CONSEIL INTERNATIONAL
DES MACHINES A COMBUSTION

INTERNATIONAL COUNCIL
ON COMBUSTION ENGINES

PAPER NO.: 44

Electronic Engine Control for Ice Operation of Tankers

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Abstract: The potential viability of the polar route for transport, leads to the need for more comprehensive studies of ship operation in ice conditions.

The response of the propulsion plant and the ship during advancing in level ice and for ice ramming interactions, is examined using a modular ship-propulsion-simulation platform, including dynamic models for the engine, the propeller and the hull of the ship.

The engine module consists of sets of performance maps of the marine diesel engine, derived by parametric simulations using the detailed engine process simulation code MoTher (Motor Thermodynamics). The developed model was initially validated with experimental data from an electronically controlled two-stroke marine engine, from steady state tests, at constant speed and propulsion operation (variable speed – propeller curve), which were found to be in good agreement with the predicted results.

The propeller module incorporates a four quadrant model of a CPP (1st quadrant: ahead ship motion, positive pitch, 2nd quadrant: ahead ship motion, negative pitch, 3rd quadrant: astern ship motion, negative pitch, 4th quadrant: astern ship motion, positive pitch) for the prediction of the absorbed propeller torque and the developed propeller thrust at various pitch settings.

The ship hull module uses an analytical expression for the prediction of the total ship resistance, for open water conditions, and a hull-ice interaction model for predicting forces and resistance during ice navigation.

The ship trajectory and the propulsion system dynamics are predicted by solving the coupled differential equations for ship motion and engine, turbocharger, propulsion train and propeller dynamics.

For control system studies, an appropriate combination of ice-class tanker hull and propulsion system with CPP and electronic engine was synthesized, using available data for the hull geometry and CPP performance in 4 quadrants.

Different control schemes were designed and tested using simulation. These schemes consisted of separate conventional controllers for engine and CP propeller, as well as combined multivariable controllers using H-infinity optimization. The hull-ice interaction models provided information about the disturbances during the brash ice navigation, as well as ice ramming and backing , so as to investigate the effects on the robustness of the controllers and the overall system sensitivity.