Analysis of Vessel Acceleration with NavCad

A HydroComp Technical Report
Report 118

NavCad is a program for the prediction and analysis of resistance and propulsion. NavCad version 4 and newer can explicitly evaluate vessel acceleration.

OVERVIEW

Hydrodynamic acceleration of a marine vehicle is based on the principal of **F = ma**. In hydrodynamic terms, the force (F) and mass (m) components can be expressed as:

$$F = T\,(1\text{-}t) - R \quad \text{and} \quad m = (1+k)W/g$$

T = propeller thrust
t = thrust deduction
R = total resistance
k = added mass coefficient
W = vessel weight (displacement)
g = gravitational constant

In other words, the force available to overcome the vessel inertia is the possible thrust less the vessel's resistance. Mass is the vessel weight with a multiplier for the added mass of entrained water that moves with the hull.

ANALYSIS

A time-step technique is at the heart of the analysis. Given a known weight and added mass coefficient, the following procedure is performed at incremental steps:

1. Given speed at start of the time step.
2. At the speed, determine thrust, thrust deduction and resistance.
3. Calculate acceleration.
4. Calculate speed at end of time step.
5. Redo the process for the next time step with the new starting speed.

The precision of the results are dependent on the value of the time step used, small values leading to more accurate results. Then you can plot speed, RPM and acceleration versus time.

NavCad can be used to predict resistance and propulsive coefficients (e.g., wake fraction, thrust deduction, relative-rotative efficiency), as well as vessel acceleration. Accurate results are critical to the reliability of the acceleration model. The results can be easily placed into a spreadsheet for the further analysis.

The calculation of thrust is a difficult step that is made very easy with NavCad's unique equilibrium torque ("towing") analysis. The thrust applied to acceleration is not the free-running thrust, but is the maximum thrust that the propulsion system is able to produce at that speed. In other words, this analysis determines the thrust that can be generated until the engine has no more torque (along its torque curve) to spin the propeller any faster.

The magnitude of the added mass coefficient (k) is typically about 0.05 for displacement modes, becoming zero at planing speeds.

ADDITIONAL CONSIDERATIONS

This is a fairly simple, but quite effective, acceleration model. A few additional calculations could be added to make the model more realistic in the first few time steps.

At start up, there can be a negative pressure region caused by propeller suction under planing hulls. This can have the effect of causing the vessel to trim or "squat". This effect could be modeled as an additional increase in the added mass coefficient or as an increase in thrust deduction at low speed.

Improvement in the model would be gained by accounting for the initial torque required to overcome the rotational moment of inertia (wr2) of the engine, gear and propeller at start up. The above model assumes that the RPM of the engine is allowed to reach its potential RPM using a maximum rotational "acceleration".

HydroComp, Inc.
13 Jenkins Court, Suite 200
Durham, NH 03824 USA
Tel (603)868-3344
Fax (603)868-3366
info@hydrocompinc.com
www.hydrocompinc.com