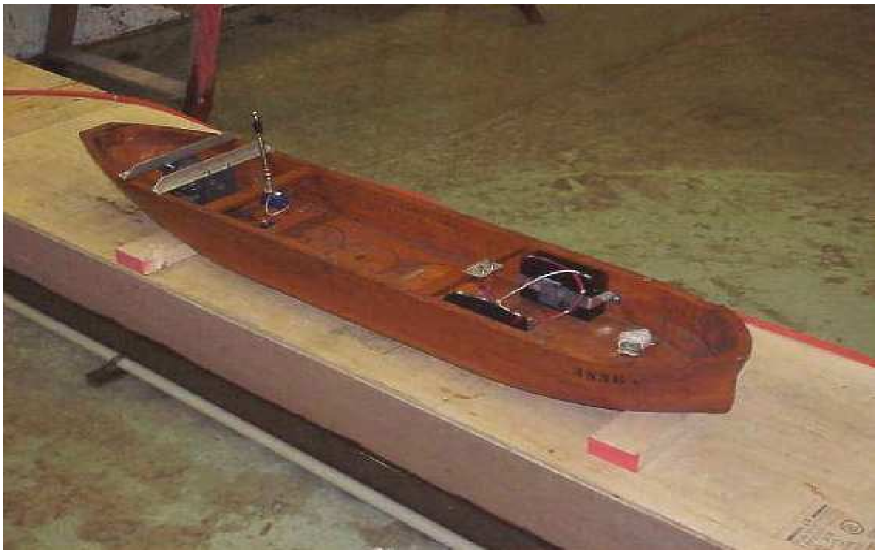


Fig. 17 Model ship M-RC

Fig. 18 Model ship M1

Fig. 19 Model ship M2

Fig. 20 The start of air injection into the water
through the perforated pipes

Fig. 21 Two eddy routs in the channel model

Fig. 22 Model M-RC (motor off) is coming in the channel following one of the eddy routes

Fig. 23 Model M-RC(motor off) is following the eddy route in the channel and passing model M2 moored to the pier

Fig. 24 Model M-RC (motor-off) and M2 are passing the channel in opposite directions following the eddy routes

Fig. 25 Following the eddy routes, model M1 is coming out
the channel, as model M2 is coming in

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 Fig 21. An uniformed model ship was smoothly maneuvered into the straight course with safe motion as Fig 22, it moved into curvilinear course as Fig 23 and safely guided into the harbor while the ship's engine and steering mechanism kept idle. As the ship moved near a waterside structure as Fig 24, the air was discharged under pressure in front of the structure, protected from bumping and it was safely birthed. It also left harbor safely along the waterside structure, straight and curvilinear courses as shown on Fig 23, 24, and 25.

Actual test showed that when the air was discharged into the water from the perforated pipes, it created the aerated zone and two eddy rollers were formed on the surface. When the model was located between the perforated pipes which eddy rollers were formed on the water surface, the kinetic energy of water movement transforms into potential energy of hydrodynamic pressure on ship's hull. As long as the ship stayed on course, the pressure was balanced on both sides while the ship's engines and steering mechanism kept idle.

Therefore, dependability of piloting was ensured and verified by applying this system.

Materials used for the test are listed as follows,

a. Plastic pipes, 1” inner diameter - 64 m
b. Plastic pipes, 6” inner diameter - 33 m
c. Plastic pipes, 8” inner diameter - 10 m
d. T-joints to connect the plastic pipes - inner diameters
   2 x 1” + 1 x 1.5” - 36 units
e. Pipe lugs, 1” diameter - 72 units
f. Pipe lugs, 6” diameter - 3 units
g. Hoses, 1.5” inner diameter, for pressure up to 30 psi (2 at) - 180 m.
h. Connecting pipes (transitional sockets) to connect the plastic pipes
   with the hoses - 80 units.
I. Hose clamps for the hoses of transitional sockets - 80 units
j. Valves, 1.5” - 32 units.
k. Valves 5” - 3 units.
l. Concrete load plates - 300 units
m. Clamps for the pipes and hoses fastening to the concrete load plates.
n. Lumber boards, 1” - 60 m2 = 645 ft2.
o. Lumber beams, 3x2”, 180 m.
p. Nails - 10 kg.
q. Screws - 4 kg.
r. Some other materials - 20 o/o of all above.

Equipments used for the test are listed as follows,

a. Air compressor, 10kgf/㎠, for normal pressure and with a highest pressure at output.
b. Pipes, fitting and valve system.
c. Equipment, devices and arrangements of power supply for the control system of the ship model motion.
d. Wires and starting regulators of electric drive for the air compressor.
e. Fan for wind action.
f. Pressure gauge. 3Kg/㎠
g. Water velocimeter.
h. Installation and assembly tools and devices for execution of the work scope below.

III. RESULTS AND DISCUSSION

The length of pipe, the size of perforated hole and the total length of pipe could be decided as (1), (2), (4) and (5).
When we decided number of holes by using formula, we must considered that the area of pipe must be grater than total area of perforated pipes as (3).
The pressure drop by the water column above the pipes was also considered as 0.075 kgf/cm^2 while the air discharge was between 2 〉 P_a 〉 1.5 kgf/cm^2 as (7).

After decide above fig, test material were installed and test was performed as belows.
The generated air flow through the perforated pipes with normal pressure of P_a = 2kgf/cm^2 by using velocimeter was checked and showed as below, on Fig 9, and Fig 10.
The water velocity was 0 when it was located on the wall and y values were -22.5, 0 and +22.5cm. Where y is width from the center of course to wall.
It also showed that if the area of ship model in the voyage was located on between -22.5, 0 and +22.5cm of perforated pipes, it moved with safe motion without idle steering mechanism.

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 Fig 2, 3, and 21. 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.

The condition of ship on the surface showed as below.

In the stable condition, model ship smoothly guided into straight course with safe motion as shown on Fig 23. When the ship moved to near waterside structure as shown on Fig 24, the air was discharged under pressure in front of the structure and did not deviate its course. It also moved into curvliniear course as shown on Fig 22 without idle steering mechanism and safely guided into harbor.

On the wind action, the model ship guided into straight course smoothly. The air was discharged under pressure in front of the structure while the ship maneuvered into near waterside structure. It also moved into curvliniear course without idle steering mechanism and safely guided into harbor as shown on Fig 22, 23, 24 and 25.

Ⅳ. CONCLUSION

The result and discussion can be concluded as follows:

1. Guiding two 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. 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.
6. 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.

V. REFERENCE

[1] A. Benilov, I. Sheynin. Application of new technology for guiding of ships through narrow channels and near waterside structures including mooring (November 1999).

[2] Douglas C.Giangoul, General Physics, Chungmungak (1998)

VI. APPENDIX

Table 1. Water velocity data at 1m distance from center line of tank

Table 2. Water velocity data at 2m distance from center line of tank

Table 1 Water velocity data of at 1m distance from center line of tank

y(cm)	Data of water velocity (cm/s)																				Mean value
-150	-4.0	0.6	-1.2	0.5	-1.7	0.9	0.8	1.3	1.6	0.8	0.6	0.7	-1.4	1.5	0.5	-1.7	-1.5	0.4	0.5	0.5	-0.01
-145	-1.6	0.7	-1.1	0.4	-5.3	-6.2	-4.4	-1.4	-1.7	-3.7	-2.9	-2.4	-1.7	-4.7	-1.2	1.0	2.2	0.8	0.5	-2.1	-1.74
-140	0.8	-6.2	-6.7	-11.5	-7.7	-1.5	-1.3	-3.8	-4.3	-2.0	-1.5	-5.3	-7.8	-8.3	-5.2	0.6	0.6	0.6	1.4	1.8	-3.36
-135	-5.2	1.0	0.9	-4.5	-4.1	-1.6	-1.9	0.6	-3.0	-4.2	-2.7	-6.0	-6.9	-9.8	-5.0	-3.7	-1.8	-3.1	-5.2	-4.6	-3.54
-130	-5.5	-2.5	-2.2	-2.4	-4.7	-8.7	-6.8	-5.0	-1.4	-1.1	-3.4	-4.8	-5.1	-6.5	-4.4	-8.8	-1.4	-5.6	-5.9	-4.8	-4.55
-125	-3.5	-1.6	-3.6	-3.1	-2.8	-4.0	-1.7	-4.3	-3.8	-5.0	-4.3	-5.9	-11.0	-4.7	-7.8	-7.8	-8.7	-11.2	-7.9	-5.1	-5.39
-120	-2.1	-7.1	-8.7	-6.2	-5.9	-11.3	-10.7	-10.3	-9.6	-12.1	-11.7	-8.0	-4.9	0.7	-3.7	-6.3	-5.8	-3.6	-8.8	-6.3	-7.12
-115	-7.8	-9.3	-8.0	-8.7	-4.0	-9.2	-9.9	-4.8	-4.4	-1.7	-7.7	-6.5	-8.0	-6.8	-9.7	-6.3	-3.9	-8.8	-10.2	-7.6	-7.16
-10	-3.2	-6.2	-12.1	-6.6	-9.4	-14.7	-8.1	-14.1	-10.5	-11.1	-10.4	-14.2	-10.1	-4.8	-6.8	-9.3	-6.8	-4.4	-3.7	-6.0	-8.62
-105	-7.1	-5.2	-11.6	-9.6	-5.2	-6.9	-7.2	-5.5	-6.9	-7.2	-5.5	-3.9	-10.2	-7.7	-3.5	-3.4	-6.8	-1.9	-6.8	-9.7	-6.59
-100	-10.2	-9.8	-7.4	0.5	-1.9	-4.1	-6.6	-8.2	-7.4	-9.1	-10.4	-7.0	-1.5	-8.9	-6.5	-4.4	-5.5	-7.8	-5.0	-1.4	-6.13
-95	-12.2	-7.4	-9.9	-14.0	-11.8	-11.4	-11.5	-9.6	-11.2	-5.0	-8.0	-6.1	-14.0	-14.7	-5.9	-11.9	-10.0	-14.0	-8.9	-5.5	-10.15
-90	-13.0	-10.9	-7.1	-12.7	-13.8	-5.2	-14.9	-13.5	-16.3	-9.9	-10.9	-11.6	-7.4	-7.1	-12.3	-16.4	-5.6	-13.1	-11.7	-9.0	-11.12
-85	-13.9	-2.9	-7.2	-8.6	-8.4	-8.7	-4.6	-5.4	-7.0	-4.7	-6.8	-4.5	-12.4	-12.2	-10.0	-11.6	-8.1	-6.9	-4.2	-7.7	-7.79
-80	-11.3	-10.4	-11.4	-14.8	-13.4	-3.4	-4.2	-7.4	-6.3	-2.4	-6.8	-4.4	-3.6	-3.1	-9.1	-12.2	-3.3	-2.9	-4.1	-1.8	-6.81
-75	-6.3	-8.3	-4.0	-6.3	-9.1	-6.6	-14.0	-4.7	-0.9	-9.3	-5.0	-11.9	-9.9	-20.0	-9.6	-7.5	-5.9	-7.9	-16.6	-15.5	-8.96
-70	-11.5	-5.9	-8.4	-12.5	-14.3	-9.0	-14.3	-11.5	-13.2	-6.3	-6.7	-7.5	-6.0	-7.5	-6.0	-8.1	-5.4	-7.7	-10.3	-12.2	-9.21
-65	-11.0	-13.5	-17.3	-6.1	-10.7	-10.6	-5.1	-7.2	-9.7	-10.3	-10.0	-10.6	-18.6	-13.5	-14.6	-16.5	-12.7	-15.6	-15.2	-20.5	-12.46
-60	-10.9	-13.5	-8.1	-16.3	-13.4	-12.3	-14.3	-15.8	-8.2	-7.6	-16.3	-10.5	-14.4	-9.6	-8.4	-11.9	-12.0	-10.5	-24.2	-21.3	-12.97
-55	-20.1	-12.1	-13.2	-20.7	-19.4	-13.0	-16.0	-16.5	-16.5	-8.0	-15.0	-14.5	-16.0	-22.4	-12.3	-18.3	-16.4	-21.0	-10.5	-13.5	-15.77
-50	-16.9	-19.0	-12.0	-17.4	-11.3	-18.5	-17.9	-19.4	-17.8	-16.3	-16.2	-12.7	-6.5	-16.6	-16.9	-23.4	-19.8	-12.5	-15.8	-18.4	-16.26
-45	-20.7	-14.4	-13.7	-18.7	-13.3	-17.8	-14.6	-20.8	-14.5	-14.4	-19.8	-14.4	-11.6	-10.8	-23.6	-24.1	-21.5	-19.1	-13.9	-20.6	-17.11
-40	-28.3	-24.0	-21.3	-19.1	-16.7	-20.2	-14.0	-9.6	-19.2	-19.0	-20.0	-16.6	-18.1	-22.8	-14.9	-16.2	-19.9	-16.2	-19.9	-16.7	-18.63
-35	-16.7	-9.8	-14.0	-13.9	-21.1	-16.6	-12.1	-19.9	-15.8	-12.2	-18.4	-12.9	-12.9	-15.6	-17.1	-14.1	-14.8	-19.9	-16.8	-19.9	-15.72
-30	-17.7	-15.5	-12.7	-16.9	-17.5	-11.8	-12.0	-15.1	-16.9	-20.3	-13.5	-17.1	-11.5	-12.3	-15.3	-16.7	-12.7	-14.7	-12.9	-15.5	-14.93
-25	-22.3	9.7	-17.3	-4.6	-4.5	-9.8	-18.2	-4.8	-8.5	6.9	-4.2	-20.7	-17.8	-8.3	-13.3	-17.0	-13.0	-5.3	-2.7	-6.5	-9.11
-22.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
-20	13.2	10.8	2.0	12.5	21.5	18.4	11.2	15.8	16.1	7.8	7.4	9.3	0.5	-5.4	-5.0	8.6	9.4	19.8	23.0	20.2	10.85
-15	19.0	23.8	23.9	16.8	26.2	23.3	25.0	25.8	16.1	13.8	30.2	25.1	24.4	23.9	27.7	30.7	27.9	33.4	22.0	13.7	23.63
-10	19.2	26.7	26.8	25.8	19.0	18.8	16.8	26.8	12.8	21.5	21.3	29.6	16.8	23.3	13.8	25.4	26.9	13.2	14.3	16.1	20.74
-5	12.4	14.9	16.5	18.4	19.6	14.7	19.1	17.6	18.1	22.1	23.0	22.8	21.7	17.8	16.3	20.9	20.6	19.5	19.4	14.8	18.51
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
5	-19.9	-28.0	-23.7	-14.6	-17.2	-22.5	-24.5	-29.1	-25.2	-24.0	-21.1	-26.7	-25.5	-20.3	-21.3	23.2	-18.0	-25.9	-12.5	-25.8	-20.13
10	-25.4	-23.5	-18.9	-24.2	-21.0	-23.5	-26.4	-27.6	-23.5	-22.8	-21.6	-27.0	-29.1	-30.9	-24.5	-23.8	-28.4	-23.0	-28.5	-20.1	-24.68
15	-25.9	-35.0	29.2	-28.6	-27.9	-28.7	-23.3	-31.4	-25.2	-30.0	-27.6	-31.1	-32.8	-31.0	-30.5	-30.4	-33.1	-32.0	-29.4	-25.7	-26.52
20	-26.0	-26.8	-28.9	-27.4	-22.2	-19.0	-27.0	-29.9	-27.7	-10.4	-12.2	-10.4	-12.2	-10.0	-21.7	-23.9	-21.6	-15.0	-13.3	-22.0	-20.38
22.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	18.1	13.6	6.7	10.4	1.5	17.5	10.6	12.4	6.5	8.0	9.7	5.2	-2.8	11.1	11.9	13.0	13.4	20.4	10.0	12.0	10.46

y(cm)	Data of water velocity (cm/s)																				Mean value
30	26.3	14.0	17.8	25.3	16.9	11.1	22.9	19.4	21.4	21.6	19.4	21.5	25.8	24.9	25.9	22.7	29.1	25.1	13.7	17.3	21.10
35	13.3	20.9	22.5	28.8	26.2	25.0	24.8	31.2	23.1	24.8	22.9	17.2	28.3	9.4	19.8	20.8	18.5	19.1	24.7	23.1	22.22
40	24.0	22.9	22.6	18.7	28.2	20.0	14.3	29.2	19.7	21.8	21.8	23.8	19.9	22.8	19.4	20.5	25.9	17.6	23.1	25.6	22.09
45	23.1	21.4	19.6	22.7	21.8	21.3	21.8	16.6	21.0	17.2	18.9	19.0	16.8	27.9	16.7	22.3	23.2	21.2	22.9	29.5	21.24
50	19.2	16.6	20.2	21.5	22.1	18.8	26.7	21.4	17.2	17.1	17.9	16.4	22.1	20.5	19.1	23.8	24.1	20.6	20.5	20.5	20.31
55	24.8	21.2	19.1	23.9	24.1	19.3	15.1	24.6	18.6	16.2	20.2	19.6	16.7	21.1	23.1	23.7	19.1	21.9	18.4	24.0	20.73
60	21.3	22.7	20.6	23.2	21.1	15.8	19.4	15.4	18.9	17.0	24.7	16.1	19.0	18.0	10.4	17.2	16.2	21.0	21.5	18.5	18.90
65	14.3	16.2	21.1	19.6	15.9	15.7	12.2	18.4	16.1	12.1	14.7	17.6	18.5	12.9	11.9	18.2	17.2	18.0	23.1	16.8	16.52
70	22.5	20.6	18.0	16.5	12.6	11.0	6.4	17.9	19.4	18.1	12.9	21.0	16.0	19.1	18.1	15.6	16.8	13.0	14.6	15.2	16.26
75	15.2	17.8	17.5	9.2	10.7	15.2	15.2	18.5	14.9	13.3	18.8	14.5	18.2	12.5	13.4	14.3	14.2	18.5	15.0	19.8	15.33
80	12.7	14.6	16.2	19.5	14.7	19.2	13.3	11.5	11.4	14.7	16.2	16.1	15.9	15.8	13.1	16.5	13.3	12.5	15.6	12.6	14.77
85	13.4	15.7	20.4	21.6	18.6	14.6	14.6	15.4	9.2	8.4	7.0	12.7	5.7	10.6	15.0	17.0	11.2	13.7	16.3	12.1	13.66
90	11.1	12.4	10.3	17.0	16.6	17.3	19.1	11.7	12.3	15.0	10.4	8.7	10.4	11.8	9.9	10.8	5.3	14.3	12.9	12.6	12.49
95	14.5	17.6	15.4	16.1	16.4	15.5	11.7	11.0	15.6	16.2	9.6	3.7	10.0	11.7	6.4	3.7	5.3	12.3	9.1	16.6	11.92
100	14.9	8.2	17.8	8.5	4.0	1.4	14.2	15.5	11.9	16.1	16.3	11.0	9.3	13.4	12.1	6.5	9.1	9.3	8.9	9.2	10.88
105	16.4	7.5	7.8	5.1	4.9	7.5	14.2	16.3	9.7	10.1	11.3	8.9	6.0	8.6	17.5	12.4	10.7	8.4	14.0	10.7	10.40

Table 2 Water velocity data at 2m distance from center line of tank

	Data of water velocity																				Mean value
-150	-12.8	-15.1	-12.2	-14.2	-12.0	-14.2	-12.0	-12.8	-11.4	-13.4	-16.8	-10.8	-12.8	-17.3	-15.4	-18.2	-16.4	-13.7	-16.1	-15.4	-14.15
-145	-17.9	-13.1	-17.5	-12.3	-17.1	-16.5	-13.9	-12.2	-14.2	-14.4	-15.9	-17.5	-15.6	-13.3	-12.3	-10.6	-13.9	-13.1	-13.9	-11.9	-14.35
-140	-15.9	-13.3	-12.8	-18.1	-17.3	-19.8	-19.3	-15.1	-12.7	-14.4	-13.7	-15.6	-11.3	-9.4	-11.6	-12.0	-13.9	-17.5	-19.3	-19.2	-15.11
-135	-16.4	-15.9	-15.3	-19.8	-18.7	-21.0	-17.5	-16.2	-15.3	-15.4	-13.7	-13.1	-13.4	-13.4	-14.4	-18.1	-16.2	-16.8	-17.1	-15.8	-16.17
-130	-12.5	-17.3	-11.7	-14.0	-14.7	-11.4	-13.3	-15.4	-11.3	-13.9	-11.6	-13.4	-14.8	-14.2	-11.6	-11.6	-16.2	-15.4	-17.9	-15.1	-13.86
-125	-15.9	-15.9	-17.0	-11.6	-14.7	-14.2	-15.6	-15.1	-12.0	-8.8	-12.5	-16.1	-18.2	-16.5	-15.9	-13.9	-14.5	-11.3	-15.1	-19.2	-14.70
-120	-11.4	-14.4	-15.8	-15.4	-18.2	-16.8	-15.1	-15.3	-20.6	-18.2	19.9	-14.0	-15.9	-17.3	-15.9	-14.8	-10.8	-14.8	-15.6	-15.6	-13.80
-115	-16.4	-16.1	-15.6	-16.8	-14.5	-17.1	-16.1	-17.8	-12.3	-13.9	-15.6	-15.6	-18.7	-25.2	-21.3	-22.9	-18.4	-17.3	-19.6	-18.1	-17.46
-110	-10.8	-16.7	-15.0	-10.9	-15.4	-16.5	-15.4	-13.0	-10.9	-14.8	13.6	-12.2	-14.4	-19.5	-10.9	-11.3	-12.3	-11.7	-10.0	-13.0	-12.05
-105	-12.3	-13.7	-7.1	-9.9	-16.5	-13.1	-16.4	-15.3	-15.6	-15.9	-18.1	-15.3	-14.7	-13.4	-15.1	-17.9	-10.5	-10.9	-11.4	-17.6	-14.03
-100	-9.6	-10.6	-12.5	-13.1	-17.1	-13.0	-12.0	-13.9	-11.6	-16.2	-18.1	-19.6	-19.8	-13.7	-13.7	-11.4	-8.8	-19.0	-11.6	-10.0	-13.76
-95	-14.5	-14.8	-19.8	-13.1	-8.8	-12.0	-11.9	-17.3	-18.2	-14.0	-12.8	-13.1	-10.3	-8.6	-17.6	-12.2	-17.9	-17.0	-15.1	-19.9	-14.44
-90	-12.8	-16.4	-16.7	-15.9	-4.7	-22.6	-16.5	-15.3	-13.9	-17.0	-12.8	-20.1	-22.3	-18.5	-24.1	-20.7	-15.4	-23.2	-15.0	-11.7	-16.78
-85	-12.8	-16.2	-17.1	-18.7	-14.7	-13.7	-14.4	-17.0	-14.4	-18.9	-12.5	-14.4	-17.8	-1837	-14.2	-9.9	-12.7	-13.1	-16.7	-20.1	-106.31
-80	-20.4	-17.3	-14.2	-17.6	-17.6	-14.0	-16.7	-18.5	-19.6	-19.0	-20.4	-18.4	-18.2	-15.0	-15.8	-19.5	-17.6	-19.9	-14.2	-16.4	-17.51
-75	-19.3	-17.5	-23.3	-17.5	-16.7	-17.0	-17.5	-13.6	-17.0	-19.9	-14.7	-15.6	-13.0	-15.9	-14.4	-15.8	-18.2	-22.3	-9.4	-14.8	-16.67
-70	-17.3	-17.9	-11.3	-14.7	-19.2	-20.6	-12.3	-23.2	-18.5	-14.5	-20.9	-19.5	-19.3	-18.7	-18.2	-16.7	-19.2	-14.4	-15.4	-16.2	-17.40
-65	-15.6	-20.1	-16.4	-16.8	-21.3	-15.1	-15.9	-24.9	-22.3	-19.5	-17.8	-12.0	-19.3	-24.1	-20.2	-15.1	-18.2	-15.1	-18.2	-22.1	-18.50
-60	-26.6	-20.6	-25.7	-20.9	-16.1	-18.5	-25.1	-18.4	-18.7	-20.7	-16.8	-14.0	-19.6	-16.2	-18.9	-9.9	-11.1	-20.1	-23.5	-24.1	-19.27
-55	-18.9	-17.9	-14.5	-20.1	-16.5	-25.1	-23.3	-28.0	-17.1	-23.7	-15.6	-13.6	-18.7	-19.0	-20.1	-19.6	-12.8	-15.9	-14.4	-20.9	-18.78
-50	-22.0	-14.2	-17.6	-19.9	-21.5	-20.2	-14.2	-11.1	-16.7	-15.3	-19.3	-19.2	-27.1	-19.2	-12.5	-16.5	-18.1	-19.9	-25.7	-23.5	-18.68
-45	-15.5	-19.7	-12.1	-18.9	-18.9	-19.0	-18.2	-18.9	-18.7	-12.9	-15.5	-20.1	-17.5	-13.3	-17.4	-17.2	-17.4	-17.8	-16.8	-15.4	-17.06
-40	-8.6	-19.9	-17.3	-13.1	-17.1	-16.8	-16.2	-22.4	-18.2	-15.4	-9.4	-10.5	-14.0	-15.2	-13.4	-23.2	-20.2	-21.8	-24.7	-11.3	-16.43
-35	-10.8	-15.8	-14.6	-14.5	-16.8	-14.2	-13.7	-14.6	-16.8	-17.5	-13.9	-15.1	-17.8	-13.7	-13.4	-10.9	-16.1	-15.3	-15.2	-13.1	-14.69
-30	-11.4	-14.4	-15.8	-15.4	-18.2	-16.8	-15.1	-15.3	-20.6	-18.2	-14.0	-15.9	-12.3	-12.1	-11.6	-12.3	-10.8	-11.3	-10.2	-12.1	-14.19
-25	-3.2	-11.9	18.1	-12.5	-10.3	-6.3	-8.0	-1.2	-6.2	-4.2	-6.2	1.7	-9.2	-14.7	-6.8	-1.0	-4.6	-10.5	-14.0	-12.7	-6.33
-22.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-20	39.3	50.4	52.4	52.3	41.9	36.7	71.2	93.3	56.4	51.7	53.6	58.2	69.9	36.9	36.1	50.6	47.1	52.4	82.9	86.2	56.48
-15	97.2	116.1	78.4	90.1	98..1	99.8	123.3	94.6	110.3	88.8	74.5	108.3	91.4	68.6	82.9	90.1	83.6	83.6	112.9	98.6	94.55
-10	86.2	82.9	77.1	68.1	73.3	68..9	58.2	88.7	96.6	75.2	87.7	96.1	52.1	52.4	66.3	74.1	53.4	88.4	36.3	62.1	72.16
-5	16.5	8.9	13.6	16.8	41.9	12.0	17.2	12.7	18.7	15.0	13.7	12.6	15.2	19.7	16.8	14.6	12.0	19.4	14.8	18.7	16.54
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
5	-13.9	-25.7	-16.8	-22.1	-22.0	-28.5	-19.5	-21.6	-24.4	-17.9	-17.9	-13.6	-5.5	-22.4	-16.7	-12.8	-19.8	-29.7	-24.0	-22.9	-19.88
10	-28.0	-12.8	-23.8	-11.6	-24.4	-24.6	-13.7	-26.6	-23.7	-15.3	-27.5	-14.8	-11.4	-20.2	-22.4	-22.1	-22.3	-21.2	-24.9	-19.6	-20.54
15	-21.3	-20.9	-25.4	-19.0	-23.7	-20.7	-27.7	-23.3	-26.9	-24.3	-35.3	-22.6	-25.8	-27.2	-23.5	-22.4	-20.9	-21.3	-27.4	-26.3	-24.29
20	-15.1	-17.5	-12.6	-12.4	-13.0	-13.2	-16.8	-13.1	-15.2	-12.1	-16.0	-16.9	-15.8	-11.3	-12.8	-12.7	-10.1	-12.0	-12.8	-15.1	-13.82
22.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25	38.2	46.5	35.4	49.7	65.4	52.3	52.2	60.1	54.7	49.1	45.1	52.2	45.2	45.0	59.5	45.5	40.6	30.2	52.1	40.3	47.96
30	44.5	40.8	47.1	31.9	54.8	32.5	32.7	28.4	43.2	38.7	61.4	43.9	55.6	49.1	45.8	56.0	55.2	53.2	64.9	51.7	46.57
35	65.4	64.2	62.4	60.6	67.3	59.4	53.0	59.7	62.7	60.3	69.7	67.2	63.2	76.4	57.5	81.4	64.2	74.9	68.6	68.7	65.34

y(cm)	**Data of water velocity (cm/s)**																				**Mean value**
40	79.7	85.5	63.2	68.2	45.2	58.8	45.8	58.2	61.4	58.8	65.4	66.0	62.4	65.4	44.5	88.1	74.5	70.6	65.2	64.0	64.54
45	53.6	35.4	43.9	51.3	48.4	50.4	53.2	55.4	47.8	94.0	62.1	56.9	58.8	87.5	62.7	65.4	66.0	66.0	58.4	44.5	58.08
50	34.8	34.1	43.2	43.6	40.0	38.7	43.7	43.9	43.6	49.6	35.4	42.6	44.9	38.0	22.4	38.4	32.8	48.4	32.1	32.6	39.14
55	25.6	29.1	18.5	29.4	26.8	31.5	36.7	26.9	12.6	25.6	13.3	23.7	18.5	26.7	19.1	22.4	20.6	22.4	28.2	32.1	24.48

저작물 이용 허락서

<table>
<tr><td>학 과</td><td>선박해양공학과</td><td>학 번</td><td>20047604</td><td>과 정</td><td>석사</td></tr>
<tr><td>성 명</td><td colspan="5">한글 조 용 선 한문 曺 墉 瑄 영문 Cho Yong Seon</td></tr>
<tr><td>주 소</td><td colspan="5">광주광역시 서구 금호동 호반리젠시빌 3차 304동 405호</td></tr>
<tr><td>연락처</td><td colspan="5">E-mail : ddh3161@naver.com</td></tr>
<tr><td rowspan="2">논문제목</td><td colspan="5">얕은 흘수에서 두 척의 선박을 동시에 자동으로 도선하는 시스템 개발</td></tr>
<tr><td colspan="5">Development of the auto pilot system for moving two ships Simultaneously in shallow water</td></tr>
</table>

본인이 저작한 위의 저작물에 대하여 다음과 같은 조건 아래 조선대학교가 저작물을 이용할 수 있도록 허락하고 동의합니다.

- 다 음 -

1. 저작물의 DB구축 및 인터넷을 포함한 정보통신망에의 공개를 위한 저작물의 복제, 기억장치에의 저장, 전송 등을 허락함.
2. 위의 목적을 위하여 필요한 범위 내에서의 편집과 형식상의 변경을 허락함. 다만, 저작물의 내용변경은 금지함.
3. 배포・전송된 저작물의 영리적 목적을 위한 복제, 저장, 전송 등은 금지함.
4. 저작물에 대한 이용기간은 5년으로 하고, 기간종료 3개월 이내에 별도의 의사 표시가 없을 경우에는 저작물의 이용기간을 계속 연장함.
5. 해당 저작물의 저작권을 타인에게 양도하거나 출판을 허락을 하였을 경우에는 1개월 이내에 대학에 이를 통보함.
6. 조선대학교는 저작물 이용의 허락 이후 해당 저작물로 인하여 발생하는 타인에 의한 권리 침해에 대하여 일체의 법적 책임을 지지 않음.
7. 소속 대학의 협정기관에 저작물의 제공 및 인터넷 등 정보통신망을 이용한 저작물의 전송・출력을 허락함.

동의여부 : 동의(○) 반대( )

2008년 2월 25일

저작자: 조 용 선 (인)

조선대학교 총장 귀하