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STUDY OF HYDRO-METEOROLOGICAL CONDITIONS AND FUEL CONSUMPTION ON THE USUAL TRADING ROUTES OF VLCC (VERY LARGE CRUDE CARRIERS)

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Abstract: In this paper will be introduced some of the usual worldwide navigation routes of VLCC type vessels, with presentation of the data collected by the author on the voyages made by a ship with DWT = 307284 tons, during the period December 2015 – December 2018. For reasons of relevance, trips to the high seas lasting more than 7 days were chosen as much as possible. The objective is to investigate the usual hydro-meteorological conditions on some of the main trading patterns of the VLCC - Very Large Crude Carriers, (vessels intended for the transport of crude oil, with a carrying capacity of approximately two million barrels, DWT approximately 270000 - 330000 tons). Diagrams and tables with data collected are also presented. This may be of further assistance in studying the opportunities of using renewable energy sources, in particular the wind one, in order to improve the energy efficiency of such voyages.

Key words: Carbon, Fuel, Routes, VLCC, Wind.

1. INTRODUCTION

EEDI of a ship stands for *Energy Efficiency Design Index*. The EEDI calculates the theoretical energy efficiency of a new ship and refers to the estimated emissions of CO_2 per tonne-mile of cargo carried.

The calculation of the EEDI is based on the theoretical specific consumption of the engines (in g/kWh). The EEDI formula can be found in IMO's MEPC.1/Circ. 681.

This includes some adjustments/factors depending on the type of ship to which it refers. EEDI is a measure of the energy efficiency of a new ship, but does not effectively measure the energy efficiency of a ship according to the actual operating conditions.

For example, two sister ships with the same Energy Efficiency Design Index may have different emissions depending on the actual navigation area (worldwide, coastal, etc), the hydro-meteorological conditions and the actual way in which the ship is operated.

EEEI or *Energy Efficiency Index of Exploitation* can be defined as the Effective Energy Efficiency Index considering the technical condition of a ship at a given time during the period of operation. In this regard, a factor of the technical condition of the ship, Technical Factor (TF), can be introduced.

EEOI or *Energy Efficiency Operational Index***.** The IMO has also defined an Energy Efficiency Operational Index that aims to measure the yield of a ship considering the real operating conditions.

The calculation is based on the actual fuel consumption related to the actual distance travelled and the cargo transported.

The complete equation is contained in the IMO MEPC.1/Circ. 684 document. Unlike EEDI and EEEI, EEOI does not refer only to new ships, but also to existing ones, and can be used to determine the effects of any changes in the technical conditions and / or operation of the ship, such as: cleaning the hull / propeller, reducing the service speed, better hydro-meteorological assistance of navigation, etc.

Since the calculation of such an EEOI depends largely on the conditions / routes of navigation, it cannot be used to determine the actual technical condition / performance of the ship at a given moment.

The *Energy Efficiency Index* of an Existing Ship. Another approach of leading international experts (Rightship Organisation, Carbon War Room) is to calculate the energy efficiency of an existing vessel using the existing data on the consumptions of a particular vessel.

The EVEI – *Existing Vessel Energy Efficiency Index* is based on the IMO's methodology for calculating the EEOI.

The main difference between EVEI and EEDI relates to the way of collecting consumption data. While EEDI data is made available by classification societies and refers to a new vessel at the time of commissioning, the data for the calculation of the EVEI are calculated retroactively for existing vessels using the data available from ship owners, charterers, shipyards, etc. However,

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the actual formula for calculating the EVEI has not been made public by the initiators.

In the calculations of the energy efficiency of the trips presented in the following chapters, the Energy Efficiency Operational Index (EEOI), as defined by the IMO, will be used. The complete equation is contained in the IMO MEPC.1/Circ. 684 document [17-19]. Unlike EEDI and EEEI, EEOI does not refer not only to new ships, but also to existing ones, and can be used to determine the effects of any changes in the technical conditions and / or operation of the ship, such as: cleaning the hull / propeller, reducing the speed of marching, better hydro-meteorological assistance of navigation, etc.

$$\text{EEOI} = \frac{\text{Effective Fuel Consumption} * \text{Carbon Conversion Factor}}{\text{Distance Travelled (Nm)} * \text{Cargo Transported (tonnes or passengers)}} \quad (1)$$

Table 1. Fuel conversion table / CO2 emissions (non-dimensional conversion factor).

No.	Fuel Type	Reference	Carbon Content	Conversion Factor
1	Diesel Oil	Grade ISO 8217 DMX to DMC	0.875	3.206000
2	Light Fuel Oil	Grade ISO 8217 RMA to RMD	0.860	3.151040
3	Heavy Fuel Oil	Grade ISO 8217 RME to RMK	0.850	3.114400
4	Liquefied Petroleum Gas (LPG)	Propane Butane	0.819 0.827	3.000000 3.030000
5	Liquefied Natural Gas (LNG)		0.750	2.750000

Source: IMO MEPC.1/Circ.681 ANNEX

2. OVERVIEW OF THE USUAL TRADING ROUTES OF VLCC-TYPE SHIPS

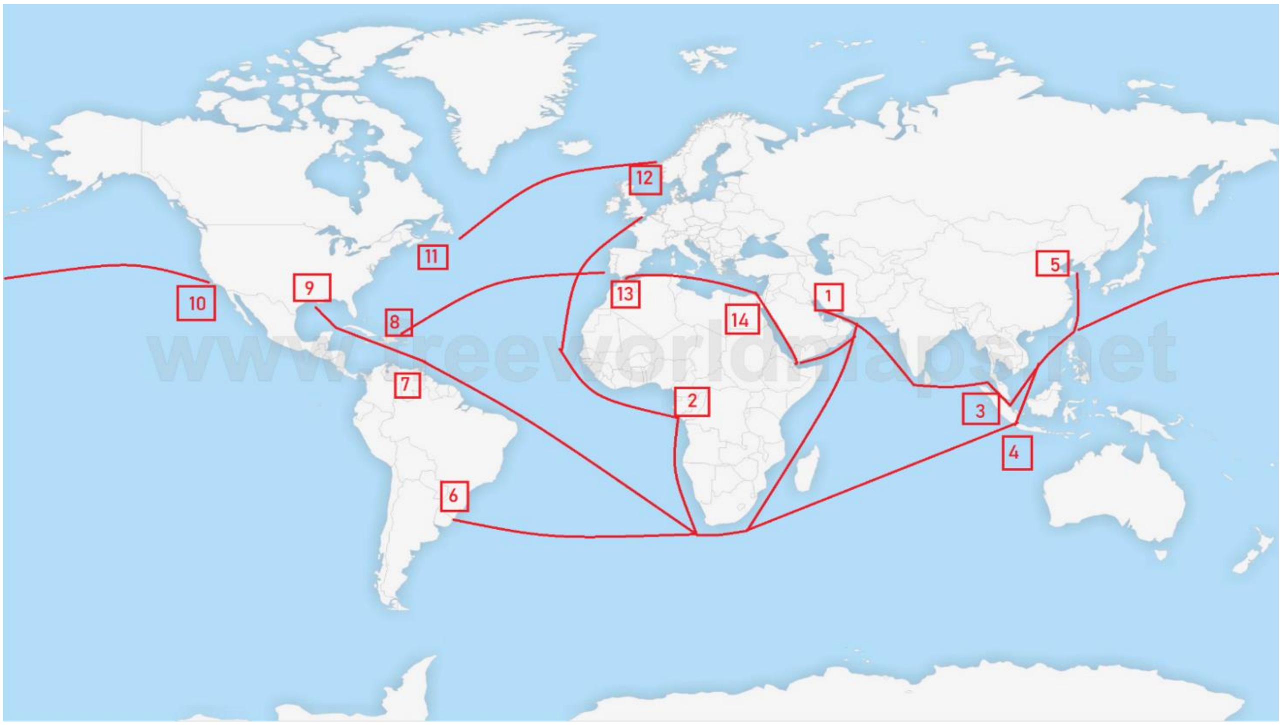

Figure 1 Main points of interest in international Crude

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Oil trade are presented. Compiled as per author's experience [14], [15].

2.1 Points of interest

1] Persian Gulf – Export of Crude Oil, Supply
2] West Africa - Export of Crude Oil
3] Singapore – Export/ Import of Crude Oil, Transit and Supply
4] Sunda Strait – Transit, Supply
5] Far East: China, Japan South Korea – Crude Oil Import
6] Brazil – Export of Crude Oil
7] Venezuela – Export of crude oil
8] Caribbean - Export / Import / Transit of Crude Oil
9] U.S. Coast to the Gulf of Mexico (U.S. Gulf) – Export/Import of Crude Oil
10] U.S. West Coast / Canada – Crude Oil Import
11] U.S. East Coast / Canada – Crude Oil Import / Export
12] The NW coast of Europe - Export / Import / Transit of Crude Oil
13] Gibraltar – Transit/supply
14] Suez - Export / Import / Transit of crude oil, transit, supply

2.2 Voyages with the laden vessel

A) Loading in the Persian Gulf – Discharging Singapore
B) Loading in the Persian Gulf - Discharging Far East (China, South Korea, Japan), Transit via Singapore
C) Loading in the Persian Gulf – Discharging at Suez or Suez Transit, Discharging in Mediterranean or the NW Coast of Europe (Rotterdam).
D) Loading in the Persian Gulf – Discharging in Caribbean. U.S. Coast to the Gulf of Mexico, via Cape of Good Hope.
E) Loading the Gulf of Mexico (USA), Caribbean, Venezuela or South America (Brazil) – Discharging in the Far East.
F) Loading West Africa (Angola, Nigeria) – Discharging in Europe.
G) Loading in West Africa – Discharging in the Far East via the Cape of Good Hope and the Strait of Singapore or via the Sunda Strait.

2.3 Voyages with the ship in ballast

H) Far East – Persian Gulf, via Singapore
I) Suez – Persian Gulf
J) Far East – South America or the Caribbean, via the Cape of Good Hope
K) Suez – Persian Gulf
L) Mediterranean - Caribbean, via Gibraltar.

Note:
Compiled as per author's personal experience and data collected whilst serving over 20 years on board Oil Tankers, out of which 15 years in the capacity of Master.

3. DATA COLLECTION DURING SEAGOING VOYAGES

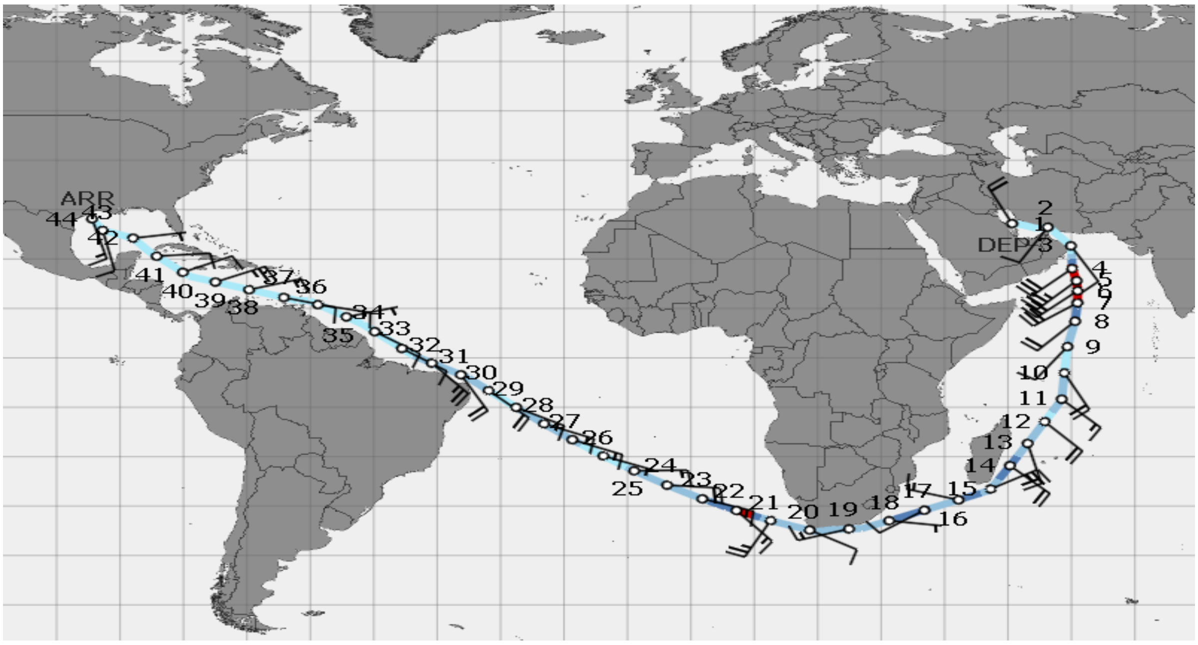

Figure 2 Wind diagram during a Laden Passage from Persian Gulf to Gulf of Mexico, via Cape of Good Hope, June – August 2017. Compiled using Meteorological Office (SMHI) specialised software.

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Table 2. Comparative data for Laden Passages

No.	Route	Period	Average Speed (Kts)	Total voyage Days	Days prevailing following wind	Days prevailing head wind	Days prevailing cross wind	EEOI achieved
1	West Africa – Far East	Nov – Dec 2018	12.22	35	3	27	5	3.085
2	Persian Gulf - Singapore	September 2018	11.30	15	8	3	4	2.323
3	Caribbean – Far East	June–July 2018	12.18	51	8	30	13	3.735
4	Persian Gulf – Gulf of Mexico	June-Aug 2017	12.60	43	30	8	5	2.579
5	Persian Gulf – Far East	Feb-March 2017	12.22	22	6	12	4	3.688
6	Persian Gulf - Suez	Nov-Dec 2016	11.97	11	6	5	-	2.786
7	South America-Singapore	Nov-Dec 2015	12.53	30	6	12	12	3.592
8	Persian Gulf – Far East	October 2016	12.41	22	15	3	4	3.166
9	Singapore – Far East	January 2016	12.24	10	1	8	1	3.628

Note: Laden passage speed as per Charterer's instructions, in general 12.0, 12.5 or 13.0 Kts, weather and safe navigation permitting. Ballast passages as per Owner's instruction for arrival "just in time" for the next loading operation.

Table 3. Comparative data for Ballast Passages

No.	Route	Period	Average Speed (Kts)	Total voyage Days	Days prevailing following wind	Days prevailing head wind	Days prevailing cross wind	Average Daily Consumption MT Fuel Oil
1	South Africa – South America	Oct-Nov 2015	7.49	24	6	11	7	24.4
2	Far East – Persian Gulf	March 2016	15.27	13	6	4	3	89.1
3	Suez–Persian Gulf	July 2016	9.68	12	-	9	3	22.6
4	Suez-Gibraltar	Nov-Dec 2017	11.72	7	1	4	2	42.8
5	Gibraltar-Caribbean	December 2017	8.29	17	14	1	2	18.6

Note:
For the comparative tables, it was considered head wind from the bow on a sector of 90 degrees (45 degrees Port / Starboard), following wind from the stern on a sector of 90 degrees (45 degrees Port / Starboard) and cross wind the sectors of 90 degrees Port / Starboard (45 degrees forward and aft of abeam).

For Laden Passages, Energy Efficiency Operational Index (EEOI) achieved was calculated according to Formula (1).

For Ballast Passages, obviously no cargo transport work, therefore average daily consumption was presented instead of EEOI.

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4. CONCLUSION

As can be seen from the comparative tables:

- The voyages with the loaded ship were generally executed at an actual average speed achieved of about 11.5 – 12.5 knots.

- The ballast voyages were executed at various speeds (the speed regime at the choice of the commercial department of the navigation company).

- Hydro meteorological conditions significantly influence fuel consumption, i.e. the operational energy efficiency index (IEEO). For this reason, hydro meteorological assistance in the planning and execution of the voyage is of paramount importance.

- The best indices of energy efficiency were reached on the routes Persian Gulf – Singapore, Persian Gulf – Caribbean, respectively Persian Gulf – Suez.

- The poorest Energy Efficiency Index was reached on the Caribbean – Far East route in the period June-July, due to the prevailing head winds (on such a route, for example, a superstructure offering minimal aerodynamic wind resistance from the bow could significantly improve the energy efficiency of the voyage)

- A good energy efficiency index was reached on the Persian Gulf Caribbean route, due to the prevailing following winds, between June and August. (In this situation, a superstructure providing maximum traction force to a following wind could assist in improving energy performance).

- On certain routes where are many days with moderate crosswinds such as South Africa – South America or South America – Singapore, a superstructure with an aerodynamic profile capable of generating significant traction from such a wind could eventually justify the installation costs.

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