Hydrodynamic Analysis of aFour BladeGlass Fiber Reinforced Plastic Marine Propeller

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Abstract: Generally, propellers are used to propel ships and underwater vehicles like submarines, torpedoes etc. at their operational speeds with significant thrust. Propeller is a type of a fan that transmits power by converting rotational motion into thrust. In general, propellers are made up of metals like Aluminium and its Alloys, Nickel, Bronze and Stainless steel etc. Composite propellers are expected to give better performance compared to metal propellers with same parameters. Hydro-elastic analysis based on CFD and FEM has been widely used in the engineering field because of its accurate results. In this Paper an attempt is made on the design and hydrodynamic analysis of a four blade marine propeller. The propeller has designed using CATIA V5.The solid model of marine propeller is developed using software HYDROCOMP PROPCAD. The flow parameters for four blade composite propeller are obtained by CFD analysis. Hydrodynamic characteristics of the four blade propeller are calculated theoretically and the suitable advance ratio (J) for designing a composite propeller is found.

Keywords: Composite propeller,CFDanalysis, advance ratio, hydro-elasticity, hydro-dynamic characteristics

INTRODUCTION

A propeller is atypeof fan that converts rotational motion into thrust bymeansofpower.Thetransmittedpowerisconvertedfromrotationalmotiontogenerateathrustwhichimpartsmomentumto thewater,resultinginaforcethatactsontheshipandpushesitforward.Apressuredifferenceisproducedbetweentheforwarda ndrearsurfacesofthe airfoil-shapedpropellerblade,andafluidisacceleratedbehindtheblade.AshippropellerisworkingontheprinciplesofBernoulli'san dNewton'sthirdlaw.

A 4 blade propellerhas followingcharacteristics

- Themanufacturingcostishigher than 3 bladepropellers.
- 4 bladepropellersare normallymadeup of stainless steelalloys.
- Have better strength anddurability.
- Gives agood low speedhandlingandperformance.

- Has abetter holdingpower in rough seas.
- 4 bladepropellerprovides a betterfuel economythan all the othertypes.

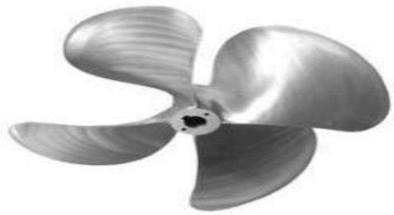

Fig. 1: Four blade propeller

Review of literature reveals that most of the work done on static and harmonic analysis. A little amount of work has been initiated on hydro-elastic analysis. Most of the work is done on 3 blade propeller by using Nickel Aluminium Bronze (NAB) alloy and CFRP. Fiber reinforced plastics are extensively used in the manufacturing of various structures including the marine propeller. The hydrodynamic aspects in the design of composite marine propellers have attracted attention because they are important in predicting the deflection and performance of the propeller blade.

In this Paper an attempt is made design and hydrodynamic analysis of a four blade marine propeller. The propeller has designed using CATIA V5. The flow parameters are calculated by using ANSYS 18

Hydrodynamic Analysis of Propeller

Influiddynamics,hydro-elasticityisabranchofsciencewhichisconcernedwiththemotionof deformable bodiesthrough liquids.Thetheoryofhydro-elasticitydescribestheeffectofstructuralresponseofthebodyonthefluidaroundit.Itistheanalysisofthetime-dependentinteractionofhydrodynamicandelasticstructuralforces.

Hydro-elasticityis of concern in various areas ofmarine technologysuchas:

- High-speedcraft.
- Ships with the phenomena springingand whipping affecting fatigue andextremeloading
- Large scale floating structures such as floatingairports, floatingbridgesandbuoyanttunnels.
- MarineRisers.
- Cablesystems and umbilical’s for remotelyoperated or tethered underwatervehicles.
- Seismiccablesystems.
- Flexible containersforwatertransport, oil spill recoveryand otherpurposes.

Hydrodynamic Characteristics:

Thehydrodynamiccharacteristics ofa propellerarethrust, torqueand efficiency. Theperformance characteristics ofa propellercanbe divided into two groups

- PropellerHullProperties
- Openwater

PropellerHullInteraction:

Whenapropelleroperatesbehindthehullofashipitshydrodynamiccharacteristicsdifferfromthecharacteristicsofthesamepropelleroperatinginopenwatercondition.Thisismainlyduetodifferentflowconditions.TheoreticallytheinteractionPhenomenoniscausedbythreemain effects:

- Wake gain
- Thrustdeduction
- Relative-rotative efficiency

Open WaterCharacteristics:

Theterm “Open water”refers to theconditionwherethe propeller is notobstructedbythe hull and is fullyexposed to the wateraroundit. Open watertests arecarried out to obtain differentcoefficientswhichare used to find the open waterefficiencyof propeller. This efficiencyis used toestimatethe powerthat apropellerwould require. Theforces andmomentsproducedbythe propellerareexpressed interms of a series of non-dimensionalcharacteristics.These non-dimensional termsexpressingthegeneral performance characteristicsare:

- Advance Coefficient $J = V_a/(ND)$
- ThrustCoefficient $K_t = T/(\rho N^2 D^4)$
- Torque Coefficient $K_q = Q/(\rho N^2 D^5)$
- Propeller Efficiency $\eta_0 = (T^* V_a)/(2\pi N Q)$
- Propulsive Efficiency $\eta_t = (R_t^* V_s) / (2\pi N Q)$

WhereV_a=the waterspeed of thevessel, N =propeller’srotationalspeed inrpm, D =propeller’s diameter, T =Thrust in Newtons, Q= Torque in N-m, A=Propulsion area, R_t= Total Ship resistance

Advance Ratio:

In marine hydrodynamics, the advance ratio is the ratio of the speed of free stream fluid to the propeller tip speed. The advance ratio is a useful non-dimensional velocity in propeller theory, since propellers will experience the same angle of attack on every blade airfoil section at the same advance ratio regardless of actual forward speed.For a specific propeller geometry, Kt and Kq are often given as a function of the advance number J. It is a dimensionless number indicating some speed. It has all the components of how fast the rpm should be. These co-efficients are experimentally determined by so-called open water tests, usually performed in a cavitation tunnel or a towing tank.

Thesenon-dimensionalparametersareusedtodisplayopenwaterdiagrams(performance)ofapropellerwhichgivescharacteristicsofth epoweringperformanceof apropeller.

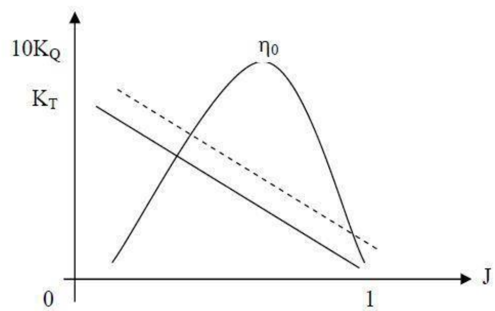

Fig.2: Model performance curves

Inthepresentpaperhydrodynamiccharacteristicsofthepropelleriscalculatedtheoreticallybyusingtheabovenondime nsionaltermsinopenwatercondition.Thethrustandtorquewhicharerequiredforcalculationsareobtainedfrom CFDanalysi s.Theopenwatercharacteristicsare doneattwodifferentrpmi.e.909rpmand454rpmand the results are compared.

Results and Discussion:

The hydrodynamic characteristics such as torque and thrust of a four blade propeller at various advance ratios is calculated theoretically for two different rpm and are presented in table 1 and table 2. torque coefficient, thrust coefficient and efficiency of a four blade propeller at various advance ratios is calculated for two different rpm and are presented in table 3 and table 4.The graphs are drawn for advance ratio Vs hydrodynamic characteristics for two different rpm and are presented in figure 3 and figure 4.

Table: 1.Thrust and torque at 909 rpm

Thrust in N	Torque inN-m
2455.8	348
1951	309.5
1456	267
988.97	224.4
527.1	180.68
303.14	133.37

Table: 2.Thrustand Torque at 454 rpm

Thrust in N	Torque inN-m
614	87.24
488.89	77.7
365.26	67.14
247.7	56.44
131.5	45.47
70.84	33.6

Table: 3.shows thrust coefficient, torque coefficient and efficiencyat 909rpm

909RPMOFPROPELLER			
J	K_t	$10K_q$	EFFICIECNY
0.5	0.082559	0.194983	0.437616296
0.56	0.065588	0.173412	0.337268864
0.62	0.048948	0.149599	0.323022973
0.68	0.033247	0.125731	0.286325999
0.74	0.01772	0.101235	0.206255843
0.8	0.010191	0.074727	0.173726747

Table: 4.Shows thrust coefficient, torque coefficient and efficiencyat 454rpm

454RPMOFPROPELLER			
J	K_t	$10K_q$	EFFICIECNY
0.5	0.082762	0.195987	0.336242488
0.56	0.065898	0.174555	0.336672803
0.62	0.049234	0.150832	0.322286667
0.68	0.033388	0.126794	0.285152896
0.74	0.017725	0.102149	0.20448544
0.8	0.009549	0.075483	0.161160696

For theabove tabulated datagraphsaredrawnandareshown in fig. no 3andfig. no 4

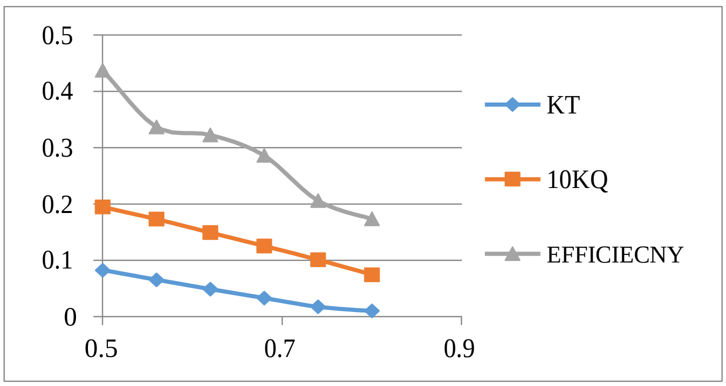

Fig. 3:Graph between thrust coefficient, torquecoefficientandefficiencyat909 rpm

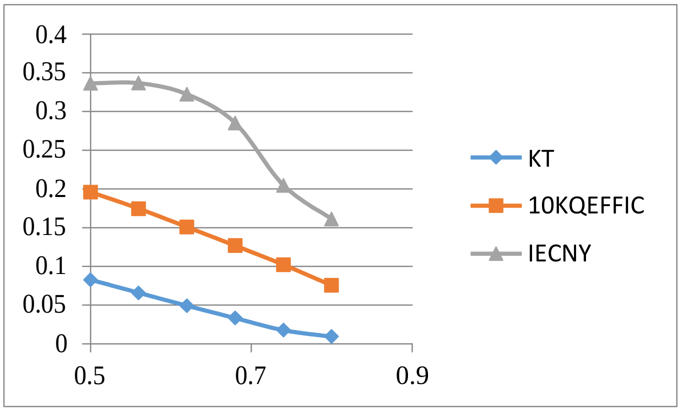

Fig. 4:Graph between thrust coefficient, torquecoefficientandefficiencyat454 rpm

CONCLUSIONS

The four blade marine propeller is designed by using CATIA V5.The flow parameters for four blade composite propeller are obtained by CFD analysis.The hydrodynamic characteristics such as torque,thrust and efficiency of a four blade propeller at various advance ratios is calculated theoretically for two different rpm and compared with the experimental data.From the above calculations it is proposed that the advance ratio, J = 0.66 is sufficient for designing a composite propeller.

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