Master Thesis in Marine Technology – 2014

Contractual and Economical Consequences of LNG Boil-Off Gas Quality

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Introduction

The global transport of Liquefied Natural Gas (LNG) has grown rapidly during the last decades and thereby the competition in the market. By 1st of October 2013 there was a fleet of 380 LNG Carriers. The total fleet compromised 56.1 cubic metres, while the orderbooks was equivalent to 35.2 per cent of the total fleet capacity (Novikova, 2013). Many ship owners have joined the LNG transport sector, which makes efficiency more important in order to provide the lowest freight rates. Some of the transported LNG will vaporize during voyage, which is normally used as fuel for the vessel. As the insulation of the cargo tanks become better the rate of evaporations decreases, and thereby requires a more efficient fuel economical carrier for transport.

The gas evaporating from the LNG, usually called Boil-off Gas (BOG), has previously been out of focus regarding its composition and corresponding heating value. A concentration of the BOG has been assumed to be identical to the loaded LNG, or has been given by another constant value, as the gas has been something to the carrier has "to get rid off". However, these assumptions have seemed to give deviating results in reported fuel consumption for the vessel in some cases. This is interesting as the assumed concentration of the BOG is used to calculate its heating value, which further is used to estimate the over all fuel consumption reported as amount of Heavy Fuel Oil (HFO).

Each vessel has a given chartering contract specifying upper limits of total fuel consumption for the vessel per day. Deviating values by assumed concentration of the BOG might result in breach of contract, and corresponding economical consequences. Thereby, it is very important to understand the properties of the BOG by a given LNG concentration, and the corresponding contractual consequences by deviations in reported fuel consumption for the vessel.

Objectives

The main objective of this thesis is to get a better understanding of the gas evaporating from the LNG during voyage, as the BOG's concentration has significant influence on the reported fuel consumption for the vessel. To accomplish this, a mathematical model to estimate day-to-day changes in concentration of the BOG by a given LNG concentration will be developed. The following output will be used to investigate changes in reported fuel consumption for the vessel by different LNG qualities, and to highlight deviations caused by assuming a concentration of the BOG to be constant or equal the loaded LNG. Finally, this will be analysed from a ship owner's perspective regarding contractual and economical consequences by assuming a wrong concentration of the BOG.

Methods

It has been developed a dynamic mathematical model to better understand the changes in physical and chemical properties of the Boil-Off Gas (BOG) during transport, in addition to how it affects the reported fuel consumption of the vessel. This model is made to give unique results depending on the vessel's specifications and duration of the transport, which is specified by the user.

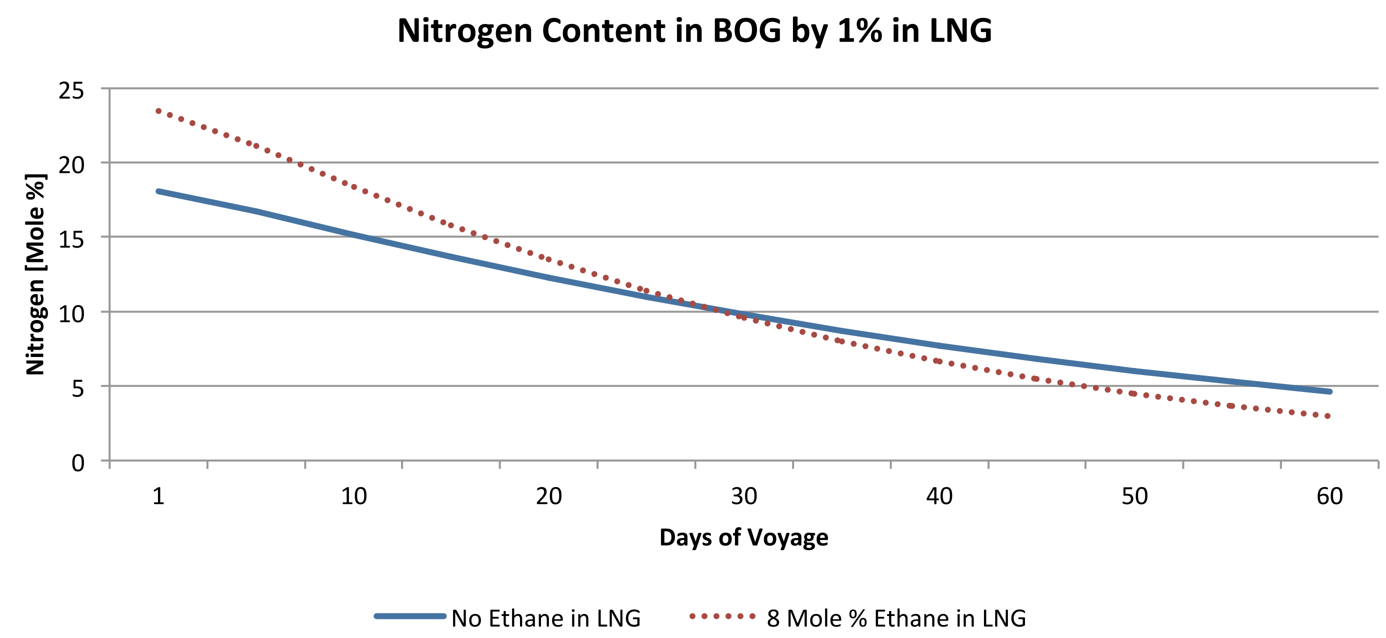
The model itself is divided into sub-models, to better illustrate the changing concentration of the BOG compared to the loaded LNG, and how this affects the reported fuel consumption for the vessel. These subpart are as follows:

- Change in concentration of the BOG compared to the loaded LNG
- Flashing of gas during loading, which influences the initial concentration of the LNG when finally loaded.
- Change in Higher Heating Value (HHV) of the fuel due to change in concentration of the BOG
- Corresponding change in Fuel Oil Equivalent (FOE), which is a conversion factor to report amount LNG used as fuel in amount HFO.

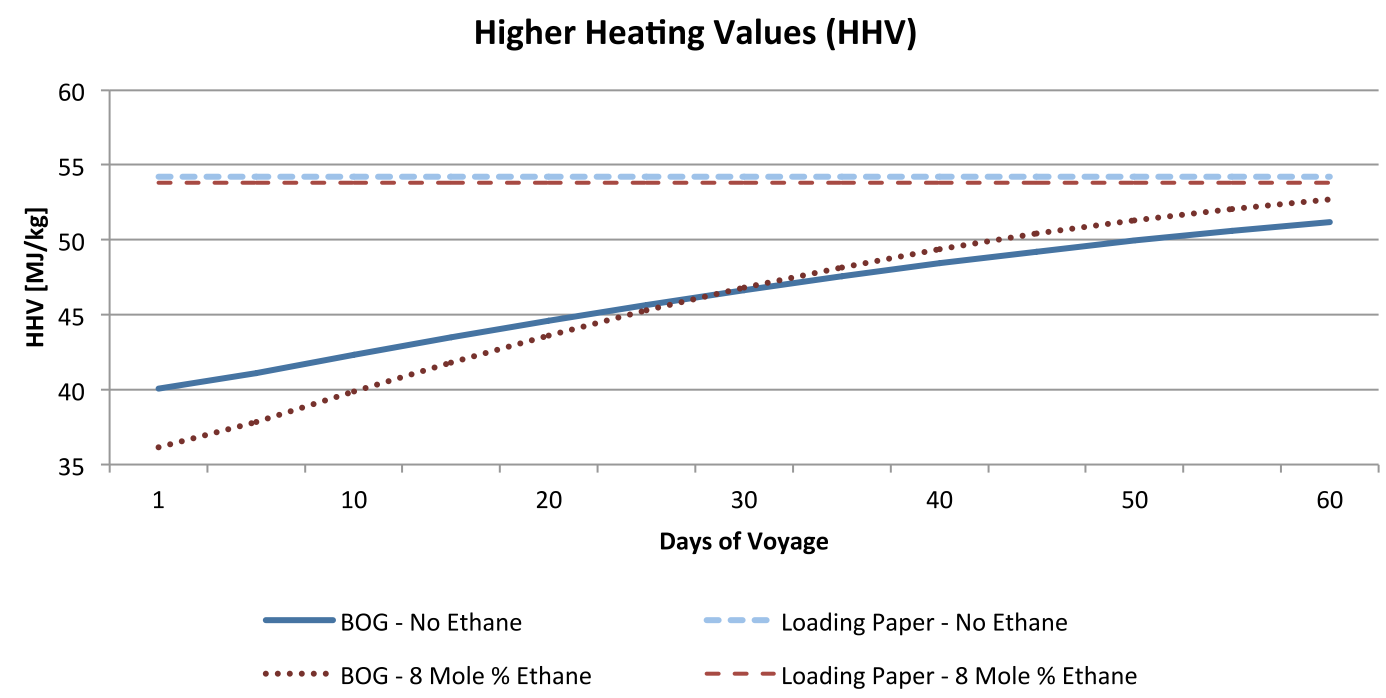
The models was later tested for results by different loaded LNG quality to see how it affected the concentration of the BOG. To know the accuracy of the results, some of the values were compared to real measurements on some LNG carriers.

Results and Conclusion

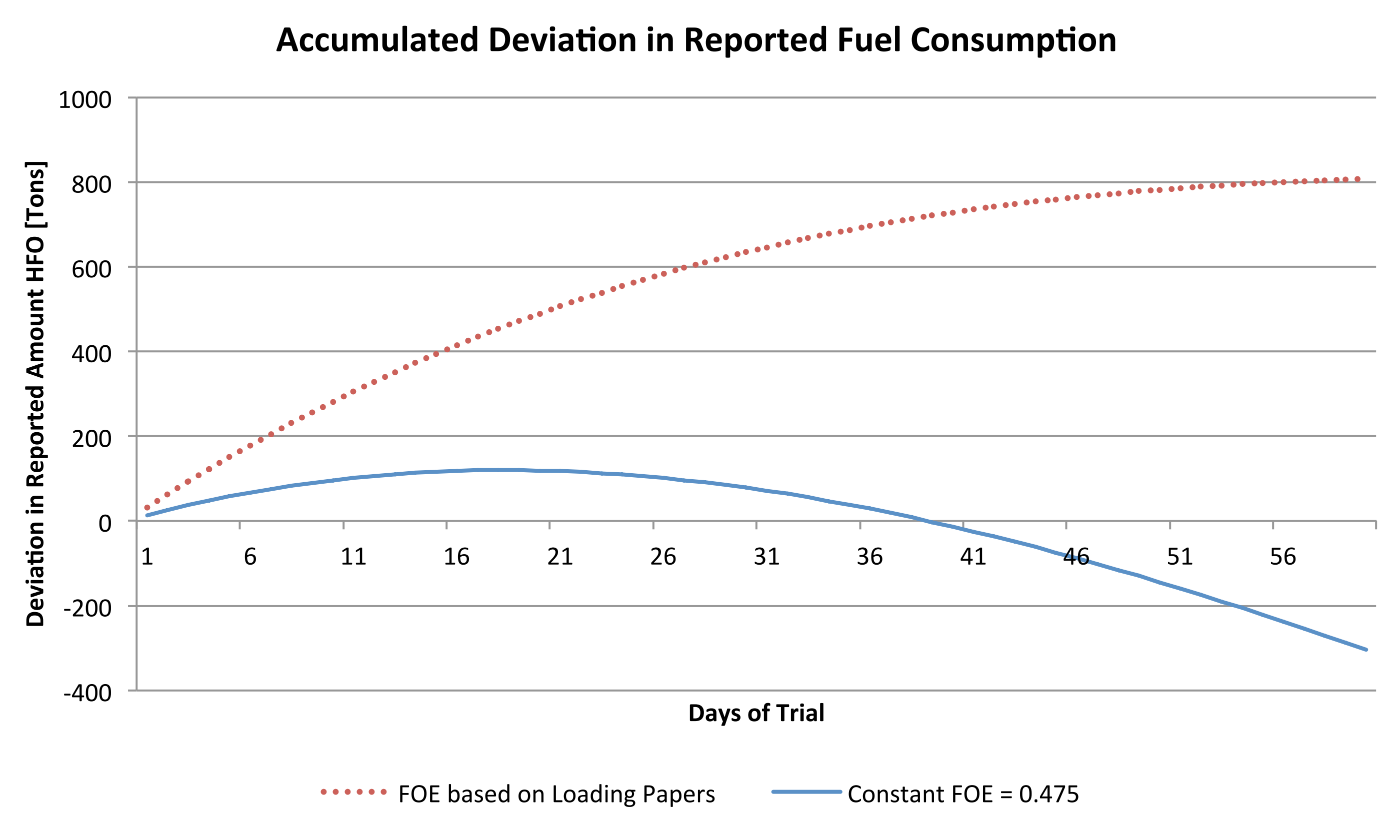
The overall trend in the results from the model was a significant increase in fraction of nitrogen in the BOG by only a small increase of nitrogen in the transported LNG. The concentration of the LNG will change during the loading process, which might influence the initial state of the cargo for the first day of the voyage. Especially LNG with a high content of nitrogen experienced a noticeable loss in fraction of nitrogen in the finally loaded product. However, the most significant difference was in concentration of the BOG compared to the LNG in the cargo tanks.



The difference in concentration of the BOG compared to the transported LNG did affect the calculated HHVs. It has been a common technique to assume the concentration of the BOG to be equal the values of the LNG given by the terminal, but this resulted in large differences in calculated HHVs. Especially in cases of high nitrogen content, where the BOG tended to have a much lower HHV than the calculations based on assumed concentrations. Additionally, this change in HHVs resulted in deviations in the calculated FOEs, which as a consequence will result in a very significant over reported fuel consumption for the vessel.



The total reported fuel consumption for an LNG Carrier is estimated by use of a fuel oil equivalent (FOE), which depends on higher heating value (HHV) of both the BOG and the HFO. This constant is very important as it affects the reported fuel consumption for the vessel when converting amount LNG to corresponding HFO. In cases of having a low fraction of nitrogen in the loaded LNG, the deviations were not that significant. However, by increasing the fraction of nitrogen and ethane it resulted in significant deviations when assuming a wrong concentration of the BOG. The worst case resulted in 31.6 tons of fuel oil equivalent over reported for the vessel at the first day, which would have resulted in an unnecessary cost of 366000 USD for a voyage of 28 days.



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