THE INTEGRATION OF MEAN VALUE FIRST PRINCIPLE DIESEL ENGINE MODELS IN DYNAMIC WASTE HEAT AND COOLING LOAD ANALYSIS

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ABSTRACT

With the inevitably increasing oil price and the focus on cleaner ships the interest in waste heat recovery systems has again increased. For practical reasons the application of these systems in Short Sea Shipping has been limited, mainly because of the complexity and not well understood dynamics of the (steam) plant. The development of first principle mean value simulation models for Diesel engines has been focussed on the analysis of ship propulsion system dynamics and the behaviour of the engine as an integral part of these dynamics.

In order to extend the analysis to the thermal balance of the total ship system, including waste heat recovery and cooling loads, an extension to the modelling has been researched and evaluated. This starts with an in depth analysis of all heat losses in the different components of the engine, and the way they are integrated in the current model. The distribution of heat to the various cooling media (water, air, lubrication oil) is added to the model using a first principle approach, enabling easy adaptation to various Diesel engines and system lay-outs.

The focus is not on replicating an exact engine or system, but rather on creating a first principle tool that enables researchers to investigate typical dynamic characteristics. This paper will show the applied modelling approach and discuss the benefits and draw-backs of analysing waste heat and cooling streams by mean value first principle models.

INTRODUCTION

As part of the Hercules-B project [1] the authors are involved in Task 6.1 “Overall Ship Power Train Optimisation” which focuses on the development of a dynamic simulation tool for ship propulsion optimal configuration and performance, and for optimizing the overall ship power train for real service conditions. Dynamic simulations of the entire ship operating profile will identify critical conditions in terms of performance emissions. Initial models of the subsystems have been developed.

Waste heat recovery (WHR) systems are in use on board many ships, and not necessarily only through the use of the exhaust gases. For instance for fresh water production on many ships flash evaporators are used that are integrated in the high temperature cooling water system, or heating systems for accommodation spaces interconnected with the cooling water systems. These systems improve the efficiency of the ship in a very direct and effective way, although it is sometimes difficult to quantify these benefits: what is the energy value of ‘freely’ produced fresh water? Or how to evaluate the heating energy required for heavy fuel bunkers? In this paper only WHR systems that deliver mechanical energy will be considered, for which the benefits are clear and (mostly) independent of ambient conditions and choice of fuel type.

A way to improve the effectiveness of the overall system is through better understanding of the behaviour and the interactions between the components. If ‘propulsion efficiency’ is defined as the ‘transport efficiency’, the calculation should clearly extend beyond the static operational point performance. A very efficient energy system with limited operational flexibility could then lose out to a less efficient system when considering real operational conditions.

INTRODUCTION OF DIESEL ENGINE MODEL

The diesel engine model applied here was originally developed by TU-Delft and NL Defence Academy in 1997 - 2001 while a major revision took place in 2001 - 2003. It was used for investigation of ship manoeuvring behaviour in [2] and for exploring new propulsion control strategies, in [3], [4] and [5]. In particular [4] gives a comprehensive overview of the theoretical backgrounds. Only the basic principle will be highlighted here.