MINISTRY OF EDUCATION AND TRAINING MINISTRY OF AGRICUL AND RURAL DEVELOPMENT

VIETNAM NATIONAL UNIVERSITY OF FORESTRY

NGUYEN THAI VAN

RESEARCH ON MOTION DYNAMICS OF SPECIAL BOAT FOR FIRE FIGHTING BOAT IN WETLAND FOREST

Specialized: Mechanical Engineering Technology

Code: 62520103

SUMMARY OF THE TECHNICAL DISSERTATION

Ha Noi, 2017

Dissertation is completed at:

VIETNAM NATIONAL UNIVERSITY OF FORESTRY

Supervisors:

Asso.Pro.Ph.D Duong Van Tai

Asso.Pro.Ph.D Cao Hung Phi

1. The first critical person:
2. The second critical person:
3. The third critical person:

The dissertation is reported before The Council of dissertation at the University level at:

Xuan Mai, …… month ……,2017 at Vietnam National University of Forestry

INTRODUCTION

1. Rationale

Vietnam has about 500.000 ha of Melaleuca forests, mainly in the Mekong Delta. Due to the characteristics of regional climates and ecology of Melaleuca forests, the risk of forest fire is high. Annually, there are dozens of fires. Typically the melaleuca forest fire in U Minh Thuong and U Minh Ha National Park in 2002 destroyed thousands of hectares of primary melaleuca forest.

At present, the forest firefighting is mainly carried out by manual methods, leading to low productivity and fire-extinguishing efficiency, taking time and efforts.

In 2008, University of Forestry conducted the State-level key project: "Research on technology and manufacturing design of specialized equipment for forest firefighting", code KC07.13/06-10 designed and manufactured fire fighting boat in wetland forest. However, the project was mainly focused on manufacturing design, but the dynamics of the boat was not deeply studied.

There are a number of restrictions that need to be overcome when using the fire fighting boat in wetland forest: the moving velocity of the boat on the canal with many obstacles (water hyacinth) is low, thus affecting the time approaching the fire, and the boat is unstable in the motion direction as it is moving and spraying fire water and unstable (easy to be capsized) when the boat revolves and turns into a perpendicular canal.

In order to have a theoretical basis for the completion of the fire fighting boat in wetland forest, it is necessary to study the motion dynamics, stabilization of the motion direction and and anti-capsize of the boat to determine the proper parameters of the boat in order to complete and improve the use efficiency of the fire fighting boat in wetland forest.

Based on the above reasons, the thesis selected and implemented the topic: "Research on motion dynamics of of special boat for fire fighting boat in wetland forest ".

2. Reseach objectives

Modeling, establishing differential equations and investigating the factors affecting the motion dynamics of the fire fighting boat in wetland forest made in Vietnam, to serve as a scientific basis for structural completion and rational use mode, to improve the motion velocity and stability, meeting the requirements of the fire fighting boat in wetland forest.

3. New contributions of the dissertation

- ***About the sciencetific aspect***

- The dissertation has built a dynamic model and has set the straight motion differential equation of the boat on the canal with many obstacles (water hyacinth), differential equation stabilizing the motion direction of the boat when both moving and spraying fire water and differential equation stabilizing against capsize of the boat when rotating and turning into a perpendicular canal.

- The dissertation has investigated the influence of some parameters on the performance criteria of the boat. The survey results have identified some reasonable structural parameters of the boat: reasonable angle of the propeller shaft $\alpha_1 = 16.6$ degrees; Cross section profile of wedge-shaped boat bow; Hydrant angle $\beta_x < 45$ degrees; location of the fire hydrant is $a_3 = 1.5$ m from the central coordinates of the steering wheel; the minimum width of the boat B = 1.5m and the height of the maximum central coordinates h = 0.4 m. The results of this research are new contributions to the scientific basis for calculating the design of a forest firefighting canoe.

- The dissertation has developed experimental methods to measure and determine the resistance coefficient of the boat when moving on canal with water hyacinth, fire hydrant force, horizontal inclination angle of the boat on rotation, the horizontally shaking angle of the boat during the forest firefighting activities. The experimental results are a new contribution to the determination of the dynamics of the fire fighting boat in wetland forest.

- ***About practical aspect***

- The research results of the dissertation have been used for the improvement of optimal design and calculation for the fire fighting boat in wetland forest, and determining the reasonable working conditions of the existing boat.

Chapter 1. LITERATURE REVIEW

1.1. An overview of melaleuca forests and the melaleuca forest fire situation in Vietnam

1.1.1. Area and distribution of melaleuca forests

In Vietnam, there are about 500,000 ha of Melaleuca forests distributed mainly in the Mekong Delta.

1.1.2. Characteristics of canals in the Melaleuca forest area

Canals in the melaleuca forest area have many water hyacinths (hyacinths) growing and developing with dense density on the canal surface, and the shallow water level is an obstacle affecting the moving ability of the boats.

When the boat moves, its bottom has a friction with the water hyacinth, creating a large friction force, thereby increasing the resistance coefficient, resulting in a low moving speed of the boat which does not meet the requirements for rapid access to the fire.

1.1.3. Melaleuca forest fire situation in Vietnam

According to statistics of the Forest Protection Department, every year, dozens of cases of melaleuca forest fire occur in the localities where melaleuca forest is located. The most common occurrence of melaleuca forest fire is U Minh Ha National Park in Ca Mau Province; U Minh Thuong National Park in Kien Giang Province, and Tram Chim National Park in Dong Thap Province.

1.2. An overview of the studies on dynamics of the small boats

1.2.1. Studies on motion dynamics of small boat around the world

There are many studies on the dynamics and stability of small boats in the world, which mainly focus on stabilization of boats. Studies on motion dynamics of small boats and firefighting boats while moving in the canals with many obstacles are very limited and not applicable to the motion dynamics study of fire fighting boat in wetland forest.

1.2.2. Studies of motion dynamics of small boats in Vietnam

In Vietnam, there are many studies on the stability and fluctuation of boats under different conditions. The above works mainly focus on studying large ships moving on rivers and seas. There have been no studies on motion dynamics of forest firefighting boats under special conditions of Melaleuca forests, on the canals with many obstacles in the Melaleuca forests of the Mekong Delta.

1.4. Research contents

1.4.1. Theoretical study

- Constructing a motion dynamics model of a boat with three problems including:

  + Boat moving straight on the canel with obstacles (water hyacinth);

  + The boat is moving and spraying water for forest firefighting;

  + The boat revolves and turns into a perpendicular canal.

- Setting the differential equation for motion of the forest firefighting boat for the three cases mentioned above.

- Examining the impact of some factors on the performance criteria of the forest firefighting boat.

- Determining a number of reasonable parameters to complete the forest firefighting boat.

1.4.2. Experimental study

- Determining the parameters of geometry, weight, central coordinates, moment of inertia, and area of wet cross section, to serve for determining input parameters of the theoretical problem.
- Defining resistance coefficient, horizontal inclination angle, hydrant force, velocity of the boat during forest fire fighting, to test the results of calculations according to theoretical model.
- Determining the propeller propulsion when the boat moves to forest fire to serve the completion of the fire fighting boat in wetland forest.

1.5. Research objects

Objects of the study are the fire fighting boat in wetland forest designed and manufactured by the State-level key project "*Research on technology and manufacturing design of specialized equipment for forest fire fighting*" code KC 07.13/06-10, and currently used in U Minh Thuong National Park in Kien Giang Province.

1.6. Research Methods

- Applying research methodology of ship calculation theory, ship fluctuations, and theoretical mechanics.
- Applying methods of measuring non-electric quantities to determine the input parameters and output parameters.

Chapter 2. CONSTRUCTION OF THE MOTION DYNAMICS MODEL OF THE FIRE FIGHTING BOAT IN WETLAND FOREST

2.1. Determining the force components on the canoe when it moves for firefighting the Melaleuca forests

When the moving canoe is subjected to forces including: motion resistance, thrust of the propeller, centrifugal force when the boat revolves, the force of the hydrant, revolving resistance when the boat revolves, force and recovery moment. These forces affect the ability to move, stabilize the motion direction and angle of inclination of the boat, the general scheme of the force on the boat during the forest fire is shown in Figure (2.1) (2.2) (2.3)

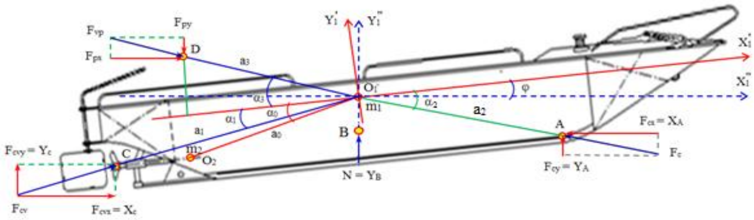

Figure 2.1. Dynamic model of the boat in the process of both moving and spraying water to fire in the XOY plane

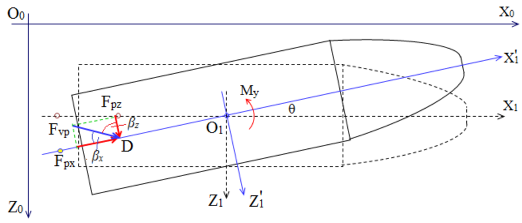

Figure 2.2. Dynamic model of the boat during the movement in the XOZ plane when spraying fire water

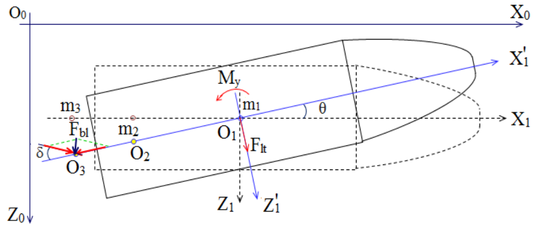

Figure 2.3. Dynamic model of the canoe during the movement in the XOZ plane when the boat revolves, and turns into the branch canal

Of which: F_c – Synthetic motion resistance of the boat;

F_{cv} - Thrust of the propeller of the boat;

F_{cq} - Resistance when the boat revolves;

N - Floating force (Acsimet force);

F_{vp} - The thrust of the hydrant affecting on the boat during the fire;

M_y – Rotating moment due to the force of the hydrant;

F_{bl} - The force of the water affecting on the steering wheel;

F_{lt} - Centrifugal force when the boat revolves.

2.3. Modeling and setting the differential equation for the movement of the fire fighting boat in wetland forest

2.3.1. Modeling and setting dynamic equations when the boat is in straight motion

2.3.1.1. Modeling

Modeling Assumption:

- The synthetic resistance force affecting to the boat set at point A is divided into two components X_A and Y_A (in which point A is the force of the resistance force at the center of the resistance area of the boat. This force depends on the longitudinal angle (lifting angle of the boat bow) φ, the sinking direction of the boat, the boat velocity, etc. and for each different position, the position of the set point A will be different and the value of the synthetic resistance F_c will be determined differently).

- The velocity of the boat is low, so the air resistance, and the wind resistance are ignored;
- The boat operating on a shallow water canel, so the wave resistance is ignored;
- Because the boat is small in size and runs on a small canal with the shallow water level, so the radiation force is calculated through the synthetic resistance force;
- When it is in straight motion, the recovery moment is ignored.

The dynamic model of the straight-moving boat is shown in Figure 2.6

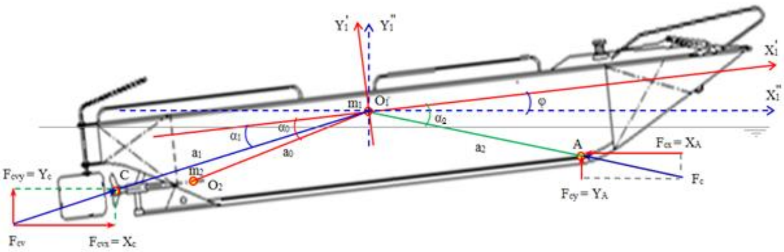

Figure 2.4. Motion dynamics model when the boat moves straight

The symbols in Figure 2.4:

$O_1 \equiv G$ - Focus of the fire fighting boat in wetland forest;

O_2 - Center of the propeller shaft system;

A - Point set for the synthetic motion resistance force of the boat;

C - Heart of the propeller;

F_{cx} - Synthetic motion resistance force in the direction of O_1X_1' located at point A;

F_{cy} - Synthetic motion resistance force in the direction of O_1Y_1' located at point A;

F_{cvx} - Jet propulsion of the propeller in the direction of O_1X_1';

F_{cvy} - Jet propulsion of the propeller in the direction of O_1Y_1';

N - Floating force (Acsimet force) of the firefighting boat.

The thrust of the water affecting to the propeller blade to the center C of the propeller will have the resistance force components at points C: X_C, Y_C, M_{cv} (Figure 2.4). In which: the propulsion F_{cv} of the propeller is determined by the moment of the propeller shaft.

Moment of the propeller shaft M_{cv} is determined by the moment equilibrium of the propeller shaft.

$$M_{cv} = M_{đc} i = N_{đc} \eta / \omega_{cv} = N_{đc} \eta / \dot{\varphi}_2 \qquad (2.1)$$

Of which: $M_{đc}$ - Moment of propulsion engine of the boat;

i - Transmission ratio of the box reducing speed;

$N_{đc}$ - Engine power;

η - Effective coefficient of the box reducing speed;

$\dot{\varphi}_2, \omega_{cv}$ - Angular velocity of the propeller shaft.

These forces (including the synthetic resistance force of the water affecting the body of the boat and the force acting on the propeller blade) of a magnitude will be determined experimentally at the scene as it depends on the water environment and state of motion.

2.3.1.2. Establishing straight moving differential equation

Applying Lagrange class II equation, the dissertation has built the following system of equations:

$$\begin{cases} (m_1 + m_2)\ddot{x}_1 + a_0.m_2 \sin(\varphi_1 + \alpha_0)\ddot{\varphi}_1 + a_0 m_2 \cos(\varphi_1 + \alpha_0)\dot{\varphi}_1^2 = X_c - X_A \\ (m_1 + m_2)\ddot{y}_1 - a_0 m_2 \cos(\varphi_1 + \alpha_0)\ddot{\varphi}_1 + a_0 m_2 \sin(\varphi_1 + \alpha_0)\dot{\varphi}_1^2 \\ \qquad = Y_A + Y_C - (m_1 + m_2)g \\ (I_{1x} + a_0^2 m_2)\ddot{\varphi}_1 + a_0 m_2 \sin(\varphi_1 + \alpha_0)\ddot{x}_1 - a_0 m_2 \cos(\varphi_1 + \alpha_0)\ddot{y}_1 \\ +2a_0 m_2 \cos(\varphi_1 + \alpha_0)\dot{x}_1\dot{\varphi}_1 + 2a_0 m_2 \sin(\varphi_1 + \alpha_0)\dot{y}_1\dot{\varphi}_1 - 2a_0 m_2 g \sin(\varphi_1 + \alpha_0) \\ \qquad = X_C a_1 (1 + \sin\alpha_1) + X_A.a_2(1 - \sin\alpha_2) + Y_C a_1 \cos\alpha_1 - Y_A a_2 \cos\alpha_2 \\ I_2\ddot{\varphi}_2 = N_{dc}\eta/\dot{\varphi}_2 \end{cases} \tag{2.2}$$

Comments: Differential equations for the straight moving boat without spraying fire water is non-uniform nonlinear differential equations whose coefficients depend only on the structural parameters of the system: masses (m_1, m_2), Geometric dimensions (a_i, x_i), and moment of inertia I_i, the angle of deviation between O_1C versus O_1X_1'' axis of the boat α_1 (propeller shaft angle).

The right side depends on the forces: the synthetic resistance force of the water environment, thrust of the propeller and engine power (X_A, Y_A, X_C, Y_C and N_{dc}).

To investigate the moving ability of the boat, as a basis for improving the structural integrity and proper use of the boat, it is necessary to solve the above differential equation system under different conditions on the structure of the boat and kinds of forces acting from water on the body of the boat. The magnitude and nature of these forces must be determined experimentally at the site of submerged Melaleuca forest at U Minh Thuong National Park in Kien Giang Province.

2.3.2. Construction of a dynamic model to stabilize the direction of motion of the boat while running and spraying fire water

2.3.2.1. Construction of motion dynamics model when the boat is both straight moving and spraying fire water

Modelling assumption:

- The boat is straight moving at a certain velocity, and spraying fire water
- The steering wheel angle does not rotate ($\delta = 0$);

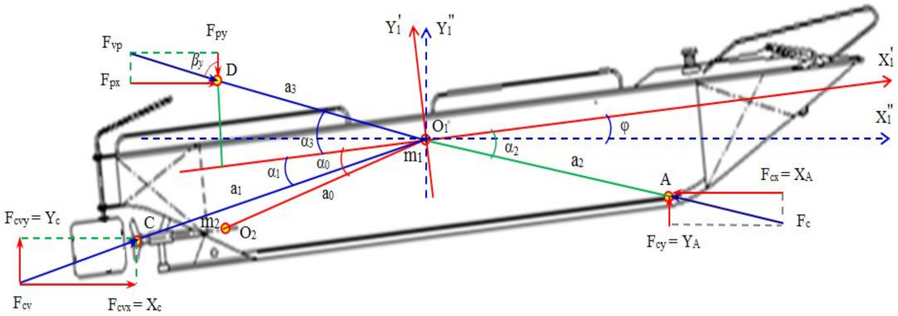

Figure 2.5. Dynamic model when the boat is both moving and spraying fire water in the vertical plane XOY

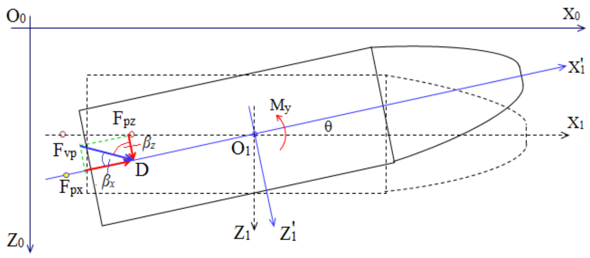

Figure 2.6. Dynamic model when the boat is both moving and spraying fire water in the horizontal plane XOZ.

The symbols in figures 2.5 and 2.6:

F_{vp} - Fire hydrant force of Melaleuca forest;

F_{px}, F_{pz} - Fire hydrant force of Melaleuca forest in the OX and OZ directions;

β_x, β_z - Deviation angle between the direction of fire hydrant and the vertical axis (O_1X_1) and the horizontal axis (O_1Z_1) of the boat body.

2.3.2.2. Establishing the differential equation for stabilizing the motion direction of the boat as it is moving and spraying fire water

From the dynamic model shown in figure 2.5 and figure 2.6, using the Lagrange type II equation, the following system of equations is constructed:

$$\begin{cases} (m_1+m_2)\ddot{x}_1 + a_0.m_2\sin(\varphi_1+\alpha_0)\ddot{\varphi}_1 + a_0m_2\cos(\varphi_1+\alpha_0)\dot{\varphi}_1^2 \\ \qquad = X_C - X_A - F_{vp}\sin\beta_y\sin\beta_z \\ (m_1+m_2)\ddot{y}_1 - a_0m_2\cos(\varphi_1+\alpha_0)\ddot{\varphi}_1 + a_0m_2\sin(\varphi_1+\alpha_0)\dot{\varphi}_1^2 \\ \qquad = Y_A - Y_C + F_{vp}\cos\beta_y - (m_1+m_2)g \\ (I_{1x}+a_0^2m_2)\ddot{\varphi}_1 + a_0m_2\sin(\varphi_1+\alpha_0)\ddot{x}_1 - a_0m_2\cos(\varphi_1+\alpha_0)\ddot{y}_1 \\ +2a_0m_2\cos(\varphi_1+\alpha_0)\dot{x}_1\dot{\varphi}_1 + 2a_0m_2\sin(\varphi_1+\alpha_0)\dot{y}_1\dot{\varphi}_1 \\ = X_Aa_2(1-\sin\alpha_2) + X_Ca_1(\sin\alpha_2-1) - Y_Ca_1\cos\alpha_1 - Y_Aa_2(1+\cos\alpha_2) \\ -a_3F_{vp}\sin\beta_y\sin\beta_z\cos\alpha_3 + a_3F_{vp}\cos\beta_y\cos\alpha_3 + 2a_0m_2g\sin(\varphi_1+\alpha_0) \\ I_2\ddot{\varphi}_2 = N_{đc}\eta/\dot{\varphi}_2 - M_c \\ (m_1+m_2)\ddot{z}_1 = F_{vp}\sin\beta_y\cos\beta_z - F_{cz} \\ I_{1y}\ddot{\theta}_1 = a_3.F_{vp}.\cos\alpha_3.\sin\beta_y.\cos\beta_z - F_{cqs}.a_S + F_{cqt}.a_T = k.S_{cqs}.a_S^3.\dot{\theta}_1^2 + k.S_{cqt}.a_T^3.\dot{\theta}_1^2 \end{cases} \tag{2.3}$$

Comments: Differential equations for the straight moving boat with spraying fire water is non-uniform nonlinear differential equations whose coefficients depend only on the structural parameters of the system: masses (m_1, m_2), Geometric dimensions (a_i, x_i), and moment of inertia (Ii), angle α_1 (deviation angle between centerline of the propeller shaft and the center of the boat relative to the OX direction in the vertical plane), deviation angle β_x between the fire (2.3) fountain and the moving direction of OX in the horizontal plane.

The right side depends on the forces: the synthetic resistance force of the water environment, thrust of the propeller, fire hydrant force and engine power (X_A, Y_A, X_C, Y_C, X_D, Y_D , F_{vp} and $N_{đc}$).

To evaluate the ability to stabilize the moving direction of the boat while moving and spraying the fire hydrant, the thesis should proceed to solve the above differential equation system under different conditions of the structure of the boat and force of hydrant, angle of the hydrant, and velocity of the boat.

2.3.3. Construction of the anti-capsized stability model when the boat turns to a perpendicular canal

2.3.3.1. Mechanic model of the revolving movement of the fire fighting boat in wetland forest

For mechanic modeling, the thesis recognizes some of the following hypotheses:

- The propeller shaft, the steering wheel shafts are connected to the body of the boat by rotary joints. They only have a relatively rotational movement around the axes;

- The steering wheel is fixed to a position with a deviation angle δ = const;

- The propeller shaft is rotating at constant angular velocity $\omega_2 = \dot{\varphi}_2 =$ const ;

- The resistance force of the water environment to the shifts is obtained in the contact domain center between water with boat body and the the steering wheel, which is proportional to the square of the velocity and the area of direct resistance.

According to the above assumptions, the mechanic model is shown in figure 2.7, figure 2.8 and figure 2.9.

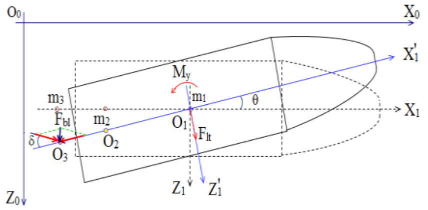

Figure 2.7. Dynamic model of the boat when it rotates in the XOZ plane

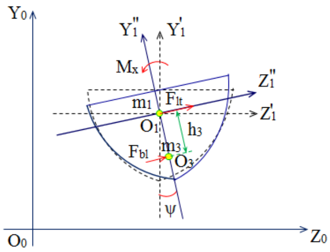

Figure 2.8. Dynamic model of the boat when revolving in the YOZ plane

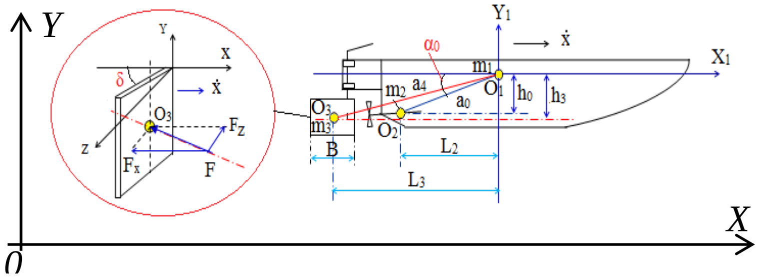

Figure 2.9. The map determines the force applied to the steering wheel when the boat revolves

The symbols in figure 2.7, figure 2.8 and figure 2.9:

$O_0X_0Y_0$ - fixed axis system (inertia);

$O_1X_1Y_1$ - dynamic axis system (attached to center of the boat body O_1);

O_1, O_2, O_3 - block coordinates of center of the boat body, propeller shaft and steering wheel axis;

δ - the relative rotation angle of the steering wheel axis, the angle between the steering wheel and O_1X_1;

θ - rotation angle of the boat body around the vertical axis O_1Y_1;

ψ - rotation angle of the boat body around the vertical axis O_1X_1 (horizontal angle of inclination);

F_{lt} - centrifugal force when the boat revolves

L_2, h_2, L_3, h_3 - horizontal and vertical distances from O_1 to O_2 and O_3.

The force applied to the steering wheel is Fbl with the intensity:

$$F_{bl} = k.S_{bl}.v_n^2 \qquad (2.4)$$

In which: k - the resistance coefficient depends on the nature of the water environment where the boat is moving;

S_{bl} - surface area of the steering wheel plate;

v_n - the velocity of water on the steering surface:

$v_n = (\dot{x}_1 + v_c)\sin\delta$ with $\dot{x}_1$- velocity of the boat body in the direction of OX;

v_c – translational velocity of the water flow by the propeller.

2.3.3.2. Establishing the differential equation for the revolving movement of the firefighting boat

Applying the Lagrange type II equation, the thesis builds the following equations:

$$\begin{cases} kS_{bl}\dot{x}_1^2 \sin^2\delta \cos\delta + (m_2h_0 \sin\psi_1)\dot{\psi}_1^2 + (kS_{cqs}a_S^2 - kS_{cqt}a_T^2)\dot{\theta}_1^2 \cos\theta_1 = 0 \\ (m_1 + m_2)\ddot{z}_1 + (m_2h_0 \cos\psi_1)\ddot{\psi}_1 + (\frac{M}{r} + kS_{bl} \sin^2\delta \cos\delta)\dot{x}_1^2 + (m_2h_0 \sin\psi_1)\dot{\psi}_1^2 \\ \qquad +\left(kS_{cqs}a_S^2\dot{\theta}_1^2 - kS_{cqt}a_T^2\dot{\theta}_1^2\right)\dot{\theta}_1^2 \cos\theta_1 = 0 \\ (m_2h_0^2 \cos^2\psi_1 + I_{1x} + I_2)\ddot{\psi}_1 + (m_2h_0 \cos\psi_1)\ddot{z}_1 \\ \qquad -h_3.k.S_{bl}.\dot{x}_1^2 \sin^2\theta_1 \cos\theta_1 + R_{Mcx}\dot{\psi}_1^2 = 0 \\ \left(m_2L_2^2 \cos^2\theta_1 + I_{1y} + I_2\right)\ddot{\theta}_1 + (m_2L_2 \sin\theta_1)\ddot{x}_1 \\ \qquad -L_3.k.S_{bl}.\dot{x}_1^2 \sin^3\delta + (k.S_{cqs}.a_S^3.\dot{\theta}_1^2 + k.S_{cqt}.a_T^3.\dot{\theta}_1^2)\dot{\theta}_1^2 = 0 \end{cases} \quad (2.5)$$

Comments:

1. The revolving motion model of the firefighting boat in the forest is a system with three solid objects moving in the horizontal plane shown in fig. 2.7 and fig. 2.8 with dynamic forces and relation as shown in fig. 2.9.

2. The differential equation for the revolving movement of the boat (2.5) is a non-uniform, nonlinear system of equations with coefficients that depend on the structural parameters including the cross-sectional area of S_n, the height of the coordinates in the center h_0 and h_3, the distance in the horizontal plane from the coordinates in the center of the boat to the center of the propeller shaft and the steering wheel center L_2, L_3 and the dynamics of the system including the moving velocity of the boat, steering angle.

3. To have a basis for improving the structure of the boat or determining the appropriate turnaround mode, the dissertation must carry out a survey of the above-mentioned dynamic equation system. Investigation of the differential equation system (2.5) is done using specialized software. Survey results are presented in Chapter 3

Chapter 3. SURVEY ON THE IMPACTS OF SOME PARAMETERS ON THE MOTION AND STABILITY OF THE FIRE FIGHTING BOAT IN WETLAND FOREST

3.1. Simulation diagram of the motion differential equations of the fire fightingboat in wetland forest

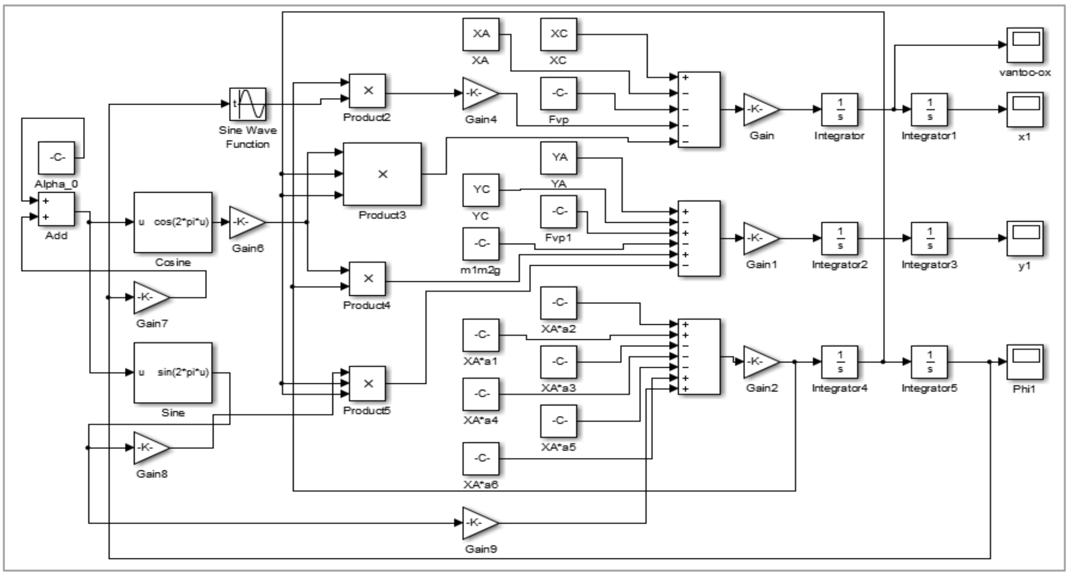

Figure 3.1. Survey diagram of straight moving dynamics of fire fighting boat

3.4. Survey results of dynamics equations of fire fighting boat

3.4.1. Survey results of the straight moving differential equation of the boat

3.4.1.1. Impact of resistance force on the boat velocity

Figure 3.2. Effects of resistance force values on the boat velocity

Comments: The greater the synthetic resistance force is, the lower the velocity of the boat is. This synthetic resistance force is caused by many factors, especially the obstacles on the canal (water hyacinth) and the boat bow profile. To improve the velocity of the boat, one of the solutions is to reduce this resistance force.

3.4.1.2 The effects of the propeller angle on the velocity of boat

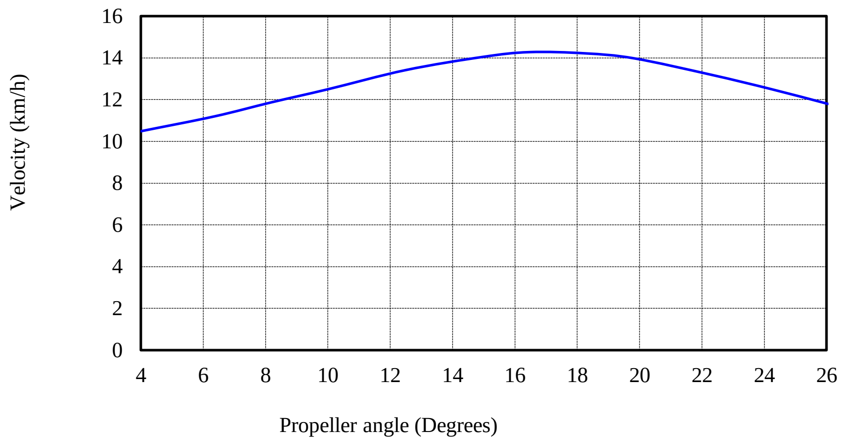

Figure 3.3. Effects of the propeller angle on the velocity of boat

Comments: The relationship between the propeller angle and the velocity of the boat is a nonlinear function. When the propeller angle is risen from 15 degrees to 20 degrees, the velocity increases. By contrast, when the propeller angle is increased by 20 degrees or more, the velocity reduces. The survey results show that the best propeller angle is between 15 ÷ 20 degrees.

3.4.1.3. Effects of lifting angle (vertical inclination) on the velocity of the boat

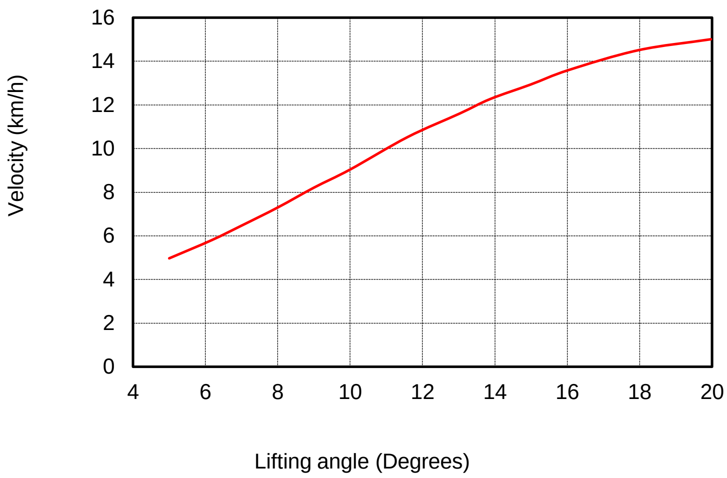

Figure 3.4. Effects of lifting angle on the velocity of the boat

Comments: The relationship between the lifting angle and the boat velocity is nonlinear. When the lift angle is greater, the resistance force is low, leading the velocity of the boat to be higher. As the boat moves, this lifting angle is higher, making the motion resistance force decrease.

3.4.1.4. Effects of the section cross section of the boat nose on the velocity

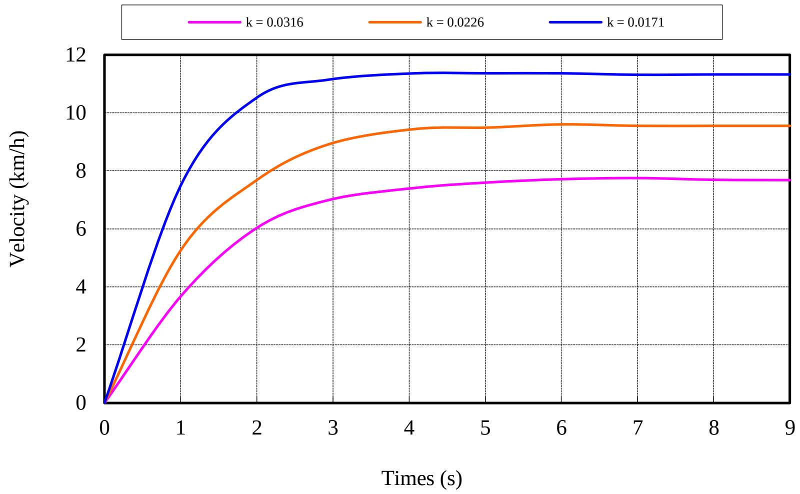

Figure 3.5. Effects of the section cross section of the boat nose on the velocity

Comments: From the survey results show that the nose structure has a wedge shape for low drag coefficient, which in turn leads to the velocity of the boat is fater. Cause most of water hyacinth is shunted to the side of the boat should reduce the drag.

3.4.2. The survey results of the differential equation stabilizing the motion direction of the boat when spraying fire water

3.4.2.1. The effects of the fire water hydrant angle on stabilization of the motion direction

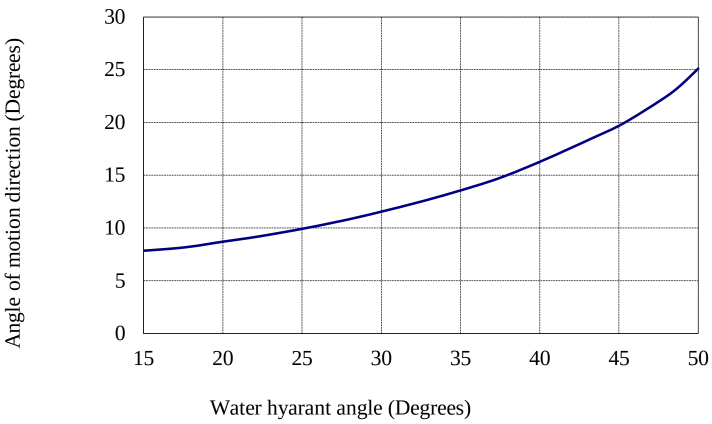

Figure 3.6. Effects of the fire water hydrant angle on stabilization of the motion direction

Comments: The larger the fire water hydrant angle is, the greater the deflection angle of motion direction is. In order for the boat to stabilize the motion direction with an angle $\theta < 20$ degrees, when the steering angle is controlled, the hydrant angle must be $\beta_x \leq 45$ degrees.

3.4.2.3. Effects of the motion velocity of the boat on stabilization of the motion direction when it sprays fire water

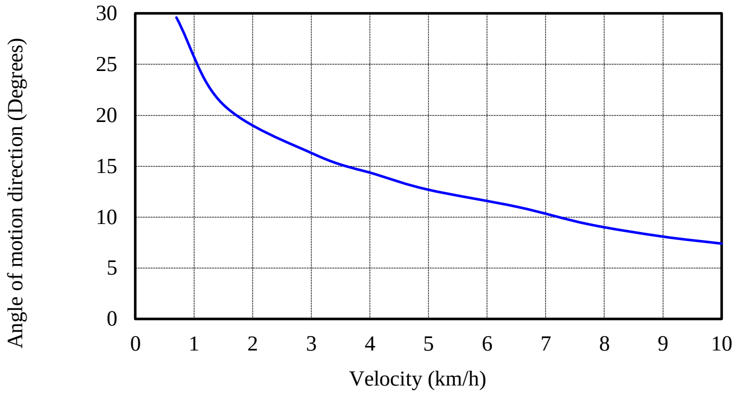

Figure 3.7. Effects of the motion velocity of the boat on stabilization of the motion direction when it sprays fire water

Comments: The larger the velocity of the boat is, the smaller the deflection angle of motion direction is. Based on the requirement of fire fighting, the velocity of the boat is v ≤ 5 km/ h. At this velocity, the boat can stabilize the direction with the intervention of the steering angle.

3.4.3. The survey results of the anti-capsized stability differential equation of the boat when rotating and turing into the perpendicular canal

3.4.3.1. Effects of the moving velocity of the boat on its horizontal inclination angle when rotating and turning into the perpendicular canal

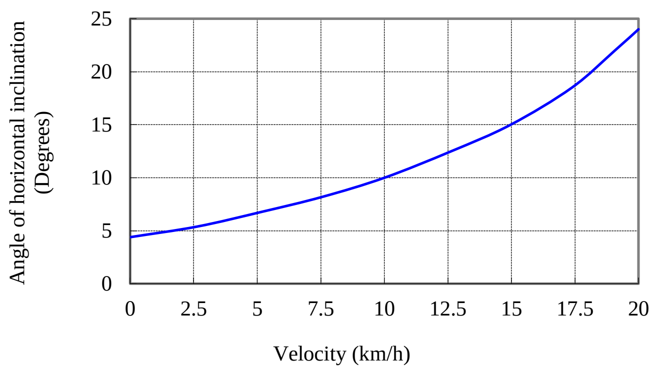

Figure 3.8. Effects of the moving velocity of the canoe on its horizontal inclination angle when rotating and turning into the perpendicular canal

Comments: When the velocity of the boat is less than 15km/h, the boat is still stable. When the boat velocity is more than 18 km/h, the boat is unstable (overflowed by the water).

3.4.3.2. Effects of section cross section S_n of the boat on its horizontal inclination angle when rotating and turning into the perpendicular canal

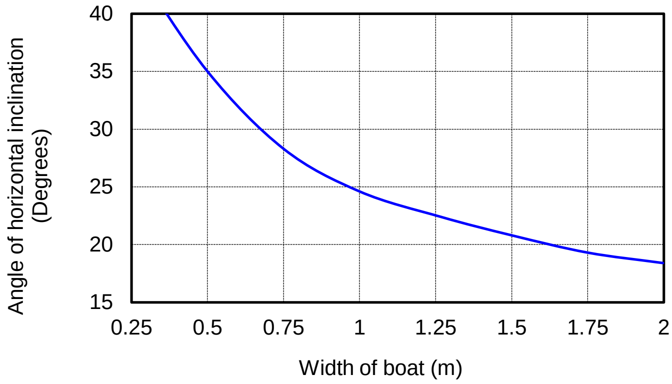

Figure 3.9. Effects of section cross section S_n on horizontal inclination angle of the boat

Comments: The smaller the width of the boat is, the larger its horizontal inclination angle is. In orer to stability boat, the minimum width of the boat is B ≥ 1.5m.

3.4.3.4. The effects of the height of the central coordinates on the horizontal inclination angle of the boat

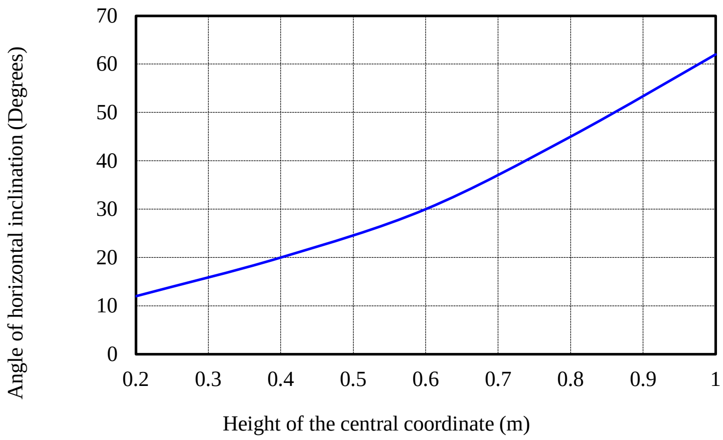

Figure 3.10. The effects of the height of the central coordinates on the horizontal inclination angle of the canoe

Comments: The greater the height of the center gravity is, the greater the horizontal inclination angle of the boat is, making the ability to anti-capsize become worse. Therefore, to ensure the stability of anti-capsize for firefighting boat, the height of the central coordinates of the boat is less than 0.4m.

3.5. Determining the parameters for completing the fire fighting boat in wetland forest

3.5.1. Structural parameters of the fire fighting boat in wetland forest

Based on the results of the survey, the dissertation has identified some parameters to improve the structure of the fire fighting boat in wetland forest as follows:

- Propeller shaft angle: to create the best synthetic thrust for the boat to move, and increase the lifting angle for the boat to reduce the motion resistance force. Based on the survey figure 3.3, when the propeller shaft angle is between 15 ÷ 20 degrees, the velocity of the boat reaches the maximum value.

- The boat bow profile: In order to cleave the water hyacinth when the boat is moving, the boat bow profile must be wedge-shaped. Then, the water hyacinth is washed to the sides of the boat to reduce the motion resistance force. Based on the survey diagram shown in fig. 3.5, when the boat bow is wedge-shaped, the velocity of the boat is the maximum.

- The minimum width of the fire fighting forest in wetland forest Based on the survey diagram shown in figure 3.9, when the width of the boat is greater than 1.5m, the maximum horizontal inclination angle is 21 degrees, smaller than the allowed inclination angle (ψ_{max} = 23 degrees). In order to stabilize the anti-capzise of the boat in all conditions, the minimum width of the boat is B = 1.5m.

- Height of the central coordinates: Based on the survey diagram shown in figure 3.10, in order to stabilize anti=capsize of the boat in all conditions, the height of the central coordinates of the boat should be highest h = 0.4m.

3.5.2. The usage parameter of the fire fighting boat in wetland forest

Based on the results of the survey, the thesis has identified some parameters used to complete the fire fighting boat in wetland forest as follows:

- Determining the velocity of the boat while moving and spraying the fire water: Based on the survey diagram shown in fig. 3.7, when the velocity of the boat is v = 3 km / h, the angle of motion direction stability of the boat is θ = 16 degrees. Then, in conjunction with the steering mechanism control, the boat can still stabilize the motion direction. According to the requirement of forest firefighting technology, the maximum allowable velocity is v = 5 km/h. Thus, in order to meet the conditions of stability of the direction and technology of firefighting, the most suitable velocity of the boat is between 3 to 5 km/h.

- Determining the firefighting hydrant angle: Based on the survey diagram figure 3.6, when the hydrant angle is $\beta_x \leq 45$ degrees, the angle of motion direction stability of the boat reaches θ = 20 degrees. Then, in combination with the control of the steering mechanism, the boat can still stabilize the motion direction. According to requirements of the forest firefighting technology, the firefighting hydrant angle β_x = 90 degrees is best. Thus, to meet the conditions of direction stability and technology of firefighting, the optimal hydrant angle is $\beta_x \leq 45$ degrees.

- Determining the velocity when the boat rotates and turns into the perpendicular canal: Based on the survey diagram figure 3.8, when the velocity of the boat is v = 18 km / h, the angle of horizontal inclination is $\psi = 20$ degrees, in which the angle of limited horizontal inclination is $\psi_{max} = 23$ degrees. Therefore, to make the boat not be overflowed by the water during rotation, the maximum velocity allowed is v = 18km / h.

Chapter 4. EXPERIMENTAL STUDY

4.1. Objectives and tasks of empirical research

4.1.1. Objectives of empirical research

1. Determining the numerical value of some quantities, some coefficients in the motion differential equation of the fire fighting boat in wetland forest for the purpose of examining the motion of the boat whose problem model was set up in Chapter 2.

2. Testing some of the theoretical calculations, from which the reliability of the established mathematical equation has been evaluated.

3. Determining some reasonable parameters of the boat as the basis for completing the fire fighting boat in wetland forest.

4.1.2. The tasks of empirical research

To achieve the goal above, the tasks of empirical research are as follows:

- Determining the central coordinates of the boat (l, b, h);
- Determining the moment of inertia (I);
- Determining of resistance force (R / XA);
- Determining propeller thrust (Fcv);
- Determining the thrust of the firefighting hydrant (Fvp);
- Determining the rocking (oscillation) of the boat (ψ);
- Determining the angle of limited horizontal inclination of the boat (ψ_{max});
- Determining the velocity of the boat (v).
- Determining the angle of motion direction stability when the b boat th moves and sprays fire water (θ).

4.3. Organizing and conducting experiments

4.3.1. Measuring the motion resistance force of the canoe

The experiment was carried out on a canal of seaweeds, water- fern, water hyacinths, etc. with a certain density at U Minh Thuong National Park in Kien Giang Province by using the canoe with high power to pull melaleuca firefighting boat (the experimental canoe) at the required velocity of the firefighting boat of 15km/h. The sensor measuring traction force is connected to the DMC Plus and the computer, and the result is stored on the computer. The measurement process is shown in Figure 4.1.

Figure 4.1. Resistance force measuring experiment

In order to ensure the reliability of the experimental data at 95%, according to the method known, the thesis has determined the number of repetitions of each experiment is 3. Figure 4.2 is the motion resistance diagram of the forest firefighting boat at the velocity of 15km/h. The experimental results were processed by DMC Labplus and Catman software.

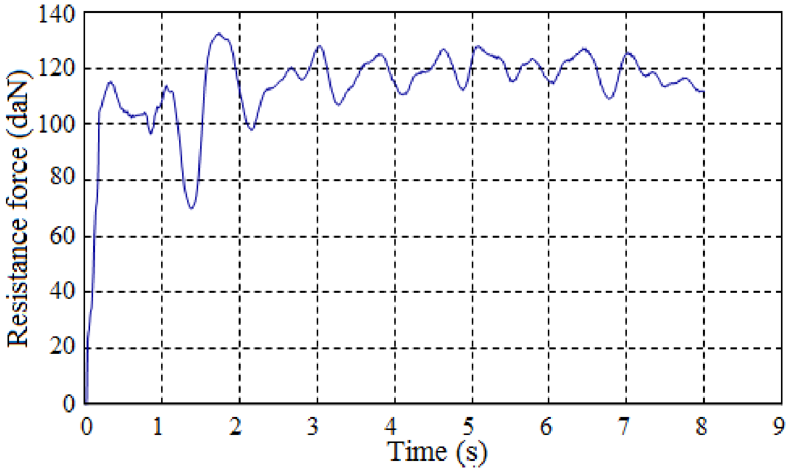

Figure 4.2. Resistance force measuring diagram

4.3.2. Measuring the horizontal inclination angle (capsized angle) of the boat when rotating

The horizontal inclination measuring experiment was conducted at the scene. The measurement process was performed as follows: running the canoe at the largest velocity, then driving with the highest steering angle to make the canoe rotates, as shown in figure 4.3.

Figure 4.3. Experiment of measuring the horizontal inclination angle when the boat rotates with the highest steering angle

Using the measuring device of horizontal inclination angle to record the value. The experimental results were processed by DMC Labplus and Catman software, as show in figure 4.4.

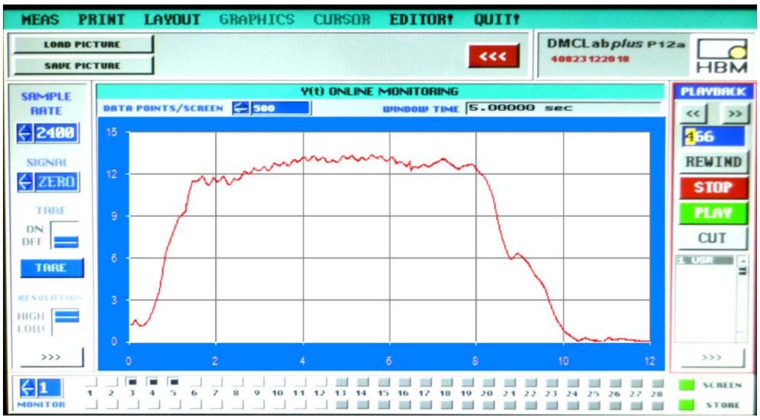

Figure 4.4. Result of measuring the horizontal inclination angle of boat

4.4 Results of empirical research

4.4.1. Determining the motion resistance coefficient between the canoe and the obstacles on the canal

Table 4.1. The motion resistance coefficient between the canoe and the obstacles on the canal

The status of canal	The resistance coefficient k varies with different velocity			
	6 km/h	**9 Km/h**	**12 Km/h**	**15 Km/h**
Water with no water-fern	0.0168	0.0171	0.0214	0.0240
Water lentil	0.0189	0.0229	0.0236	0.0262
Water hyacinth	0.0241	0.0258	0.0264	0.0271
Mixture	0.0225	0.0231	0.0261	0.0266

Table 4.2. The motion resistance coefficient of the boat correlates with the different boat bow profiles

The status of canal	**The resistance coefficient k varies with the different boat bow profiles**		
	Wedge-shaped	**Ellipse –shaped**	**Trapezoid - shaped**
Water with no water-fern	0.0240	0.0274	0.0316
Water lentil	0.0262	0.0296	0.0331
Water hyacinth	0.0271	0.0319	0.0358
Mixture	0.0266	0.0305	0.0346

4.4.2. Determining the velocity of the forest firefighting boat in relation to the different propeller axis angles

Table 4.3. The velocity of the boat varies with the different propeller axis angles

No	**Measurement parameters**	**The propeller axis angles**				
		5^0	10^0	15^0	20^0	25^0
1	The velocity of the boat (km/h)	9.3	10.8	12.4	12.8	11

4.4.3. Determining the horizontal inclination angle (capsized angle) when the boat rotates

Table 4.4. The horizontal inclination angle of the boat when it turns into the branch

No	**Measurement parameters**	**The horizontal inclination angle varies with different velocity**			**The limited horizontal inclination angle**
		5 km/h	10 km/h	15 km/h	
1	**The horizontal inclination angle (degree)**	5.6	9.2	13.7	23

4.4.4. Determining the angle of motion direction stability

Table 4.5. Motion deviation angles of the firefighting canoe at different velocity

No	**Specified parameters**	**The velocity of the boat**			
		2 km/h	3 km/h	5 km/h	10 km/h
1	Deviation angle θ (degrees)	16.5	14.2	11.3	6.6

4.5. Comparing the results of theoretical and empirical calculations

4.5.1. Comparing the motion velocity of the boat when moving on the canal with obstacles

Table 4.6. Comparing the motion velocity of the boat in the theoretical and empirical model

No	Comparison status	Motion velocity (km/h)		
		Theoretical survey results	Empirical results	Error (%)
1	Propeller angle ($\alpha_1 = 5^0$)	10.5	9.3	11.4
2	Propeller angle ($\alpha_1 = 10^0$)	12.5	10.8	13.6
3	Propeller angle ($\alpha_1 = 15^0$)	14.1	12.4	12
4	Propeller angle ($\alpha_1 = 20^0$)	14.0	12.8	8.5
5	Propeller angle ($\alpha_1 = 25^0$)	11.8	11.0	6.8

Comments: From the above experimental results, we have had some following comments:

- The discrepancy between the results determining the motion velocity of the boat on the canal with many obstacles; the stability of the boat through the motion deviation angle and the capsized angle of the boat when revolving and turning into a perpendicular canal by empirical test in comparison with theoretical calculation is allowed and acceptable. Therefore, the motion dynamics model of the boat in theory can be reliable. The difference between the results in the problem of theory and experiment is impacted by some factors affecting mutually during the experiment that the theoretical research has not been mentioned.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

Based on theoretical and empirical studies on the motion dynamics of the fire fighting boat in wetland forest, the dissertation has achieved the following results:

1. The fire fighting boat in wetland forest is new equipment designed by the State-level key project and being used effectively in fire fighting units at the forests in the Mekong Delta. However, there are a number of shortcomings that need to be addressed to meet the requirements of forest firefighting technology.

2. The dissertation establishes the model and the straight moving differential equation of the boat (2.2), the differential equation when the boat is both moving and spraying the fire hydrant (2.3), the differential equation when the boat revolves and turns into the perpendicular canal (2.5).

3. The dissertation investigated the differential equations that were established in Chapter 2. The results of the survey identified a number of reasonable structural

parameters of the fire fighting boat in wetland forest including: Proper angle of the propeller shaft of 15 ÷ 20 degrees, the horizontal section of the bow of the boat is wedge-shaped to cleave water-fern for reducing the resistance coefficient of the boat, reasonable hydrant angle of $\beta_x \leq 45$ degrees; the rational use mode includes the velocity of the boat when it is traveling and spraying water v = 3÷5 km/h; the maximum velocity when rotating and turning into the perpendicular canal v = 18 km/h makes the boat stable (not flooded in the boat).

4. The dissertation has developed an empirical research method identifying a number of dynamic parameters including: central coordinates, moment of inertia, and resistance coefficient corresponding to the boat bow profile of the canal with various obstacles, propeller thrust, fire hydrant force. The thesis conducted comparing the results of the calculation of theoretical and empirical models. The comparative results show that the error lies within the allowable range (<15%), thus confirming that the mathematical model of the theory developed in Chapter 2 is credible.

5. By experimental research, the dissertation has identified some structural parameters and rational use regimes to complete the fire fighting boat in wetland forest, including the best propeller shaft angle α_1 = 16.6 degrees, the position of the fire hydrant is 1.5 m towards the steering wheel from the central coordinates of the boat, the angle of the fire hydrant β_x = 45 degrees, the velocity when the boat is moving and spraying fire water v = 3 ÷ 5 km/h, the velocity of the boat when rotating and turning into the perpendicular canal v = 15 km / h.

6. The parameters of the boat derived from the research results have overcome the shortcomings of the current used boat and met the technical and technological requirements of the firefighting boat: the large velocity of the boat to reach the fire, stabilization of the motion direction when the boat is moving and spraying fire water, and stabilization of anti-capsize when the boat rotates and turns into the perpendicular canal.

2. Recommendations

Studying motion dynamics of the fire fighting boat in wetland forest is a big issue that takes a long time to research. Therefore, in order to complete the dissertation, the following contents should continue to be studied:

1. Study of boat fluctuations to limit the impact on the health of the firefighter and the quality of fire fighting equipment.

2. In-depth study of the boat bow profile and boat line to minimize the resistance coefficient but still ensure stability in the operating mode of the boat.

3. In-depth study of the resistance coefficient of friction between the boat surface and obstacles on the canal (water hyacinth) to reduce the resistance coefficient.

4. Study of the motion dynamics models of the boat when it goes through dry areas with hoist.

LIST OF PUBLISHED ARTICLES

1. Duong Van Tai, Cao Hung Phi, **Nguyen Thai Van** (2013), *Stability calculation of mangrove forest fire fighting boat*, VietNam mechanical engineering magezine – No 12^{sd}, 2013, Pages 65 ÷70.

2. Nguyen Thi Luc, **Nguyen Thai Van** (2014), establishing the motion differential equation of firefighting boat in wetland forest by theory of multiples systems mechanics , Science and Technology Journal of Agriculture and Rural Development – No 11st, 2014, Pages 78 ÷ 82.

3. Duong Van Tai, **Nguyen Thai Van** (2016), *Modeling dynamic of curve motion of special boat for fire fighting in wetland forest*, - Forestry Science and Technology Journal of Vietnam National University of Forestry – No 4th, 2016, Pages 103 ÷ 108.

4. **Nguyen Thai Van**, Duong Van Tai, *Survey the factors that affect the speed, direction stability and anti-roll of special boat for fire fighting in wetland forest*, - Forestry Science and Technology Journal of Vietnam National University of Forestry – No 4th, 2016, Pages 116 ÷ 123.

5. **Nguyen Thai Van**, Duong Van Tai, Nguyen Quang Tuyen, *Survey the factors that affect direction stability of special boat for fire fighting in wetland forest* - Forestry Science and Technology Journal of Vietnam National University of Forestry, No 1st, 2017, Pages 94 ÷ 101

6. Duong Van Tai, **Nguyen Thai Van,** Nguyen Qunag Tuyen, *Experimental results measuring dynamic parameters of fire fighting boat in wetland forest* - Forestry Science and Technology Journal of Vietnam National University of Forestry, No 1st, 2017, Pages 74 ÷ 79