MANOEUVRING CONTROL FOR PUSHER BARGE IN INLAND WATERWAY

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To my great Father and Mother, Brothers and Sisters, my Dear Wife and my Sons, whose prayers always afforded me the power to accomplish this work. To all I dedicate this work with great respect and love.

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ABSTRACT

This paper presents the result of analysis on manoeuvring control system for pusher barge in inland waterway by using Proportional Integral Derivative (PID) and Active Force Control (AFC). The study was carried out with two main objectives; firstly is to develop a fast time domain simulation program as a 'tool' for the manoeuvring control analysis. The analysis will be used to predict the manoeuvring characteristics and control system at the early stage of design. Secondly, to evaluate the difference of control system for manoeuvrability of pusher barge in inland waterways for both conditions of Proportional Integral Derivative (PID) and Active Force Control (AFC). The paper begins with the literature review on manoeuvring characteristics, the pusher barge system and definition of control system as generally and focusing on Proportional Integral Derivative (PID) and Active Force Control (AFC). The simulation program will be used to manipulate the data calculated. The result and analysis of this study will be presented in order to highlight the effectiveness of manoeuvring characteristics and control system for pusher barge. Finally, the paper proposes the effectiveness of using Proportional Integral Derivative (PID) and Active Force Control (AFC) as a system that use for control pusher barge in inland waterway.

ABSTRAK

Thesis ini mengemukakan keputusan kajian analisa sistem kawalan barj tolak di perairan pendalaman dengan menggunakan pendekatan Sistem Terbitan Perlu Seimbang (Proportional Integral Derivative) dan Kawalan Daya Aktif (Active Force Control). Kajian ini mengandungi dua (2) objektif teras; pertama ialah membangunkan satu program simulasi yang digunakan sebagai alat pembantu bagi meramal dan menyelesaikan analisa sifat olah gerak sistem berj tolak pada peringkat permulaan reka bentuk. Kedua, bagi menilai perbezaan di antara sistem kawalan yang digunakan dalam pengendalian barg tolak di kawasan pendalaman untuk dua (2) sistem yang berbeza iaitu Sistem Terbitan Perlu Seimbang (Proportional Integral Derivative) dan Kawalan Daya Aktif (Active Force Control). Thesis ini bermula dengan pendekatan ilmiah tentang sifat-sifat olah gerakan, jenis sistem barj tolak, maksud sistem kawalan secara amya dan Sistem Terbitan Perlu Seimbang (Proportional Integral Derivative) dan Kawalan Daya Aktif (Active Force Control) secara khususnya. Program simulasi yang dihasilkan akan diguna bagi menjana data yang dikumpul. Keputusan dan analisa yang diperolehi dari kajian ini akan diketengahkan bagi melihat kesan dan pengaruh yang dimainkan dalam sifat olah gerak dan sistem kawalan barj tolak. Akhir sekali, thesis ini mencadangkan pendekatan yang harus digunakan dalam sistem kawalan samaada Sistem Terbitan Perlu Seimbang (Proportional Integral Derivative) dan Kawalan Daya Aktif (Active Force Control) sebagai sistem kawalan bagi barj tolak di kawasan pedalaman

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LIST OF NOMENCLATURE

Abbreviation

ATB	-	Articulated pusher barge
IMO	-	International Maritime Organization
ITB	-	Integrated Tug Barge
MMG	-	Mathematical Manoeuvring Model
PMM	-	Planar Motion Mechanism
PID	-	Proportional Integral Derivative
AFC	-	Active Force Control

Symbols

a_1, a_2, a_3	-	Constant
a_H	-	Rudder to hull interaction coefficient
A_R	-	Rudder area
B	-	Ship breadth
C_B	-	Block coefficient
C_N	-	The gradient of the lift coefficient of rudder
C_P	-	Prismatic coefficient
C_{WA}	-	Water plane area coefficient, after body
C_{WPa}	-	Water plane area coefficient
D_P	-	Propeller diameter

F	-	Vector force acting on the ship
F_N	-	Rudder normal force
g	-	Acceleration due to gravity
I	-	Moment of inertia
I_{ZZ}, J_{ZZ}	-	Moment of inertia and add moment of inertia around Z-axis
J_P	-	Advance coefficient
K_T	-	The trust coefficient of a propeller force
L	-	Ship length
M	-	Vector moments acting on the body
m, m_x, m_y	-	Mass of ship and added mass in X and Y direction
N	-	Yaw moment
n	-	Propeller revolution
P	-	Propeller pitch
r	-	Yaw velocity
r'	-	Dimensionless turning rate [$r' = r(L/U)$]
T	-	Ship draught
t_P	-	Thrust reduction coefficient in straight forward moving
t_R	-	Coefficient for additional drag
U	-	Ship speed
u	-	Surge
U_R	-	Effective rudder inflow velocity
V	-	The linear velocity vector
v	-	Sway
W_{RO}	-	Effective wake fraction coefficient at rudder location in straight forward motion
w_P	-	Effective wake fraction coefficient at propeller in r location

w_{PO}	-	Effective wake fraction coefficient of propeller in straight running
x_H	-	The distance between the center of gravity of ship and center of lateral force
X_O, Y_O	-	Total forces in X and Y direction
X_P	-	Propeller trust
x_R	-	The distance between the center of gravity of ship and center of lateral force
$\ddot{x}$	-	Second derivatives of x with respect to time, t
$\dot{y}$	-	First derivative of y with respect to time, t
$Y_\beta, Y_r, N_{\beta\beta r}$	-	Hydrodynamic derivatives
α_R	-	Effective rudder angle
β	-	Drift angle at the center of gravity C.G. [$\beta = sin^{-1}(v/U)$]
γ	-	Flow straightening factor
δ	-	Rudder angle
η	-	The ratio of propeller diameter by rudder height (DP/h_R)
ρ	-	Density of fluid
Ω	-	The vector angular velocity
ψ	-	Yaw angle

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Simulation is an important feature in engineering systems or any system that involves many processes. A simulator may imitate only a few of the operations and functions of the unit it simulates. Contrast with: emulate. (Source: Federal Standard 1037C). Most engineering simulations entail mathematical modeling and computer assisted investigation. There are many cases, however, where mathematical modeling is not reliable.

Simulation process is critical, in achieving cost and time savings during the design stage. Simulator can be used to design processes and optimize production systems by using well established routines available within the software package. Computing tools such as MATLAB can be used to model these new technologies or modify existing ones. However, MATLAB lacks the extensive thermo-physical property and equipment database. The connection of this software package leads to an integral powerful simulation tools for the study of new processes.

A computer simulation or a computer model is a computer program that attempts to simulate an abstract model of a particular system. Computer simulations have become a useful part of mathematical modeling of many natural systems in physics (Computational Physics), chemistry and biology, human systems in economics, psychology and social science and in the process of engineering new technology, to gain insight into the operation of those systems. Traditionally, the formal modeling of systems has been via a mathematical model, which attempts to find analytical solutions for problems which enable to predict the behaviour of the system from a set of parameters and initial conditions. Computer simulations build on and are a useful adjunct to purely mathematical models in science, technology and environment.

Therefore, the aims of the research are to develop two types of control system simulation programs to predict and analyze the effectiveness in term of manoeuvring control of pusher barge system in inland waterways and costal regions. Importantly, it is to compare the most effectiveness system that will be use inboard of the ship.

1.2 Problem Statement

In the carrying out the simulation study for pusher barge control system, several issues will be addressed as follow:

1. What is the critical condition of the inland waterway around the world;
2. For the vessels using this passage, how they monitor the manoeuvring characteristics such as turning ability and zig-zag manoeuvre and what is the problem they faced;
3. What type of control system they used to control the manoeuve of the vessel and how effective they are?

1.3 Objectives of the Research

In addressing the above issues, this research work is carried out with the following objectives:

1. To develop a fast time domain simulation program as a tool for the manoeuvring analysis of pusher barge system to predict the manoeuvring control system at the early stage of design;
2. To evaluate the difference and effectiveness of manoeuvrability control system for pusher barge in inland waterways for both types of systems Proportional Integral Derivative (PID) and Active Force Control (AFC).

1.4 Scope of the Research

The scope of the research is listed as follows:

1. Conduct literature research on Pusher-Barge Systems, Mathematical Modelling of manoeuvring behaviour of pusher-barge, Proportional Integral Derivative (PID) and Active Force Control (AFC);
2. Calculate important parameters (such as propeller and rudder parameters) and hydrodynamic derivatives;
3. Develop fast-track time domain simulation program for the manoeuvring analysis;
4. Analyze the manoeuvring criteria by incorporating the derived hydrodynamic derivatives in the simulation program.

1.5 Approach

This topic discusses the approach of the project that has been taken to ensure the objectives of the project will be achieved. It also presents the project flow chart.

The approach can be explained in the following three phases of development:

1. First Phase - 'Tool' Development
2. Second Phase - Identification of the control characteristics;
3. Third Phase - Improving the manoeuvrability control of pusher barge

The first phase of the research involves the development of fast time domain simulation programs. This is basically to simulate the manoeuvring control motion of the pusher barge. Using time integration techniques, the pusher barge's control are computed from the equations of motions, forces and moments using the approximate formulae or derived from previous works.

The second phase of the research involves the running of simulation programs in order to assess manoeuvrability of pusher barge in PID and AFC conditions. Simulated manoeuvres result should be reliable with control characteristics involved.

The third phase of the research involves the improvements of the manoeuvrability of the pusher barge in deep and shallow water conditions in case of getting poor manoeuvring characteristics. And that can be simulated by applying further changes on hull and/or rudder and/or propeller parameters until achieving the optimum manoeuvring characteristics which comply with the IMO criteria.

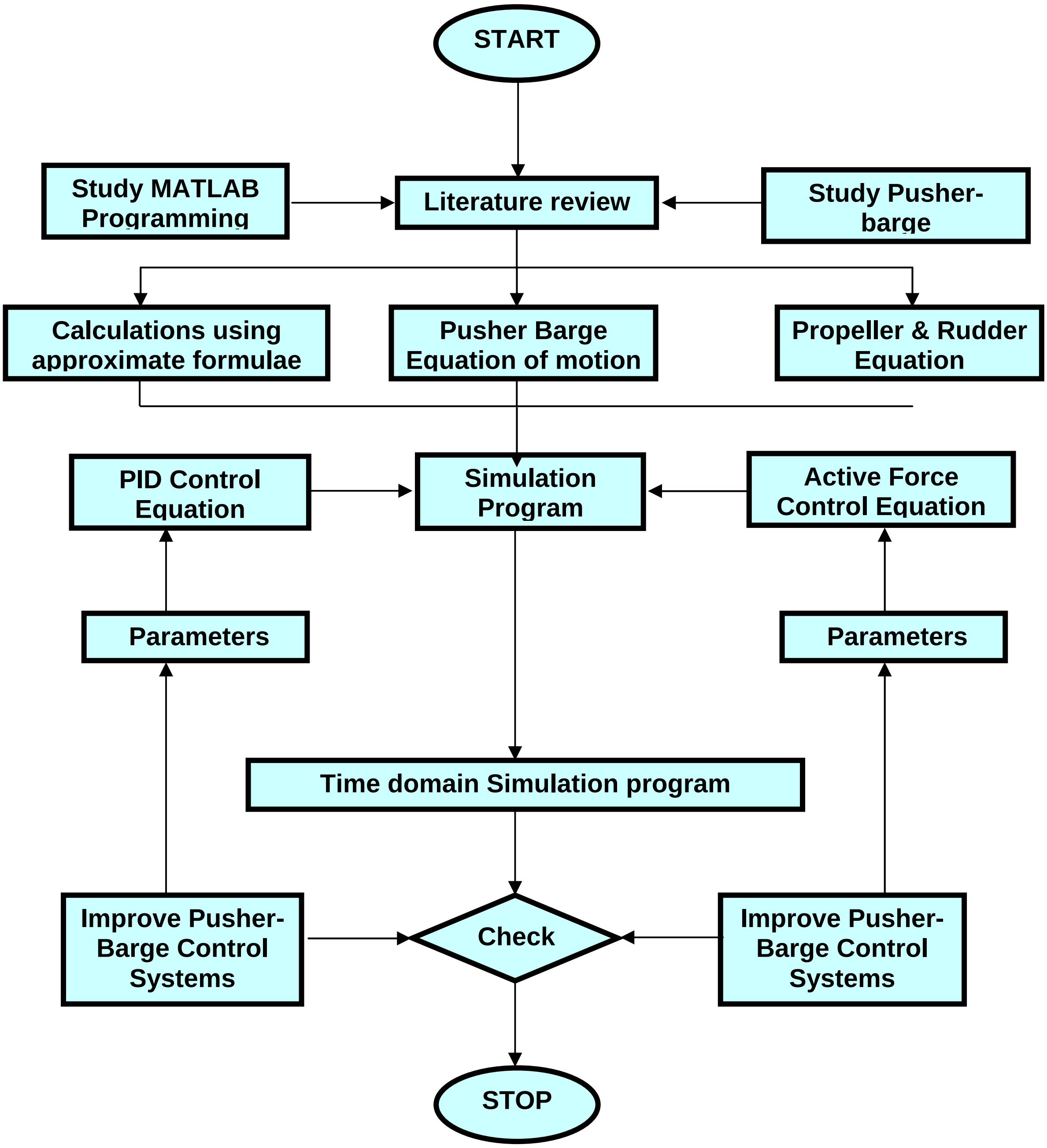

Figure 1.1: Flowchart of the methodology