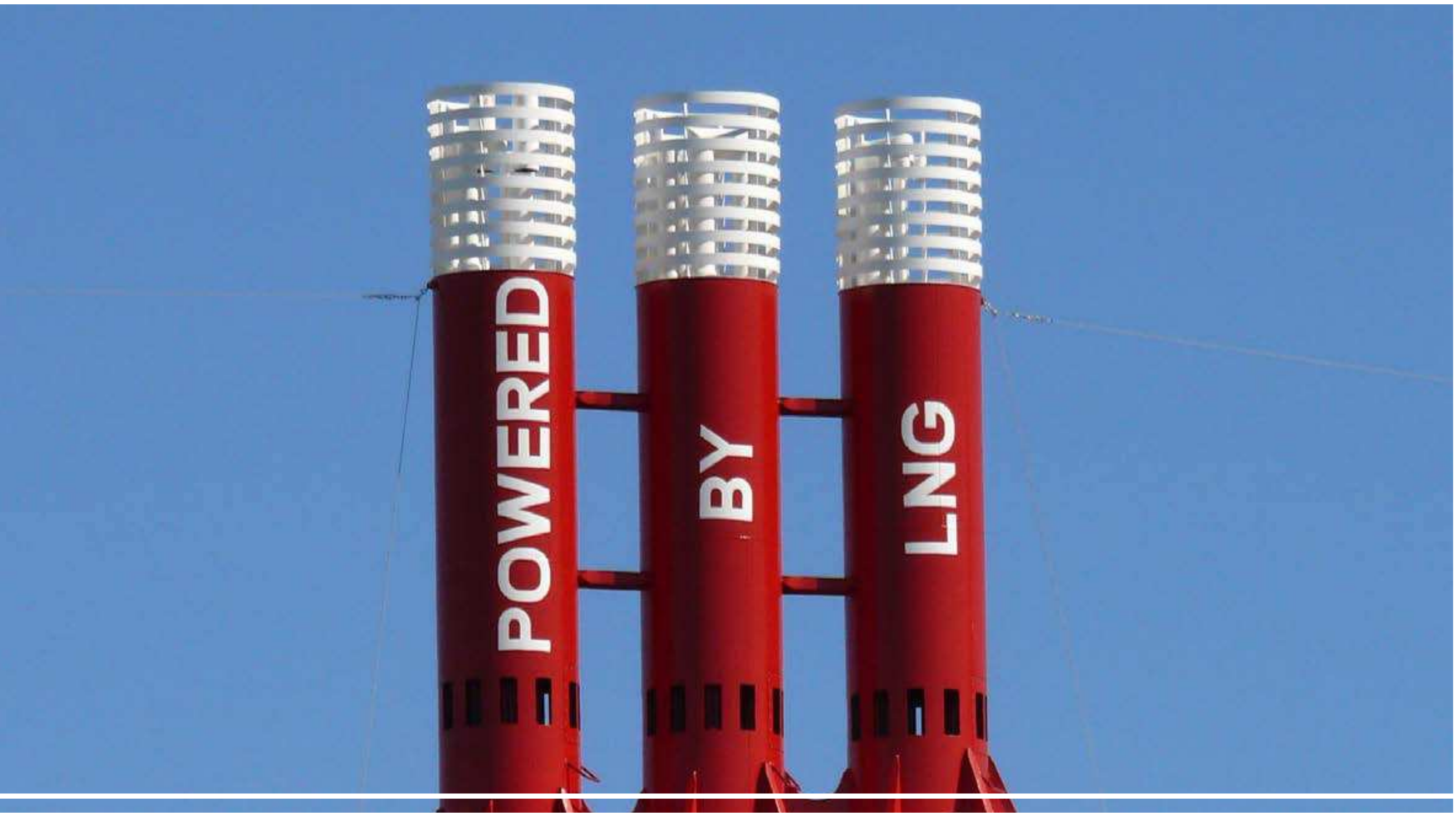

MARITIME

LNG FOR SHIPS – KNOCK PREDICTION

Background

LNG is becoming an attractive alternative to traditional transportation fuels such as diesel and heavy fuel oil. The composition of LNG, also called LNG "quality", available in the market varies strongly. To ensure that the engines to be used in LNG-fuelled ships are matched with the expected variations in fuel composition, the knock resistance of the fuel must be determined unambiguously.

DNV GL contribution

DNV GL has developed a method that accurately characterizes the knock resistance of fuel gases in a stationary gas engine. To facilitate the use of the method in marine engines we extended the model to pentane-containing LNG fuels. Furthermore, the effects of humidity and the effects of boil-off on the knock resistance were studied and included in the model to guarantee safe and optimum engine performance. The extended knock model has been tested against experiments on two different types of gas engines using fuel gases with different gas compositions. Excellent agreement was observed between the predicted and measured knock resistance. Since the DNV GL method is based on the physical and chemical processes that govern knock, it can be adapted in a straightforward manner to new engines and fuels; this makes the methodology uniquely suited to serve as the basis for a robust standard. To be able to extend the method to cover the variety of marine engines, an inventory of the gas engine types used for marine propulsion and auxiliary drives was conducted. The analysis of the result identified groups of engine types that, based on similarities in their operating regimes, can be expected to have similar knock behavior.

Project results

Engine knock is characterized by autoignition of the unburned fuel mixture, known as end gas, ahead of the propagating flame in the engine cylinder. The DNV GL model simulates engine knock by calculating autoignition of the compressed end-gas during the engine cycle. In this project, the detailed chemical mechanism describing autoignition used in the model has been extended with the oxidation chemistry of the pentane isomers. The extended model was tested and optimized against autoignition delay times of methane/pentane mixtures measured in the Rapid Compression Machine at the DNV GL combustion facility. In addition to the effects on autoignition itself, the effects of pentane on the in-cylinder pressure and temperature conditions relevant for knock, such as changes in heat capacity of the air-fuel mixture and changes in the burning rate of the fuel were also incorporated in the model.

The extended knock model was tested for two types of gas engines; a medium-BMEP, high-speed, spark-ignited engine and a high-BMEP, pre-chamber, medium-speed gas engine. For both engines, the predicted knock resistance agreed with the measurements within the uncertainty of the measurements for all gases studied, attesting to the veracity of the method. By comparison, predictions obtained using existing methods, i.e., those developed by the companies AVL and MWM, for the same range of gas compositions studied in the two different types of gas engines showed large discrepancies with the experimental results.

Effects of humidity and boil-off on the knock resistance

In addition, the impact of humidity in the combustion air on the knock resistance was investigated experimentally and the effects of humidity on engine processes are incorporated in the knock model. The experiments show that the knock resistance increases substantially with increasing water content in air. Comparison with the experimental results shows that the effects of varying water content in air on engine processes leading to knock are faithfully captured by the model. When coupling the knock model with a gas quality/humidity sensor, the positive effect of humidity on knock allows increasing the engine load under humid conditions, which will improve engine efficiency. The knock method developed by DNV GL has also been coupled with a boil-off model, which allows us to predict the changes in knock resistance in time during a voyage. This is valuable input for the discussion regarding the acceptability of the range of LNG qualities in the ports at which ships bunker.

The DNV GL method has been demonstrated to be an excellent predictor of engine behavior regarding engine knock, and is a superior alternative for existing knock methods. It has been proven for two of the five groups of engine types that are used on ships. To ensure that the method accurately predicts the knock behavior of LNG of all types of gas engines for maritime use, the aim is to extend the DNV GL method to the remaining three groups of engines.

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