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# Partially Submerged Propeller Analysis in Open Water Condition by Developing Boundary Element Method Based on Potential

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**ABSTRACT:** Since the design algorithm of partially submerged propeller (PSP) is under influence of various geometrical and physical parameters; so a new convenient method and numerical tools are required for flow analysis on propeller and considering the effect of all parameters simultaneously. The aim of this study is developing a boundary element method (BEM) based on potential for PSP analysis under open water condition. Using the concept of material derivative and kinematic boundary condition, a BEM algorithm has been developed to analyze the growth, development and change in thickness of ventilation-cavitation regimes in both chord and radial directions on wide range of advance velocity coefficients. Based on the obtained results, in high advance coefficients there are very good conformity between values obtained from the numerical simulation compared with experimental data and observations. This adaptation is reduced by reducing the value of advance coefficient. For low advance coefficients ($J$<0.4) due to intense eddy shedding (according to experimental results), oscillation of the ventilated surface end is effective on the propeller wake and is the cause of instability. While at higher advance coefficients ($J$>0.4), hydrodynamic coefficients obtained from numerical results and efficiency of propeller are in agreement with experimental measurements.

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## 1- Introduction

PSP is a propeller that is operating behind the high speed crafts. It is immersed about one-third of the diameter. On the other hand, it is working in two phase flow, water and air. The blade of the PSP almost like super-cavitating blade is sharp at leading edge and blunt at the trailing edge.

Up to now, many experimental and numerical researches are carried out for the PSP. Experimental literature can be found in [1-7]. Olofsson worked on his Ph.D. thesis by experimental set up on the PSP [5]. Ferrando et al. carried out open-water test for the PSP [6-7].

This paper presents BEM-based potential flow employed to PSP-841B. Many results are determined at various operating conditions. Open-water characteristics are presented.

## 2- Mathematical Formulations

Velocity potential in fluid domain $\Omega$ is obtained using classic integral. Based on Green's third identify equation $\phi$ can be written as

$$2\pi\varphi(x,t)=\int_{S_B+S_C+S_V}\left[\varphi_q\frac{\partial G(p;q)}{\partial n_q}-G(p;q)\frac{\partial\varphi_q(t)}{\partial n_q}\right]ds+\int_{S_W}\left[\Delta\varphi(t)\frac{\partial G(p;q)}{\partial n_q}\right]ds \quad (1)$$

where $p$ is a field point, $q$ is a singularity point, $n_q$ is normal vector and $G(p;q)$ is a proper Green's function for a 3-dimensional analysis of fluid flow. Fig. 1 shows the 3D model of the PSP.

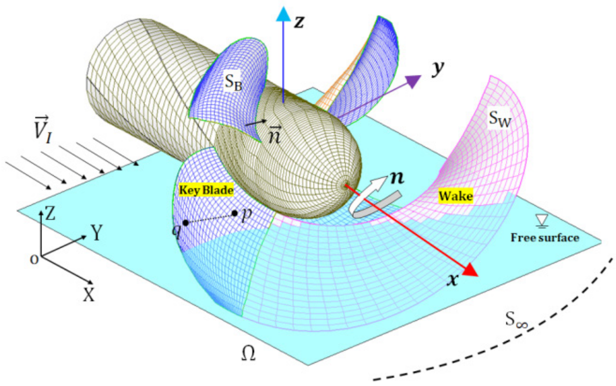


**Figure 1. 3D model of the PSP**

## 3- Numerical Results and Discussion

In propeller analysis it is important to determine the hydrodynamic characteristics (thrust, torque and efficiency). Propeller is rotating and the inflow to the propeller is uniform. Main data of the PSP is given in Table 1.

**Table 1. Main data of the PSP-841B**

| Parameter | Symbol | Value |
|---|---|---|
| Diameter (mm) | $D$ | 250 |
| Hub diameter (mm) | $d$ | 85 |
| Pitch at 0.7 radius (mm) | $P$ | 310 |
| Hub-diameter ratio | $d/D$ | 0.34 |
| Pitch-diameter ratio at 0.7 radius | $P/D$ | 1.24 |
| Expanded Area ratio | $AE/A0$ | 0.58 |
| Number of blades | $Z$ | 4 |
| Rotation | R.H. | |

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By averaging the fluctuations of force and moment about the x- axis after some rotations, thrust-torque coefficients and propeller performance ($K_T$-$K_Q$ and $\eta$) are calculated. Fig. 2 shows propeller performance prediction at some selected conditions, covering advance coefficients from $J$=0.4 to $J$=1.2. Numerical results are relatively in good agreements with experimental measurements in high advance coefficients. Because usually the maximum efficiency is related to the design point of propeller, therefore, at this point the maximum agreement can be seen between the numerical and experimental results. In low advance coefficients, less than 1, greater difference can be seen that are related to operation of PSP in heavy condition.

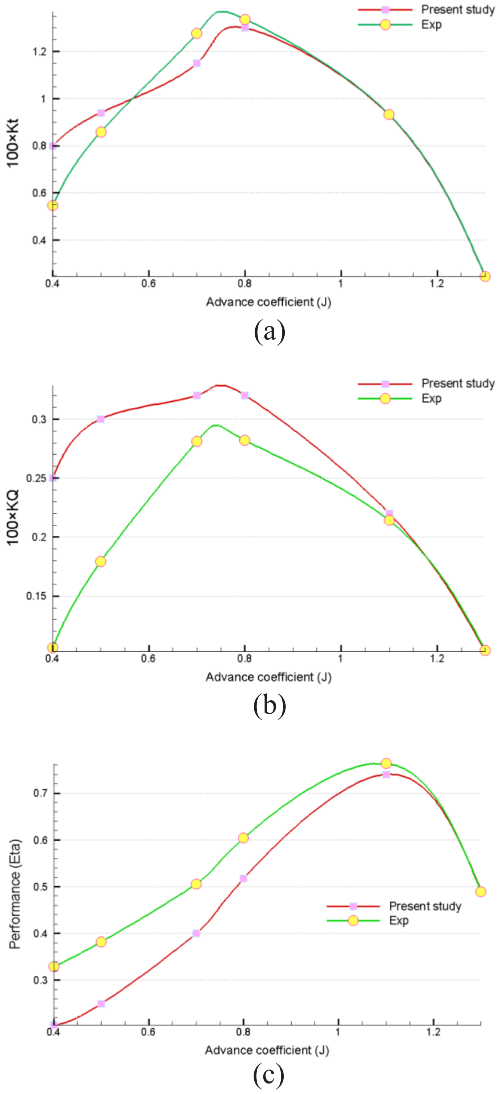


**Figure 2. Comparison of the (a) thrust coefficient,(b) torque coefficient (c) Efficiency for the model of 841B**

## 4- Conclusion

In this article, we experimentally investigated a constructed WEC in the wave tank of Hydrodynamic, Acoustics and Marine Propulsion Laboratory of Babol Noshirvani University of Technology. First, generated waves were calibrated and surveyed by wave maker system. Regarding the Caspian Sea wave specifications, calibration results were applied for generating specified waves. Then, we placed the WEC in the wave tank and evaluated its performance in a wide range of waves. The waves were presented in which system had suitable pitch motions and acceptable extracted electrical energies. Moreover, according to diagrams and data obtained for WEC performance and annual energy diagram of the Caspian Sea, scales 1:5 and 1:6 are selected for making the WEC prototype. Selecting the scales of 1:5 and 1:6, extracted power from them are about 28 and 53 kW.

## References

[1] Rains, D. A., "*Semi-submerged propellers for monohull displacement ships*". *Propeller '81 Symposium*, 15–40, Virginia Beach, VA. Society of Naval Architects and Marine Engineers, 1981.

[2] Rose, J. C. and C. F. L. Kruppa, "Surface piercing propellers – methodical series model test results". *FAST'91*, Norway, 1991.

[3] Rose, J. C., C. F. L. Kruppa, and K. Koushan, "Surface piercing propellers - propeller/hull interaction". *FAST'93*, 867–881, Japan, 1993.

[4] Kruppa, C. F. L., "Testing surface piercing propellers". *Hydrodynamics :Computations, Model Tests, and Reality*, 107–113, 1992.

[5] Olofsson, N., " *Force and flow characteristics of a PSP*". PhD thesis, Department of Naval Architecture and Ocean Engineering, Chalmers University of Technology, Goteborg, Sweden, 1996.

[6] Ferrando, M., M. Viviani, S. Crotti, P. cassella and Caldarella., "*Influence of weber number on surface piercing propellers model test scaling*".Universita degli studi di Genova (DINAV),Genova,Italy,pp.667-676, 2006.

[7] Ferrando, M., S. Crotti and M. Viviani, "Performance of a family of surface piercing propeller", *the 2nd International Conference on Marine Research and Transportation (CMRT2007)*, Ischia, Naples, Italy.

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