Tribological Performance of Different Geometries of Piston Rings in Marine Diesel Engines

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ABSTRACT

Friction in the piston ring package (piston, piston rings and liner) is a major source of power consumption in two stroke marine diesel engines (Priest, 1998) (Hamatake, 2001,4). It is well-known that a typical piston ring operates under full separation in the mid-part of the stroke, and in the mixed lubrication regime at the dead centres. A theoretical model is developed to predict the performance of piston rings throughout the entire cycle. This model is based on Reynolds equation coupled with a pressure-density relation for modelling of cavitation. It is assumed that the infinite width bearing assumption is valid, which effectively reduces the spatial dimension by 1. The viscosity of the oil is based on a tabulated viscosity-temperature relation and the measured temperature of the piston ring segments. Thus, it is not necessary to include the energy equation in the theoretical model. Asperity interaction is included in the model. Conservation of oil is ensured by considering the amount of oil outside the piston ring/liner interface.

In order to validate the theoretical model a reciprocating lab scale test apparatus has been developed (Volund., 2006.). Straight test specimens with radii of curvature of 80 mm, 160 mm, and 240 mm are manufactured from real piston ring material. The mating slider is manufactured from cylinder liner material. Experiments are conducted at five different speeds and a fixed dead-weight loading. The friction force and the bulk temperature of the test specimen are recorded as a function of crank angle position. Good correlation between the measurements and the simulations has been observed, especially when running at a high speed.

INTRODUCTION

The life time of large two stroke marine diesel engines can easily be more than 3 decades. The longevity of the engines requires that some of the components need to be exchanged. A typical engine runs for more than 3000 hours each year which is a substantial figure compared to engines used for automotive applications. The piston rings are some of the components which have to be replaced during the lifetime of the engine. The piston rings usually operate in all the classical lubrication regimes. At the top dead centre (TDC) the piston ring is operating in the boundary lubrication regime, and as the piston starts to move there is a change to a partial lubrication regime, only to shortly after reach the hydrodynamic regime in the middle part of the stroke. Once the piston rings passes the mid part of the stroke and the piston starts to slow down the piston ring once again has to operate in the mixed lubrication regime and finally at the bottom dead centre (BDC) undergo the situation around the BDC where boundary lubrication regime is present. These harsh operating conditions makes it difficult to design a bearing suited for optimal operation conditions in all three lubrication regimes. The fact that wear is also present makes the situation more complicated. The goal of the research project funding the work reported in this paper is focused on the design of low friction operating conditions of selected bearings in large two stroke marine