Proceedings of MARTEC 2010
The International Conference on Marine Technology
11-12 December 2010, BUET, Dhaka, Bangladesh

HYDRODYNAMIC CALCULATION AND EFFECTS OF DEADRISE ANGLE ON THE PLANING CRAFTS

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ABSTRACT

Hydromechanics calculations are one of the important steps in planing crafts design. In this paper, it is described some parts of prepared software which is used with different modules for hydromechanics calculations (hydrostatic curves, GZ-φ), hydrodynamic calculations (pressure distribution, lift and drag forces, wake) and drawing 3D of planing crafts in AutoCAD. The method is based on the numerical boundary element method (BEM) and developed Savitsky's formulae. The results show that this software has high capability. Methods of calculations in this paper are boundary element for pressure distribution, free surface wave and Savitsky's method for drag force.

***Key words**: planing crafts, pressure and lift and drag forces, free surface wave*

1. INTRODUCTION

A vessel is planing when the length Froude number be greater than 1.0~1.2. Hydrodynamic prediction of the planing is one of the important aspects. Many parameters may affect on the lift and resistance of the planing hull [1]. Deadrise angle and hull form are very important to generate the lift. Multi-chine hull form may help the craft that to be stable. Because the streamline is parallel to the longitudinal direction and causes that the hull to be straight on the surface of the water [2-3].

Up to date, some researchers carried out on the hydrodynamics problem of the planing craft. Most of them are experimental work. Savitsky (1964, 2007) did very extensive regression method and provided many practical formulae for determining the drag of the craft. His method is still useful for calculations of the drag of prismatic hull form. From the numerical view point, some people carried out like Savander et al, Wang et al and Ghassemi et. al. [5-6-7].

In this paper, BEM and practical modified Savitsky's formulae employed to calculate the hydrodynamic lift, drag, pressure distribution and free surface pattern. The effect of the deadrise and center of gravity are presented.

2. SOFTWARE

This software is including of different modules such as hydrostatic calculations for merchant vessels, hydrostatic calculations for planing craft, hydrodynamic calculations for merchant vessels, hydrodynamic calculations for planing craft and drawing 3D plan of vessels in Auto CAD.

One of the most important points in this software is receiving infinity table of offset with unequal spaces for sections and water plans. Mean while the table of offset can have dimension or non-dimension. Also user can select wanted unit (English or Metric) in each modules for information's.

2.1 Hydrostatic calculations

This part of software can calculate 20 hydrostatic parameters including: S_{WP} ,V ,M ,I_{XX} ,I_{YY} ,X_C ,C_B ,C_M ,C_W ,C_{VP} ,C_{HP} ,X_B ,Z_B ,BM_T ,BM_L ,GM_L ,GM_T M_{UT} ,TPC ,GZ and Bonjean curves. User can include the chine in calculations and also to determine the shape of vessel's bottom (flat, concave, convex). The method of integration in this part is Gauss (10 points) and for comparing curves used spline method.

$$\int_{-1/2}^{1/2} \Phi(u)du = R_1\Phi(u_1) + ... + R_{10}\Phi(u_{10}) \qquad (1)$$

$R_1 = R_{10} = 0.03333567215$
$R_2 = R_9 = 0.07472567458$
$R_3 = R_8 = 0.1095431813$
$R_4 = R_7 = 0.1346333597$
$R_5 = R_6 = 0.1477621124$
$u_{10} = u_1 = 0.4869532643$
$u_9 = u_2 = 0.4325316833$
$u8 = u_3 = 0.3397047841$
$u_7 = u_4 =0.2166976971$
$u_6 = u_5 =0.0744371695$

2.2. Hydrodynamic calculations

For calculations of this part, Savitsky's method is used and the results are shown from $F_n = 2.0$ to user definition. These results are including trim changes, wet length of keel, wet length of chine, length of stagnation line, wet height of transom, spray area, total resistance, effective power and relation of total resistance to weight.

3. Extracting results and Analysis

A prismatic planing craft which its dimensions have been shown in the table (1) is selected for our calculations. In this paper first author has used boundary element method and second author used developed Savitsky's method and Bowles method for spray area and spray resistance [2].

Figures (1), (2) show body plan and 3D plan of vessel. Figures (3), (4) show BM_T, GM_T in different water lines and GZ curve in different conditions of center of gravity. These calculations show that vessel at $F_n = 0$ has suitable stability. Figure (5) shows pressure and lift forces which calculated by boundary element. Pressure distribution in stem area is more than other area of vessel and pressure distribution in stern area is near the atmosphere pressure because separation phenomena is occurred in transom. Figure (6) shows current of wake and free surface of sea at two speeds: 10, 20 m/s. Created wave and current profile in free surface at behind of vessel show that waves are transverse and convex.

Table (3) shows hydrodynamic calculations of 5 types of planing craft HSC5, HSC4, HSC3, HSC2 and HSC1 from software. In figure (7) 3 crafts HSC1, HSC2, HSC3 which are different in dead rise angle have been compared. By increasing dead rise angle the vessel's draft and total resistance are increased but slamming is decreased. Averagely total resistance in HSC2 about 5.5% and in HSC3 about 11%, effective power and trim in HSC2 about 6% and in HSC3 about 12%, spray area in HSC2 about 10% and in HSC3 about 20% are decreased.

In figure (8) 3 crafts HSC1, HSC4, HSC5 which are different in longitudinal center of flotation have been compared. If LCF is near to stem the trim decreases and wet surfaces will be increased. Averagely total resistance in HSC4 about 5% is decreased and there is no change in HSC5, trim in HSC4 about 35% and in HSC5 about 57% is decreased, effective power in HSC4 about 2% and in HSC5 about 14%, spray area in HSC4 about 27% and in HSC5 about 73% are increased.

Table 1 Characteristics of main vessel

	L(m)	B(m)	T(m)	LCB(m)	β (D)	Δ(ton)
HSC1	17	4	0.8	3.7	22	25

Table 2. Characteristics of secondary vessels

	L(m)	B(m)	T(m)	LCB(m)	β (D)	Δ(ton)
HSC2	17	4	0.8	3.7	18	25
HSC3	17	4	0.8	3.7	14	25
HSC4	17	4	0.8	5.7	22	25
HSC5	17	4	0.8	7.7	22	25

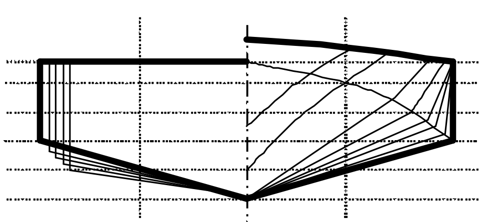


Fig. 1 Body Plan

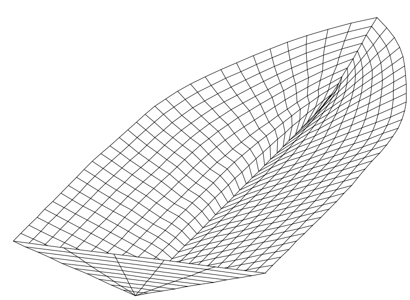


Fig. 2 Three dimensional view of planing craft

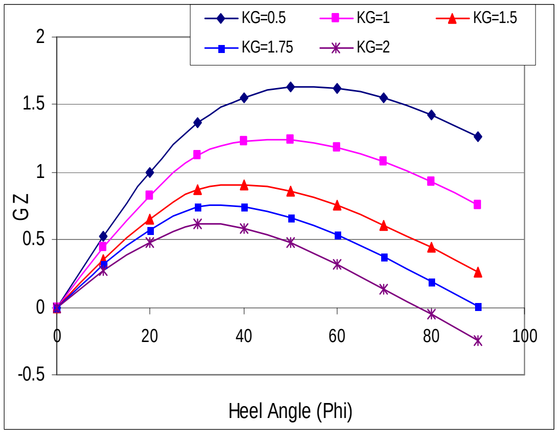


Fig. 4 GZ curves

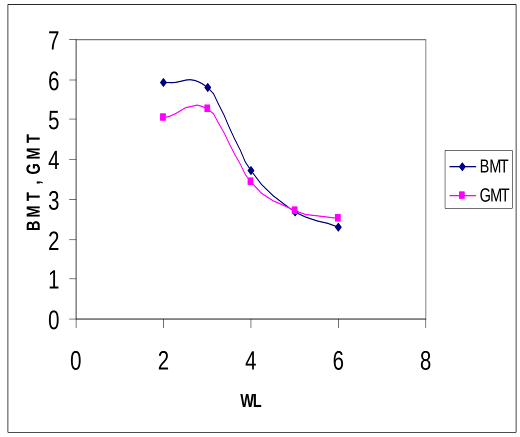


Fig. 3 BM_T, GM_T in different drafts

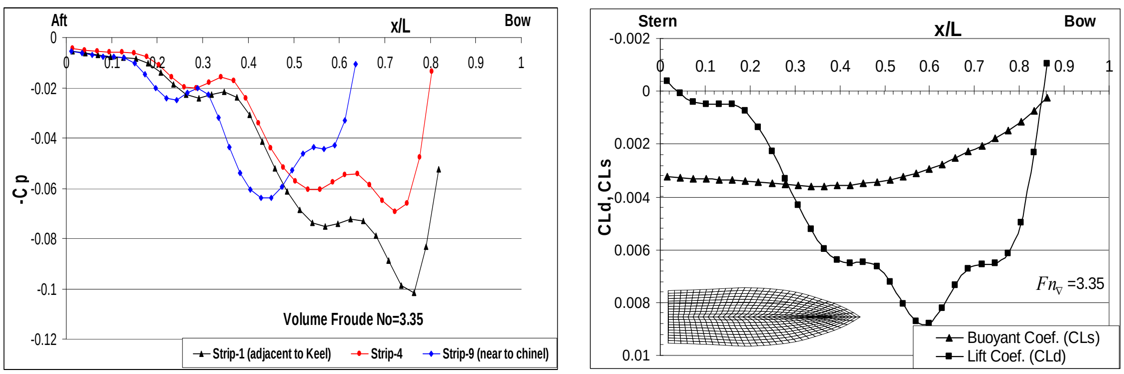
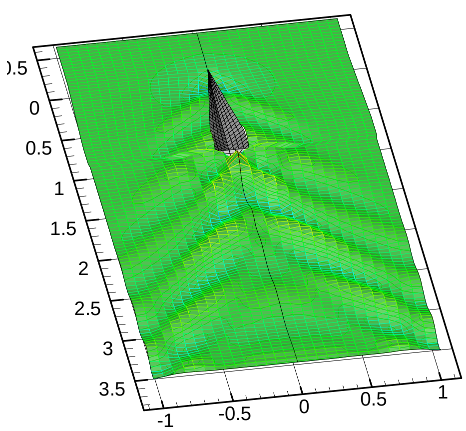
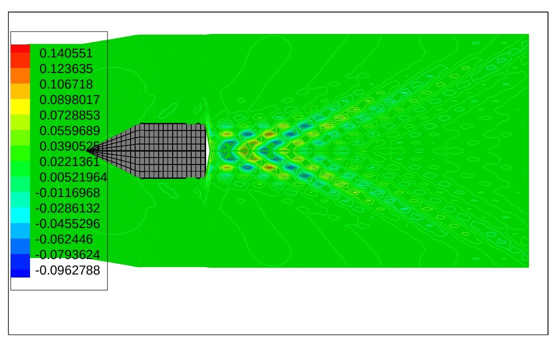


Fig. 5 Pressure distribution and lift force on bottom ($F_n = 3.35$)



Speed: 10 m/s



Speed: 20 m/s

Fig. 6 Simulation of created wake and wave in sea water

Table 3. Results of hydrodynamic calculations for 5 type of vessels from software

V(kn)	*Fn_V*	*Trim (D)*	*EHP (hp)*	*Spray Area (m^2)*	*R_T (N)*	*Project Name*
20.817	2	13.925	918.388	4.3170442	63948	HSC1
31.226	3	8.7712	969.682	4.889846	45013	
41.635	4	5.9976	1118.77	6.1620329	38950	
52.044	5	4.4472	1493.2	7.7859871	41589	
62.452	6	3.4987	2166.22	9.5873042	50278	
V(kn)	*Fn_V*	*Trim (D)*	*EHP (hp)*	*Spray Area (m^2)*	*R_T (N)*	*Project Name*
20.817	2	13.357	881.933	4.2459188	61409	HSC2
31.226	3	8.2744	921.146	4.4695831	42760	
41.635	4	5.5693	1051.98	5.4523301	36625	
52.044	5	4.0676	1399.63	6.8398895	38983	
62.452	6	3.1538	2035.28	8.4548514	47239	
V(kn)	*Fn_V*	*Trim (D)*	*EHP (hp)*	*Spray Area (m^2)*	*R_T (N)*	*Project Name*
20.817	2	12.816	846.933	4.392318	58972	HSC3
31.226	3	7.8096	874.963	4.1665248	40616	
41.635	4	5.1751	990.094	4.7885636	34470	
52.044	5	3.7235	1308.87	5.8724748	36455	
62.452	6	2.8454	1901.6	7.2281124	44136	
V(kn)	*Fn_V*	*Trim (D)*	*EHP (hp)*	*Spray Area (m^2)*	*R_T (N)*	*Project Name*
20.817	2	6.6694	499.269	5.7254576	34764	HSC4
31.226	3	5.8649	786.419	6.2627038	36506	
41.635	4	4.4295	1131.77	7.8119899	39403	
52.044	5	3.4223	1733.01	9.7792784	48268	
62.452	6	2.7496	2711.78	11.955095	62941	
V(kn)	*Fn_V*	*Trim (D)*	*EHP (hp)*	*Spray Area (m^2)*	*R_T (N)*	*Project Name*
20.817	2	2.9741	319.045	11.114744	22215	HSC5
31.226	3	3.6476	710.124	9.2379074	32964	
41.635	4	3.2635	1233.33	10.208465	42939	
52.044	5	2.7003	2052.55	12.159307	57168	
62.452	6	2.2436	3323.23	14.490149	77133	

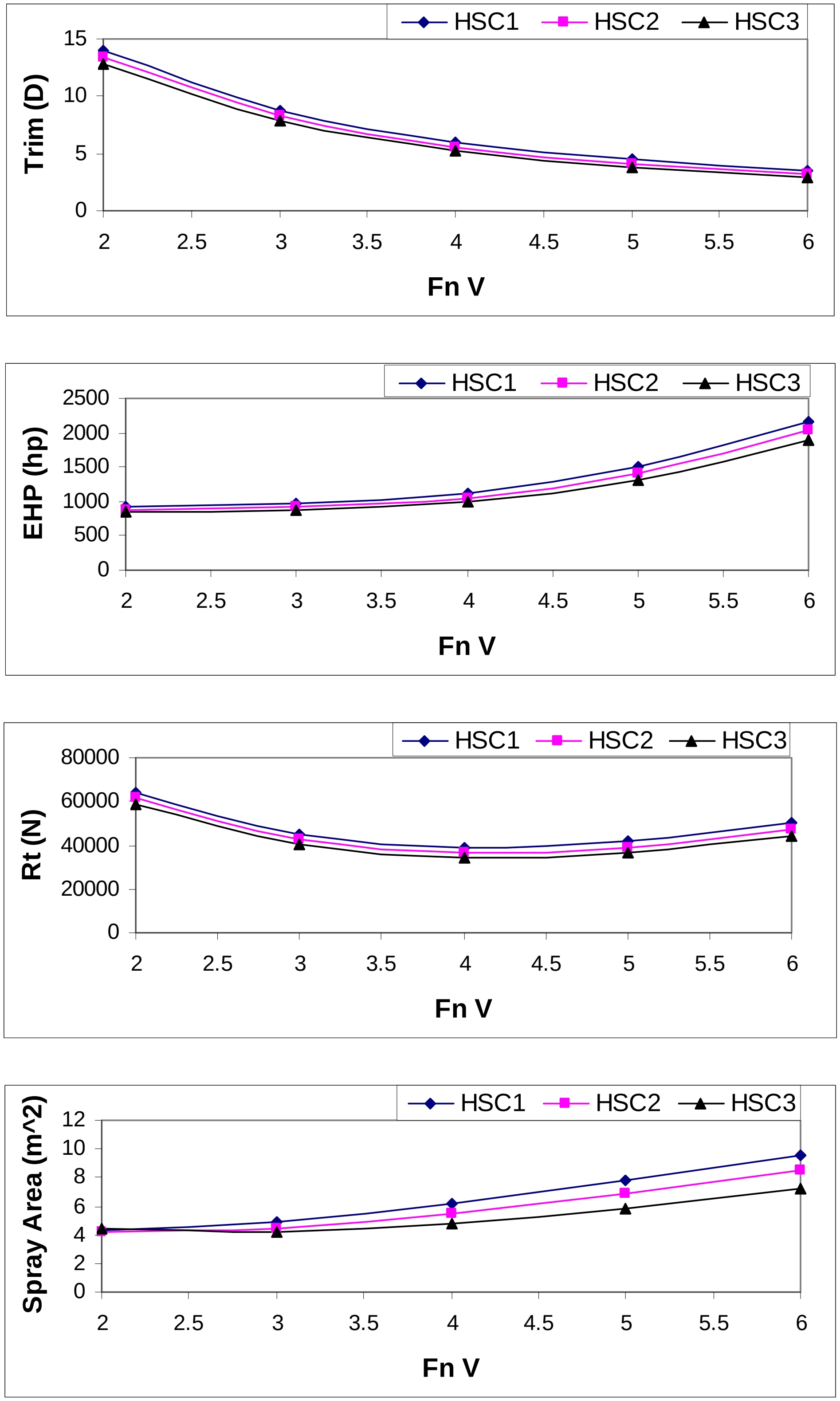


Fig. 7 Comparison of trim, effective power, total resistance, spray area for HSC1, HSC2, HSC3

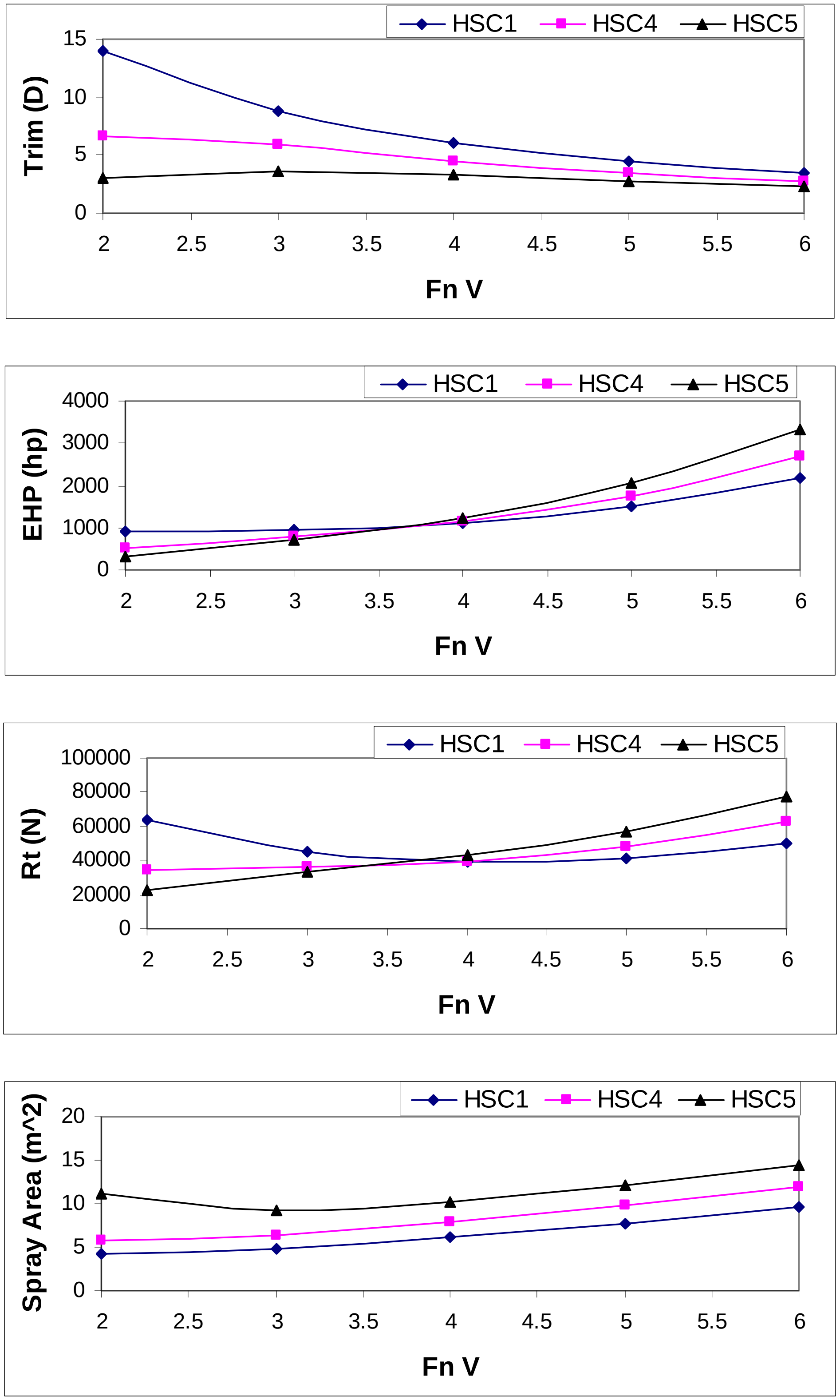


Fig. 8 Comparison of trim, effective power, total resistance, spray area for HSC1, HSC4, HSC5

4. Conclusion

In this paper, hydromechanics calculations for prismatic planing craft have been done by both boundary element method and Savitsky's method. It is concluded that:

1. Prepared software has different modules for hydrostatic and hydrodynamic calculations of planing craft and merchant vessels. In part of hydrostatic calculations, the Gauss 100 points for integrations is used, in part of hydrodynamic calculations, Savitsky's method is used and the effects of dead rise angle and center of gravity has been calculated. Also the lift and drag forces in different conditions are calculated.

2. Using boundary element method, the pressure distribution, lift, drag, wake and free surface wave calculated. The results show that boundary element numerical method is powerful tool for calculation the planing crafts.

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