Development on Design of Optimum Contra-Rotating Propellers under Slipstream Contraction Condition

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Abstract

From previous study, contra-rotating propellers (CRPs) are designed based on lifting line theory where radius of free vortex lines are adjusted in order to correspond to the slipstream contraction condition. The calculus of variations method is then applied on equations that derived from the lifting line theory. The effect of slipstream contraction is included in order to find the optimum CRPs where the required thrust with minimum power can be achieved under the condition that CRPs are operated in axial uniform inflow. Results from calculation are then converted into a 3-dimensional CRPs configuration and is simulated by CFD method as preliminary verification.

Comparison study on results obtained from calculation and CFD shows some differences in thrust and torque on each propeller. To find the cause of these differences, further investigation is done and presented in this study. It is found that the inflow velocity that appears on each propeller is differ from the assumption used in calculation in which inflow velocity appearing on propeller equals to initial inflow velocity that entering through CRPs.

The modification is done by introducing correctors for fore and aft propellers. These correctors are multiplied with the initial inflow velocity to represent new values of inflow velocities appearing on propellers. Initial inflow velocities on propellers are then replaced by these new values. Through the same calculation process, new CRPs configurations are obtained and simulated by CFD method. Correctors are adjusted in each calculation to find proper values that conform both results from calculation and CFD. Through different trying out of corrector values, it can be concluded that the inflow velocity appearing on propeller not only changes differently in each condition but also between fore and aft propellers.

It's found that the inflow velocity is directly proportional to advance ratio and inversely proportional to thrust coefficient. This is because at low advance ratio and high thrust coefficient, the propeller has high rotational speed and strong circulation which tend to create stronger flow field turbulence. This causes the reduction of inflow velocity on propeller. Moreover, the inflow velocity on aft propeller is always less than that on fore propeller, as aft propeller has to encounter with wake flow behind the fore propeller while fore propeller approaches to more uniform flow.

***Keywords**:* contra-rotating propellers, lifting line, slipstream contraction, inflow velocity, correctors