The Effect of Boss Cap Fins to B – Series Propeller Performance With CFD Method

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Abstract**— propeller is *similar to rotating fan blade with having primary function as propulsion system. In order to increase propeller performance, Engineer is developing Energy Saving Devices (ESD) to reduces operational cost, clean energy and for long term utilization. The global emmision from marine is 2.7 % in 2007. One of ESD is Propeller Boss Cap Fins (PBCF). The focus of this thesis is to design and developed PBCF B - series propeller. This thesis studies the performance of a propeller without and with PBCF such as efficiency, thrust, torsion and dynamic hub vortex phenomenon. To obtain the results this thesis uses Computational Fluid Dynamic (CFD). The PBCF simulations were based on its pitch angle. The simulation results shows that PBCF is achieved the highest efficiency which is 0.60 %, and increases thrust 3.21 %, and torsion increase 2.64 % compared to propeller without PBCF. It also shows that the PBCF is able to break the vortex flow and it will reduces the porosity to the rudder and decrese the corrosion potention to the rudder*.**

*Keywords***—** *CFD, hub vortex PBCF, Thrust, Torsion*

I. Introduction

According to (IMO) Internasional Maritime Organization, global emision about 2.7 % from marine activity at 2007[2]. For ESD commontly devide into 8 devices. They are : Twisted Rudder, Costa – Bulb with Twisted Rudde, Costa – Bulb with Conventional Rudder, Boss Cap Fins, Propeller Optimizing, Wake Equalising Duct, Becker Mewis Duct, Bullbous Bow Retro – Fit. From that, its devices have different characteriztic and efficiency [9].

Since developed in 1987 by Mitsui O.S.K Lines, West Japan Fluid Engineering Laboratory, and Nakashima Mitsuwa Propeller was adapted over more than 2000 vessel at world wide [11]. The next stage of the development was conducted by Ouchi [4], since that there are several researches regarding the PBCF. This paper focuses on analyze increases performance of propeller including thrust, torsion, efficiency and eliminating hub vortex which reduces the propeller efficiency and may caused rudder corrotion [7] behind the propeller after and before installing PBCF.

II. Method

This research using experimental method and comparative method. Experimental method is study of cause, effect and it differs from non – experimental method in that involver the deliberate manipulation of one variable while trying to keep all other variables constant [10]. Comparative method for this research because the author who make compared result before and after propeller performance caused by installation PBCF. It will try to make new design of PBCF according shape and hub fortex phenomenon whic affect the propeller. performance. The role of the fins is weaken energi from rotating flow around propeller cone and the fins can impact of increase propeller efficiency [1].

A. Propeller Modeling

Propeller modelling using (CAD) Computer Aided Design Software. It can be making geometry and send to the (CFD) Computer Fluid Dynamic Software for take the data. For detail can shown in **Figure. 1.**

B. PBCF Modeling With Pitch Angle

PBCF design depend on fluid flow and hub vortex of B-series propeler. This paper propose a NACA foil as the blade with pitch angle 70˚.

C. Flow Simulation, Thrust and Momment

Flow simulation for this thesis are using (CFD) Computational Fluid Dynamic Software. From that method, we can find thust and momment propeller B-series with or without PBCF. Each analyse, can determine from each (J) advance velocities.

III. ResultS and Disscussion

A. Propeller Boss Cap Fins Geometry

The propeller model was build in CAD Software. PBCF geometry was built based on NACA foil and in half circle blade. The position of the PBCF blade based on the flow behind the main propeller. The main propeller for this paper uses B4-85 which can be shown in **Table. 1.**

The specification of the PBCF can be shown in **Table. 2.** Where the PBCF has the same number of blade as the propeller [8].

B. Mesh Generation

In order the solver manager to solve the computation based on RANS. The model which has been built in 3D model is meshed in full hexahedral unstructured meshes.

The model geometry built into the object and boundary

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condition which represents the environment around the object as can be shown in **Figure. 2.** The object is combination of trailing edge, leading edge, tip and hub of the system. The inlet and outlet built and meshed also.

The meshing result for the propeller is 2,604,431 cell and 2,844,566 vertices while the propeller installed with PBCF is 3,279,982 cells and 3,593,238 vertices as shown in **Table. 3.**

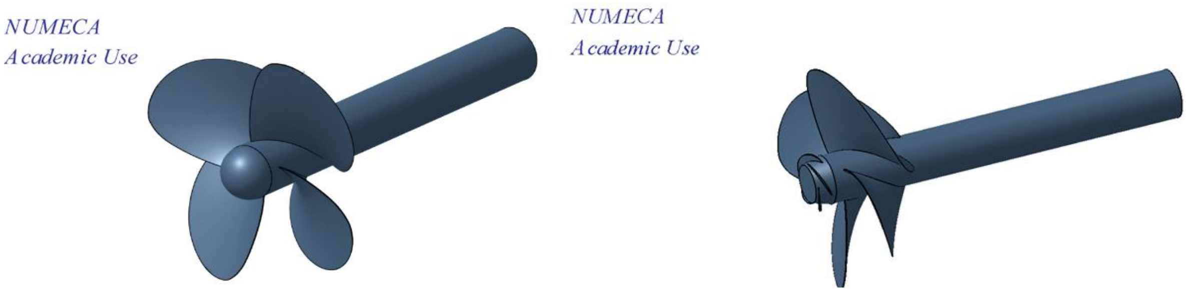

Figure. 1. (Left) Propeller B4-85, (Right) propeller B4-85 with PBCF

TABLE. 1.
SPESIFICATION B4 – 85 PROPELLER

No	Diameter (m)	Number Blade	Rotation (Direction)	Revolution (Rpm)
			Propeller Prinsipal Dimention	
1.	3.262	4	Left	210

TABLE. 2.
SPESIFICATION PROPELLER BOSS CAP FINS

No	Diameter (m)	Number Blade	Rotation (Direction)	Revolution (Rpm)
			Propeller Boss Cap Fins Principal Dimention	
1.	0.816	4	Left	210

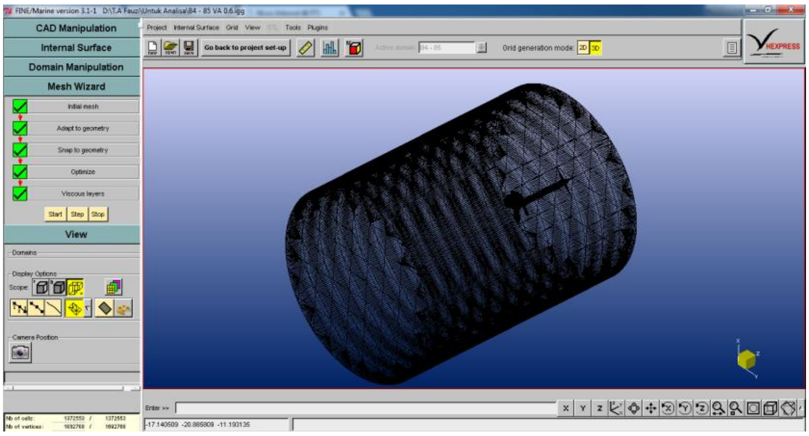

Figure. 2. Meshing Geometry Propeller B4 – 85

TABLE. 3.
MESH QUALITY DETAIL

No	Model	Total Number of Cells	Total Number of Vertices
		Mesh Quality	
1.	Propeller B series.	2,604,431	2,844,566
2.	Propeller With PBCF	3,279,982	3,593,238

C. Flow Setting

Flow setting is to define the type of physical configuration of the flow such as k-ω SST for turbulence model. The cylinder of the free slip domain was applied and the propeller or the object is using non slip wall. The domain setting is 3D in radius and 5D in length of the cylinder.

The cavitation which enable the hub vortex to be simulated is activated.

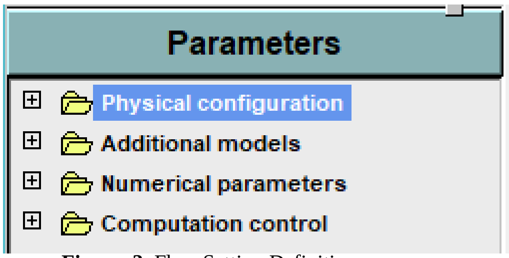

Figure. 3. Flow Setting Definition

D. Post Processing

This final Step is post processing. For CFD. Result from flow setting that analyze was implemented to vector, pressure, turbulency depend from output value that we design.

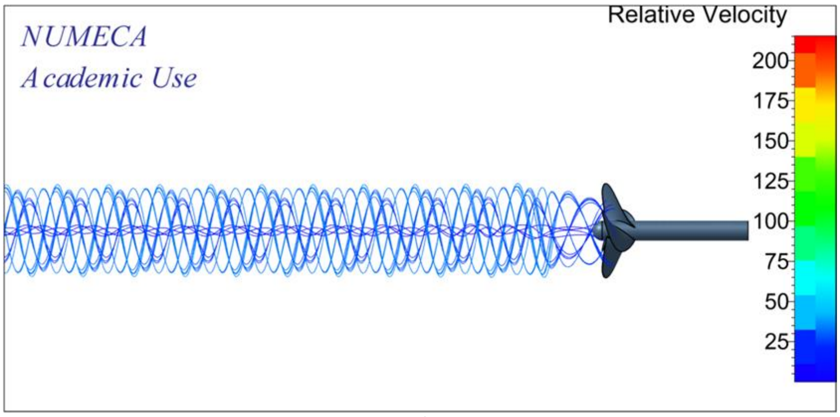

Figure. 4. Example of Post Processing Result

E. Validation of Thrust and Momment From Theory vs CFD

Before install PBCF to propeller B-Series, it must be validate from manual calculation result vs CFD result.

TABLE. 4.
MANUAL CALCULATION PROPELLER B-SERIES

Result of Manual Calculation						
No	J	KT	10*KQ	Efficiency	Trust (kN)	Momment (kNm)
1.	0.100	0.354	0.468	0.120	503.268	217.033
2.	0.200	0.320	0.428	0.238	454.931	198.483
3.	0.300	0.274	0.384	0.341	389.535	178.075
4.	0.400	0.230	0.330	0.444	326.982	153.036
5.	0.500	0.191	0.276	0.551	271.537	127.994
6.	0.600	0.144	0.225	0.612	205.003	104.343
7.	0.700	0.093	0.175	0.589	131.504	81.155
8.	0.800	0.040	0.125	0.408	56.866	57.968

TABLE. 5.
CFD RESULT OF PROPELLER B-SERIES

Result of Computational Fluid Dynamic						
No	J	KT	10*KQ	Efficiency	Trust (kN)	Momment (kNm)
1.	0.100	0.305	0.405	0.120	433.252	187.774
2.	0.200	0.291	0.392	0.237	413.460	181.564
3.	0.300	0.262	0.361	0.346	371.775	167.275
4.	0.400	0.227	0.324	0.446	322.804	150.224
5.	0.500	0.191	0.283	0.537	270.994	131.064
6.	0.600	0.149	0.237	0.599	211.736	110.122
7.	0.700	0.107	0.189	0.628	151.498	87.737
8.	0.800	0.063	0.138	0.585	89.855	63.811

TABLE. 6.
DEVIATION MANUAL VS CFD RESULT OF B-SERIES

No	J	Deviation Between Manual Calculation Vs CFD ΔKT (%)	Δ10*KQ (%)	ΔEfficiency (%)
1.	0.100	16.16	15.58	0.50
2.	0.200	10.03	9.32	0.65
3.	0.300	4.78	6.46	1.58
4.	0.400	1.29	1.87	0.57
5.	0.500	0.20	2.34	2.60
6.	0.600	3.18	5.25	2.18
7.	0.700	13.20	7.50	6.16
8.	0.800	36.71	9.16	30.33

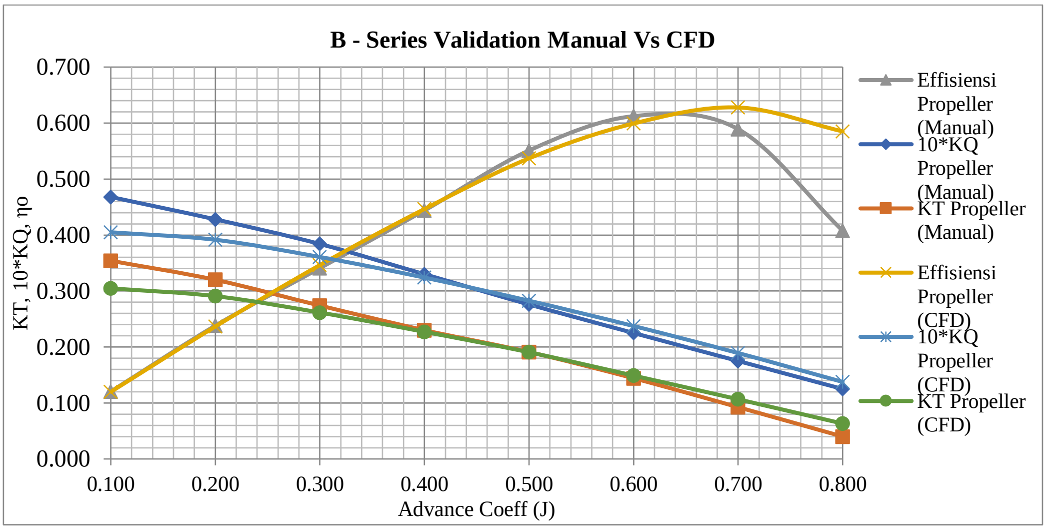

Figure. 5. Open Water Test Validation Resul

From **Table 4** we can conclude the validation model for propeller B4-85, validation do by each (J) velocity advance. The deviation very difference each J. For the detail can see figure 5 that represents deviation from J = 0.1 to J = 0.9. From this model, the maximum deviation at J = 0.8 and minimum deviation at J = 0.4.

F. PBCF Installation effect on Propeller B-Series

After the data has been obtained, difference between before and after installation PBCF will provide performance improvement. The detail can seen **Table 5**

TABLE. 7.
RESULT OF WITHOUT PBCF

No	J	Without PBCF KT	10*KQ	Efficiency	Trust (kN)	Momment (kNm)
1.	0.100	0.305	0.405	0.120	433.252	187.774
2.	0.200	0.291	0.392	0.237	413.460	181.564
3.	0.300	0.262	0.361	0.346	371.775	167.275
4.	0.400	0.227	0.324	0.446	322.804	150.224
5.	0.500	0.191	0.283	0.537	270.994	131.064
6.	0.600	0.149	0.237	0.599	211.736	110.122
7.	0.700	0.107	0.189	0.628	151.498	87.737
8.	0.800	0.063	0.138	0.585	89.855	63.811

TABLE. 8.
RESULT OF WITH PBCF

No	J	With PBCF KT	10*KQ	Efficiency	Trust (kN)	Momment (kNm)
1.	0.100	0.306	0.409	0.120	437.513	189.620
2.	0.200	0.294	0.396	0.237	418.000	183.481
3.	0.300	0.267	0.366	0.348	379.207	169.958
4.	0.400	0.233	0.330	0.450	331.408	153.175
5.	0.500	0.195	0.289	0.537	276.830	133.318
6.	0.600	0.154	0.244	0.602	218.800	113.318
7.	0.700	0.112	0.197	0.633	159.307	91.578
8.	0.800	0.069	0.147	0.601	96.553	68.188

TABLE. 9.
INCREASEMENT RESULT

No	J	Increasement Performance ΔTrust (%)	∆,Mommert (%)	∆Efficiency (%)
1.	0.100	0.97	0.97	0.00
2.	0.200	1.09	1.04	0.04
3.	0.300	1.96	1.58	0.39
4.	0.400	2.60	1.93	0.68
5.	0.500	2.11	2.17	0.07
6.	0.600	3.23	2.82	0.42
7.	0.700	4.90	4.19	0.74
8.	0.800	8.83	6.42	2.57
	Average	3.21	2.64	0.60

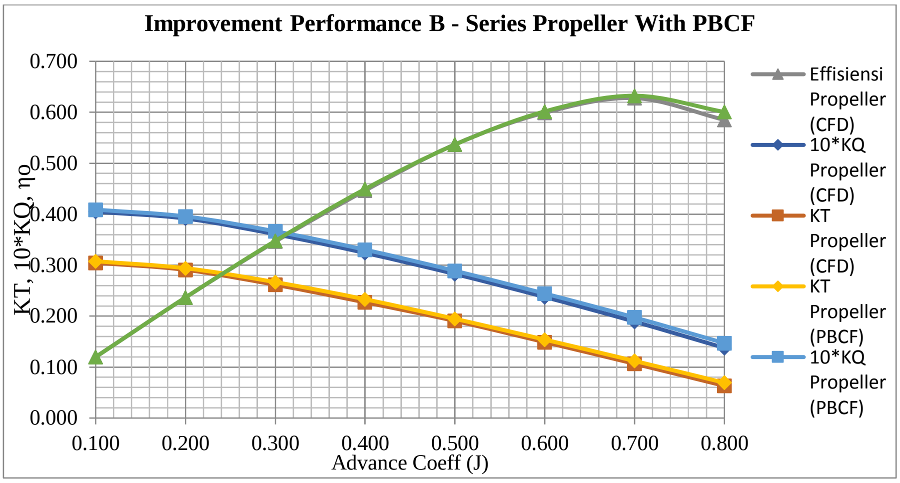

Figure. 6. Open Water Test Propeller Vs PBCF

From **Table 5** we can conclude performance between propeller B4-85 vs B4-85 with PBCF , average improvement performance from J=0.1 until J=0.8 is efficiency (0.60%), Thrust (3.21%) and momment (2.64%). Higher efficiency can impact better performance.

G. Fluid Flow Analyze

Make sure if the data are correct, we must check the fluid flow for see the detail of fluid flow and hub vortex phenomenon. Propeller whithout PBCF can be explained by **Figure 7**. From that we can conclude strong hub vortex generated by propeller itshelf. But figure 8 unformed hub vortex phenomenon because fluid flow from propeller is blocked by fins and caused fluid flow can not forming hub vortex.

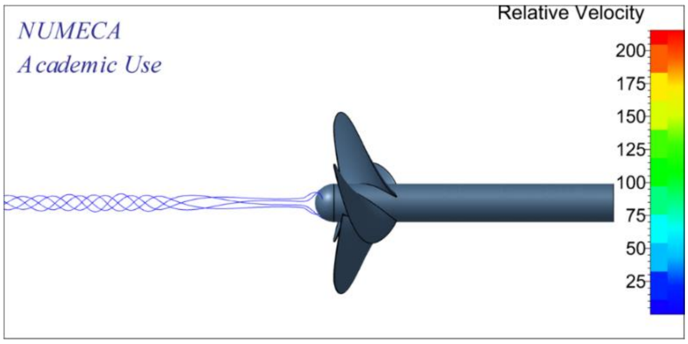

Figure. 7. Strong Hub Vortex Formed at Propeller Whitout PBCF

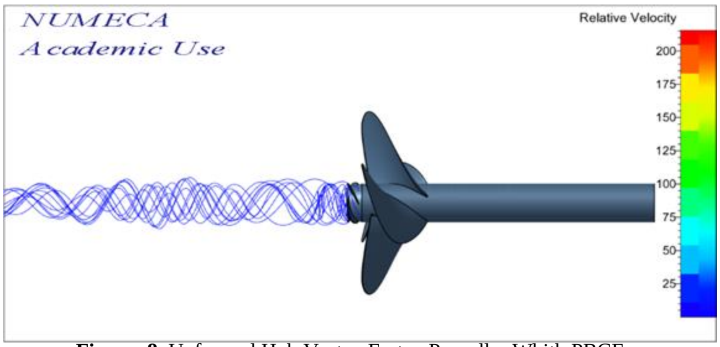

Figure. 8. Unformed Hub Vortex Fortex Propeller Whith PBCF

IV. Conclusions

From that several result of simulation, there are several main conclusions which can be describe bellow :

A. Open water test result B-Series produce average efficiency 0.437 %, thrust 283.173 kN and momment 134.946 kNm

B. Open water test result obtained from CFD shows that PBCF improve the efficiency around 0.60%, thrust is increased around 3.21% in average and momment increases 2.64%.

C. PBCF is able to reduce hub vortex which resulted rudder corrosion reduction and provide additional thrust for the propeller and reducing rudder corrotions.

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