PERFORMANCE PREDICTION FOR HIGH SPEED CRAFT

ANUAR BIN BERO

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Dedicated with love to my wife and children

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ABSTRACT

Generally the performance of the high speed craft can be divided into six main components such as resistance and powering, propulsion, dynamic instability, seakeeping and manoeuvring. Performance prediction on high speed craft especially in planing hull is complicated due to complex combination of ship behaviour in rough sea condition. The performance of high speed craft is becoming more important due to their various functions and purposes to marine community which is unable to be predicted using conventional methods. The fundamental of this research is to study the two main components of the vessel i.e. resistance and seakeeping quality by incorporating stern foil at aft portion planing craft (M Hull) that gives significant effect to the performance of the vessel. Theoretically, stern foil has a similar function with transom flap, trim wedges and trim tab which is to reduce the resistance and also as a damping for motion reduction. In the scope of resistance performance for this vessel with stern foil, the Savitsky and two dimensional Methods are used for resistance prediction at different angle of attack. While Computational Methods i.e. SEAKEEPER program was applied to seakeeping prediction in regular wave (head sea). Both result of resistance and seakeeping performance prediction was validated by conducting model test for the model with and without stern foil. The performance of ship model with stern foil gives a positive performance in term of seakeeping quality at constructive resistance. By adapting with stern foil the heave and pitch Response Amplitude Operator (RAO) trim down by 4.0% and 18.91% respectively. Furthermore, the reduction of forward and aft acceleration RAO also occurs concurrently which the decreasing of both acceleration are 21.10% and 6.14%.

ABSTRAK

Secara amnya, prestasi kapal laju dibahagikan kepada enam komponen utama iaitu rintangan dan daya tujahan, dorongan, ketidakstabilan dinamik, *seakeeping* dan *manoeuvring*. Anggaran terhadap prestasi kapal laju terutamanya *planing hull* adalah sangat sukar disebabkan gandingan sifat kapal yang komplek pada keadaan laut yang bergelora. Kajian ini lebih menumpukan kepada dua perkara iaitu rintangan dan kualiti *seakeeping* pada kapal laju berbentuk M Hull yang dipasang dengan foil buritan. Secara teori, foil buritan mempunyai fungsi yang sama dengan kepak buritan, baji buritan dan *trim tab* yang mana berpotensi bagi mengurangkan rintangan dan juga sebagai peredam untuk meminimumkan pergerakan kapal. Kaedah anggaran Savitsky dan dua dimensi telah diaplikasi bagi mengira prestasi rintangan kapal yang mempunyai sudut pesongan yang berbeza. Sementara program simulasi SEAKEEPER pula digunakan dalam anggaran sifat kapal seperti *heave, pitch*, pecutan haluan dan buritan pada keadaan ombak yang seragam. Hasil keputusan secara teori bagi pengiraan rintangan dan simulasi seakeeping dibandingkan dengan keputusan data ujian rintangan dan ujian seakeeping untuk mengesahkan prestasi kapal dengan foil buritan atau sebaliknya. Ini dibuktikan secara eksperimen, dengan memasang foil buritan prestasi kapal laju dapat ditingkatkan yang mana pengurangan *heave* RAO sebanyak 4% dan *pitch* RAO 18.91%. Malahan pecutan haluan dan buritan juga berkurang, masing-masing menunjukkan prestasi dapat ditingkatkan sehingga 21.10% dan 6.14%.

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NOMENCLATURE

L_{OA}	-	Length Overall (m)
L_{WL}	-	Length waterline (m)
B_{oa}	-	Breadth overall (m)
B_{WL}	-	Breadth at waterline (m)
T	-	Moulded draft (m)
Δ	-	Displacement (tone)
∇	-	Volume (m^3)
V	-	Ship speed (m/s)
LCB	-	Longitudinal Centre of Buoyancy (m)
LCG	-	Longitudinal Centre of Gravity, from transom (m)
B/T	-	Breadth draught ratio
L/B	-	Length breadth ratio
$L/\nabla^{1/3}$	-	Length-displacement ratio
g	-	Specific gravity (9.81m/s^2)
ρ	-	Mass density, (1025 kg/m^3)
ν	-	Kinematic velocity, m$^{2/}$s
R_n	-	Renault number $\frac{VL}{\nu}$
F_n	-	Froude number $V/\sqrt{g}L$
S	-	Wetted surface area
R_T	-	Total resistance (N)
R_F	-	Friction resistance according to the ITTC-1957 friction formula (N)
R_R	-	Residual resistance (N)
P_E	-	Effective power (kW)
$1 + k_1$	-	Form factor the viscous resistance of the hull form in relation to R_F
C_F	-	Coefficient of friction
C_R	-	Residuary resistance coefficient

C_A	-	Ship model-ship correlation
C_T	-	Total resistance coefficient
i_E	-	The angle measured in the plane of the water plane, between the hull and the centerline (deg)
β	-	Deadrise angle (deg)
C_B	-	Block coefficient
C_{WP}	-	Waterplane area coefficient
R_W	-	wave resistance
C_M	-	Midships coefficient
C_P	-	Prismatic coefficient
C_v	-	Speed Coefficient $\frac{V}{\sqrt{gB_{WL}}}$
τ	-	Trim angle (deg)
C_{Lo}	-	Flat plate lift coefficient
$C_{L\beta}$	-	The lift coefficient for finite deadrise
λ	-	Wetted length beam ratio
λ_k	-	Wetted length of the keel (m)
W	-	Vessel Displacement (N)
R_{nb}	-	Renault Number based on B_{WL}
ΔC_F	-	Correction factor which obtained from ATTC Standard Roughness
I_w	-	Linearized Integral
w_i	-	Vertical Inflow Velocity
φ	-	Velocity Potential
Γ	-	Circulation
D	-	Foil Drag
R_v	-	Viscous resistance Foil or Strut (N)
C_{Dv}	-	Viscous resistance coefficient Foil or Strut
L_v	-	Lift Force due to Viscous
C_{Lv}	-	Lift coefficient due to Viscous
C_F	-	Friction coefficient
R_{nc}	-	Reynolds number Chord Based
t/c	-	Foil thickness to chord ratio
V	-	Ship speed (m/s)
$\boldsymbol{C}$	-	Chord length (m)

ν	-	Kinematic viscosity (m^2/s)
A	-	Planform area Foil or Strut (m)
R_i	-	Induced resistance Foil or Strut (N)
L_i	-	Lifting Force (induced) Foil or Strut
C_{Di}	-	Induced resistance coefficient
C_{Li}	-	Lift coefficient
Λ	-	Aspect ratio, $\left(\frac{4s}{\pi c_0}\right)$
α	-	Angle of attack (radian)
c_0	-	Chord length at midspan (m)
A	-	Planform area (projected area of the elliptical foil ,$\left(\frac{s^2}{\Lambda}\right)$ (m^2)
s-	-	Span length (m)
$A(\theta)$	-	Complex wave amplitude function
B	-	Parabolic strut
C_{Lw}	-	Lift coefficient (wave)
R_w	-	Wave resistance Foil (N)
C_{Dw}	-	Wave resistance coefficient
C_{Lw}	-	Lift coefficient
f	-	Maximum camber (m)
R_s	-	Spray Resistance
$\sum F$	-	The sum of various fluid forces (vertical hydrodynamic forces as well as the wave excitation force)
$\sum M$	-	The sum of corresponding moments acting on the vessel because of relative motion of vessel and wave.
$\ddot{z}, \dot{z}, z$	-	Heave acceleration, velocity and displacement, respectively.
$\ddot{\theta}, \dot{\theta}, \theta$	-	Pitch angular acceleration, velocity and displacement respectively.
Δ/g	-	Mass of vessel.
Iyy	-	Pitch inertia moment of vessel.

$a_{zz}, b_{zz}, c_{zz}, a_{z\theta}, b_{z\theta}, c_{z\theta}, a_{\theta\theta}, b_{\theta\theta}, c_{\theta\theta}, a_{\theta z}, b_{\theta z}, c_{\theta z}$- Stability derivatives

ΔF	-	Foil excited force
ΔM	-	Foil excited moment
ζ	-	Amplitude of heaving (m)
α	-	Maximum slope of the surface wave
ω	-	Frequency of the surface

ε	-	Phase angle between exciting moment and wave elevation
ω_0	-	Wave frequency
Λ	-	Tuning factor $= \omega / \omega_0$
M	-	Magnification factor = $1 / \{ (1-\Lambda^2)^2 + 4k^2 \Lambda^2 \}^{½}$
$\delta\Delta$	-	Added mass moment of Inertia
k_{xx}^2	-	Radius of gyration
$\in_1$	-	phase angle between exciting moment and wave elevation

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Generally, the performance of high speed craft is difficult to obtain due to several factors that shall be considered by designer such as resistance and powering, propulsion, dynamic instability, seakeeping and manoeuvring criteria. Normally, all these considerations are not fully achieved due to low budget and the owner has to cut cost. Another factor that contributes to the failure of performance of high speed craft is many of the assumptions used either with numerical or experimental techniques. The formulation of conventional vessel is not suitable for predicting the performance of high speed craft especially after several modifications has been conducted on their hullform.

High speed crafts are known to have rough water problem is essentially one of compromise between speed and seakeeping performance. As the speed of vessels increases, the resistance also increase and required more power to move. At high speed regime, the seakeeping becomes more important especially for passengers vessel and vessel fit in with high technology equipment. However, speed is the main factor and followed by comfort condition (seakeeping quality) to be considered during preliminary design of this vessel and that factor must go well with rough sea condition in order to achieve the mission or task within time frame.

In this study will discuss in detail the performance prediction of high speed craft in term of resistance and seakeeping quality for the high speed craft (planing craft M-hull) before and after incorporating with stern foil. The reason of this adapting of a stern flap foil is to combine the seakeeping qualities of the vessel with the dynamic effect and higher speed attainable at favourable ship resistance.

1.2 Objective

1. To investigate the effect of stern foil on resistance and seakeeping of M-Hull Planing Craft.

1.3 Scope of Work

1. Literature review on stern foil analysis of M-Hull Planing Craft.

2. To develop a computer program for resistance prediction of M-Hull Planing Craft by using Savitsky and two dimensional methods with effect of stern foil.

3. To perform seakeeping analysis by using an existing computational software Maxsurf SEAKEEPER.

4. To conduct resistance and seakeeping tests with and without stern foil.

1.4 Schedule of the Project

1.4.1 Project I

1. Literature review on resistance and seakeeping behaviour of high speed craft. The study shall begin by determining the characteristic of the parameters of high speed craft in high speed region. The study also expands on the effect of tool for

controlling motion in waves which gives a significant effect to the speed of the vessel.

2. The work will be continued with collecting all data and ships particulars including hydrostatic data, drawing and materials for appropriate vessel which is related to research objectives.

3. Perform the theoretical calculation and introduce the Savitsky equation and develop the foil and strut formulation in FORTRAN programming to predict the resistance of effect of stern flap foil on research vessel.

4. Conduct seakeeping simulation by using SEAKEEPER programming in order to predict the motions by effect of stern flap foil.

1.4.2 Project II

1. A model will be constructed at Marine Technology Laboratory, Universiti Teknologi Malaysia UTM.

2. Model test shall be conducted in order to assess the theory of performance of high speed craft against the results from model test. Basically the purposes of this experiment are:

a. To determine the resistance of the vessel with and without stern foil at speed of 25 knots (12.86m/s).

b. To determine the significant effect of motions (heave and pitch) in head sea at design speed with and without stern foil.

c. To confirm that by adapting stern flap foil at transom stern to the motion of the vessel will decrease at vertical acceleration.

3. To perform the performance comparison for research ship between the results of model test and theoretical estimates.

4. The details of methodology being simplified is illustrated in the figure 1.1 (project flow chart) while the detail planning chart for Project I and Project II is in Appendix A.

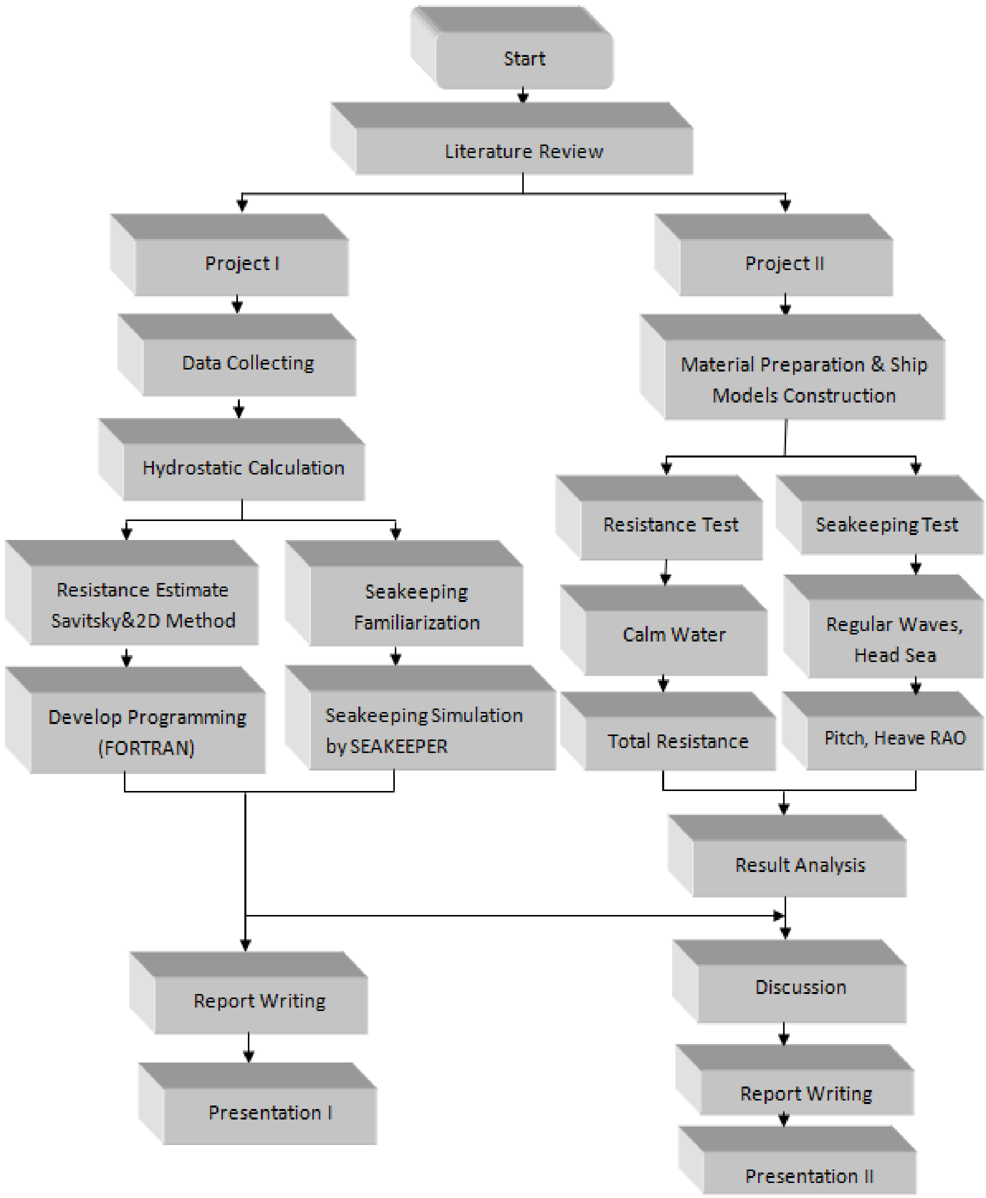

Figure 1.1 : Project Flowchart