Available online at www.sciencedirect.com

ScienceDirect

Journal of Ocean Engineering and Science 000 (2016) 1–10

www.elsevier.com/locate/joes

On the estimation of ship's fuel consumption and speed curve: A statistical approach

Nicolas Bialystocki[a], Dimitris Konovessis[b,*]

[a] Technical Department, Antares Shipping Ltd., Israel
[b] School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore

Received 18 December 2015; accepted 26 February 2016
Available online xxx

Abstract

When fuel efficiency is at stake, along with the reduction of the environmental foot print of air pollution, a need is presented to estimate a ship's fuel consumption for a forthcoming voyage, and means for decision making and for cost saving. This paper suggests an operational approach for obtaining an accurate fuel consumption and speed curve, on the basis of major factors affecting it, namely, ship's draft and displacement, weather force and direction, hull and propeller roughness. A statistical analysis on 418 noon reports of a Pure Car and Truck Carrier case ship is carried out and the influence of the above factors is calculated. As expected, stronger wind and head weather increases the fuel consumption, and the difference between several weather conditions could be quantified. A simple and accurate algorithm is proposed in order for ship owners, managers and operators to be in a position to apply the suggested method on their fleet. Finally, applications of the structured algorithm are introduced with examples, in estimating the fuel consumption of the case ship for a future voyage, and also the same for a sister ship. Furthermore, voyage planning in several scenarios is proposed in order to assist the stakeholders with decision making aimed to fuel saving and environmental friendliness of their ships.

Keywords: Fuel consumption; Ship's noon report; Weather; Hull and propeller roughness; Service performance; Decision-making.

1. Introduction

In recent years, fuel efficiency of ships is a major topic addressed by every private, national and international body related to shipping, receiving considerable attention due mainly to fuel cost increase, and environmental deterioration, in particular air pollution.

Fuel onboard ships, commonly referred to as "bunkers", has become the largest cost item of a ship's Operational Expenses (OPEX), accounting today almost 50% of a voyage cost, even greater than crew wages [21]. The level of interest in designing a fuel efficient ship is linearly related to the fuel price [24]. Between 1970 and 1980 fuel oil price increased significantly (nearly ten-fold), leading to ships with high fuel consumption being laid up. During the period 1985–2000 prices of fuel oil fell, with research and development on energy efficiency not receiving particular attention by the maritime industry. However, from 2000 onwards, the crude oil cost started to climb again, which pushed engine manufacturers, shipyards and designers to re-investigate design and operational solutions for reduced fuel consumption and energy efficiency.

Shipping is no different than other industries, and is highly affected by fuel prices. However, there is, to a certain extent, a control on the ship's fuel consumption by means of technical innovation fitted or by a better ship operation such as weather routing, trimming, slow steaming, etc. [8].

Even though oil price decreased for a brief period of time after the 2008 recession, today is again at record high levels, meaning that ship operators cannot ignore this expense as in the past, or just embody it into the price of the commodities carried, but there is a need to design and operate more efficient ships, consuming less fuel per carrying capacity.

* Corresponding author. Tel.: +65 67904433.
E-mail address: dkonovessis@ntu.edu.sg (D. Konovessis).

http://dx.doi.org/10.1016/j.joes.2016.02.001

Furthermore, the intense focus on environmental protection, supported by considerable research findings, has led the International Maritime Organization (IMO) to take concerted measures towards this direction, in limiting the environment foot print of ships significantly.

In particular, one of the top environmental topics is global warming due to increasing Green House Gases (GHG) in the atmosphere. The shipping industry contributed about 4% of the world carbon dioxide (CO_2) emissions in 2007 [19]. The aim to reduce CO_2 emissions comes hand in hand with the increasing fuel price, and is leading towards the adoption of technological and operational innovations in order to decrease fuel consumption.

In order to set means to improve ship's fuel efficiency, it is initially required to define the prevailing fuel consumption rate. For this purpose, the importance of carrying out a full scale ship performance analysis is highlighted in several publications as offering benefits to the designers and the operators. The aim of such an analysis can, for example, be the prediction of the required propulsion power [18], or monitoring of the hull resistance due to fouling [1]. Boom et al. [6] suggested that since sensors are already found onboard, along with equipment to transmit the information, continuous monitoring can be achieved with an adequate analysis.

The research presented in this paper, uses a similar approach, with the well-defined goal of plotting accurate speed and fuel consumption curves from relevant operational data, whilst overcoming intermediate factors normally taken into account, e.g. power and SFOC [14]. Applications of the derived method are also presented and discussed.

2. Factors affecting ship's fuel consumption

Typically a ship's power vs. speed curve is prepared during the delivery sea trials. Power is a more stable parameter compared to fuel consumption and hence easier to be measured. On the other hand, the corresponding ship's speed is measured, being the most significant parameter determining both the power and the fuel consumption.

In addition to increases in speed, resistance and fuel consumption increase by any of the following three parameters [2]:

- Increased draft and displacement
- Worsening of weather conditions
- Worsening of hull and propeller roughness

Theories and methods on the estimation of the contribution of each of these parameters on increased resistance and fuel consumption can be found in the literature [3]. However, most are based on experiments obtained from series tests on specific types of ships and hull forms. Therefore, a statistical voyage analysis [16] was carried out for investigating the influence of ship's draft, of the weather and the hull and propeller condition to produce the fuel consumption vs. speed curve, which represents a more realistic and accurate approach for contemporary ships, as required. The approach assumes that predictions based on a previous year performance are more accurate and reliable than based on sea trials.

The existing power-speed curve has two drawbacks. First, when fuel efficiency and CO_2 emission are of concern, the fuel consumption is more important to be calculated than the engine power.

Secondly, the production of a single curve during sea trials is far from adequate for the entire ship's lifetime, and such a curve is truly theoretical rather than practical. In addition, the operators do not have an analytical and systematic method to come up with a more accurate, updated curve, which is applicable for aged ships, not only for new ones.

By computing a fuel consumption and speed curve, with high degree of preciseness, a more reliable estimation of the fuel needed in a future voyage or even for a sister ship is likely to be obtained.

A simple example for appreciating the importance of establishing such a method can be drawn by taking into account that the main expense of ship owner under voyage charter is fuel cost, and considering 280 yearly running days at a consumption of 50 ton/day in fuel cost of 400 USD/ton, a 5% error in fuel calculations easily accumulates to 280,000 USD/year, meaning about 770 USD/day increase of hire rate. Hence, a small deviation in the fuel calculation immediately is reflected in an operational cost significantly higher or lower than the predicted, which means that operators can respectively decrease their expected revenue, or loose fixtures.

It is therefore essential for decision making, to have better predictions of the fuel consumption, particularly nowadays due to the diminished profit margin of the shipping business and due to the interest in running lower emissions ships.

3. Algorithm and initial corrections

Fig. 1 presents an outline of the process developed in predicting the fuel consumption and speed curve.

For this purpose, four parameters are evaluated:

- Ship's draft in the suggested voyage
- Weather force
- Weather direction
- Date of the fore coming voyage

The draft can be calculated from hydrostatic and stability tables, whereas the input should be the intended cargo weight and arrangement in the cargo holds. Weather forecast is to be used to predict wind force and direction, while the date of the expected voyage is also required for the fuel consumption calculation.

On this basis, Fig. 2 illustrates the algorithm developed for the prediction of fuel consumption and speed curve. By utilizing the final curve obtained through the algorithm described in Fig. 1, it is possible to estimate the fuel consumption in a future voyage, based on predetermined information.

Initially, three corrections are applied before a preliminary curve is plotted: