Tanker Propulsion Plant Transient Behavior During Ice Breaking Conditions

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ABSTRACT

The demand for crude oil exports from the Arctic region has led to increased investments in ice-class tonnage. In this paper, the ship and its propulsion plant dynamics during ice breaking conditions are examined based on a modular ship propulsion simulation platform using the Matlab/Simulink tool. Simulation results, regarding the transient engine load response, are presented for the cases of ice breaking during ice channel navigation as well as ice ramming and backing out.

KEY WORDS: Propulsion plant dynamics; ice ramming; engine maps;

INTRODUCTION

The increased interest in oil and gas deposits in the Arctic area as well as the potential viability of the polar route for transport lead to the need for more comprehensive studies of ship operation in these regions. The behavior of the propulsion plant of a tanker during ice breaking is studied in this paper.

Most ice class tankers are designed to navigate escorted by ice breakers, which keep the existing fairways to the harbors open. It is very common for tankers to navigate in an old channel covered by brash ice, Lehtinen (1994). If the brash ice channel is too old or the ice field is compressive, the track opened by the icebreaker may start to close after the icebreaker has passed and large ice floes are created from the consolidation of the brash ice. In this case, the escorted vessel either will try to penetrate into the ice floe or wait for additional icebreaker escort.

The ship navigation in ice environment was investigated in detail by Riska (1987) in the late eighties. Riska (1987) performed a comprehensive analysis of the ramming interaction occurring when a ship rams a massive ice floe. In this study, the ship was considered unpowered and an analytical calculation of the forces developed on the ship's bow was performed. After a decade, Riska (1997) derived a speed dependent formula of brash ice resistance. In the late nineties, Valanto (1997) developed a 3-D numerical model for ice resistance during the ice breaking process at the waterline zone of the ship, when advancing in level ice, for the investigation of ice resistance forces on ship hulls.

The ship propulsion system response during ice navigation is rarely assessed with full scale ship trials performed in ice conditions, since most of the shipyards are far away from the arctic region and the cost is prohibiting. The development of cost effective simulation tools for such investigations is attractive.

In the literature, the ship propulsion system dynamics is usually investigated for open water conditions. For example, a detailed simulation study of slow speed diesel engine performance during ship maneuvers was performed by Kyrtatos (1994). In this simulation work, the detailed engine process thermodynamic simulation code MoTher (Motor Thermodynamics) was used and the engine response was adequately predicted.

The objective of the work presented in this paper is the study of the ship propulsion plant dynamic response in ice operating conditions. In these conditions due to the complexity of the ice ramming interactions, the use of a detailed engine thermodynamic simulation tool would lead to much increased computational time. Thus, a reduced model, including engine performance maps, was developed in Matlab/Simulink environment and is presented here.

SIMULATION PLATFORM DEVELOPMENT

The developed platform considers the ship and its propulsion plant as a set of three interconnected modules, namely the engine, the propeller and the ship hull module. Each module is capable of predicting the operation and response of the relevant system. All modules are analyzed in detail below, whereas their interconnection is described and diagrammatically depicted in the corresponding chapter.

Engine Module

The operation and performance of the marine diesel engine is represented through a set of parametric performance maps. The use of parametric maps, in order to describe thermodynamic engine performance, allows for increased flexibility regarding engine