Preliminary Study of Medium-Speed Monohull Passenger Ferries

W.R. Hetharia, A. Hage, and Ph. Rigo

University of Liège, ANAST, Liège, Belgium

Abstract

The recent development of medium-speed monohull passenger ferries has shown their importance for certain routes. The aim of the intensive studies performed in the recent years is to fulfil the pending technical and environmental issues concerning the HSC crafts. They operate at the Froude number range of 0.55 to 0.80 which is beyond the last hump of the wave resistance curve. In fact, they need a high power to maintain their operation speeds. The present project is to find the best design based on the layout of the passenger arrangement and the hull form configurations. The layout includes the seat arrangement and the distribution of passengers at the main and upper decks. Due to the lack of design data base of those kinds of semi-planning ships, a parent ship of 250 passengers is considered in this study. During the design process, the rules and mandatory issues are taken into account. The results of the design parameters and general layout of a series of parent ships are presented in this paper. The results will be applied in a future parametric study, particularly to find the best layout and hull form with the minimum engine power.

Keywords: Ship design, general arrangement, engine power, passenger vessel

1. Introduction

Nowadays, there are a lot of medium-speed passenger ferries operating in all regions of the world. Those ships operate up to a top speed of 23 knots. The existence of those ships is to fulfill a transition speed region between the conventional ferries (speeds < 15 knots) and HSC (speed ranges 25 to 40 knots). Also their existence is to fulfill some pending issues about HSC ferries such as cost, comfort, safety and environmental issues. Since emerging-time of those ships, they had been developed to be operated in many regions. Most of the ships are multi-hulls but due to their simplicity, the monohulls have also been developed and have a promising future markets. Most of those ships constructed recently use Aluminu as hull material. The application of this material to those ships gives the benefits of increasing the payload or reducing the engine power. In addition, in some Asia and Pacific regions, there are a lot of monohull medium-speed passenger ferries in composite material (Fibreglass Reinforced Plastic).

In fact, those medium-speed ships operate at the range of Froude number Fn from 0.55 to 0.80. This range is beyond the last hump of the wave resistance curve (Fn > 0.50). Therefore, they need a great amount of energy to maintain their service speed. An effort should be done in order to find the solution of minimizing the engine power for those ships. Since there was no the database available for these kind of ships then a parent ship was designed in this preliminary study. In addition, a modified ship was developed also. The design parameters of the modified ship were compared to those of the parent ship. The comparison was made particularly for the two important design parameters, i.e., ship propulsion and stability.

2. Design of Parent Ship

2.1 Input Design

Several important key factors were summarized from Knox (2003), Levander (2003), Calhoun (2003), Gale (2003) and Olson (1990) concerning the arrangement of the passenger ferries. They are:

- Spaces, volumes, service rooms, access and services are provided for the passengers.
- Accommodations are provided on board to ensure the comfort for the passenger during the travel.
- The arrangement of ship is fixed to fulfill the safety standart regulations.
- The facilities are provided to support the operation of the ship.
- The design parameters that should be considered during the operation such as safety, stability, seakeeping and manuevering capability.

Input design parameters include:

- Type of ship : Passenger Ferry/Class B
- Number of passenger : 250 pax
- Passenger Distribution: 70 % at main deck
- Number of crew : 5
- Service speed : 22 knots
- Navigation range : 200 n.m
- Type of pax accomodation : seat
- Type of seat : West Mekan

The input design parameters were computed and analyzed during the design process. The process is finished when the outputs meet the ship
requirements. The layout of the ship was determined to fit the rules of International Code of Safety for High-Speed Craft (2000), 2008 Edition. The structure components of the ship were determined based on the Rules for the Classification of High Speed Craft, Bureau Veritas, February 2002. The hull material of the ship is Aluminium Alloy. The type of alloys used for the ship are 5083 H111 for plating and 6082 T6 for profile.

2.2 SHIP DIMENSIONS

The dimensions of the ship (parent ship), obtained from the design process are presented in Table 1. The hydrostatic parameters of the ship were computed by using Maxsurf Version 13.01. The results of hydrostatic parameters are presented in Table 1. The lines plan of the parent ship are showed in Figure 1.

Table 1: Main Dimensions and Hydrostatic Parameters of Parent Ship

<table>
<thead>
<tr>
<th>No</th>
<th>Parameters</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Length Overall, L&lt;br&gt;A</td>
<td>52.00</td>
<td>m</td>
</tr>
<tr>
<td>2</td>
<td>Length of Vessels, L&lt;br&gt;W</td>
<td>49.625</td>
<td>m</td>
</tr>
<tr>
<td>3</td>
<td>Beam, B</td>
<td>7.00</td>
<td>m</td>
</tr>
<tr>
<td>4</td>
<td>Beam of Waterline, B&lt;br&gt;W</td>
<td>5.606</td>
<td>m</td>
</tr>
<tr>
<td>5</td>
<td>Draft, D</td>
<td>1.375</td>
<td>m</td>
</tr>
<tr>
<td>6</td>
<td>Dead Height, D</td>
<td>2.50</td>
<td>m</td>
</tr>
<tr>
<td>7</td>
<td>Volume</td>
<td>94.655</td>
<td>m³</td>
</tr>
<tr>
<td>8</td>
<td>Displacement</td>
<td>97.02</td>
<td>tonne</td>
</tr>
<tr>
<td>9</td>
<td>Waterplane area, WPA</td>
<td>627.74</td>
<td>m²</td>
</tr>
<tr>
<td>10</td>
<td>Max cross sec area</td>
<td>4.993</td>
<td>m²</td>
</tr>
<tr>
<td>11</td>
<td>Waterplane area, WPA</td>
<td>161.688</td>
<td>m²</td>
</tr>
<tr>
<td>12</td>
<td>Prismatic Coefficient, Cp</td>
<td>6.662</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Block Coefficient, CB</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Midship Coefficient, CM</td>
<td>0.543</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Waterplane Area Coefficient, Cup</td>
<td>0.845</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>TOP form and ship</td>
<td>0.140</td>
<td>m</td>
</tr>
<tr>
<td>17</td>
<td>Lift Coef.&lt;br&gt; from ship</td>
<td>2.023</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Vertical C. Buoyancy KB</td>
<td>0.956</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Vertical C. Gravity, KG</td>
<td>0.895</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Transverse Radius of Metacenter, BM</td>
<td>5.667</td>
<td>m</td>
</tr>
<tr>
<td>21</td>
<td>Height of Metacenter, GM</td>
<td>6.023</td>
<td>m</td>
</tr>
<tr>
<td>22</td>
<td>Immersion (H&lt;sub&gt;B&lt;/sub&gt;)</td>
<td>1.857</td>
<td>tonne</td>
</tr>
<tr>
<td>23</td>
<td>Ship Lwt. Weight, LWT&lt;br&gt;W</td>
<td>60.55</td>
<td>tonne</td>
</tr>
<tr>
<td>24</td>
<td>Deck Weight, DWT</td>
<td>30.12</td>
<td>tonne</td>
</tr>
<tr>
<td>25</td>
<td>Total Weight</td>
<td>90.67</td>
<td>tonne</td>
</tr>
<tr>
<td>26</td>
<td>Longitudinal C. Gravity</td>
<td>4.693</td>
<td>m</td>
</tr>
</tbody>
</table>

2.3 SHIP LAYOUT

The layout of the ship is defined considering the requirements linked to the passengers and their comfort during the travel. The place of the passengers is in the passenger saloon. In addition, access and services were provided for the passengers. Other service rooms such as toilets and small kiosk are provided also in this layout. The equipments and ship systems of the ship are also provided and placed to their proper locations. The layout of the ship is presented in Figure 2.

2.4 MODIFICATION OF PARENT SHIP

The modification of the parent ship was performed in order to assess the effect of changing the dimensions of few design parameters. For instance, this was done by increasing the number of seats in row from 10 to 11 seats. The results of such modification are presented in Table 2.

During the process of modification, some parameters changed such as:

- Increasing of ship beam, dB = 7.48 – 7.00 = + 0.48 m or 6.42 %
- Decreasing of ship length, dL<br>OA = 32.00 – 31.03 = -0.97 m or 3.03 %
- Increasing of structural weight, dW = 33.76 – 33.06 = + 0.7 tonne = + 2.07 %
- Decreasing of draft, dT = 1.375 – 1.365 = - 0.01 m = - 0.73 %

The design parameters of parent and modified ships were investigated. However, in this
preliminary study, two important design parameters are concerned i.e. the power and stability of the ship. In the next sections, these two ships are named P250S10 (the configuration with 250 passengers and 10 seats in row) and P250S11 (the configuration with 250 passengers and 11 seats in row).

Table 2: Main Dimensions and Hydrostatics Parameters of the Modified Ship

<table>
<thead>
<tr>
<th>No</th>
<th>Parameters</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Length Overall, LA</td>
<td>31.03</td>
<td>m</td>
</tr>
<tr>
<td>2</td>
<td>Length of Waterline, LW</td>
<td>27.64</td>
<td>m</td>
</tr>
<tr>
<td>3</td>
<td>Beam, B</td>
<td>7.48</td>
<td>m</td>
</tr>
<tr>
<td>4</td>
<td>Beam of Waterline, BW</td>
<td>7.163</td>
<td>m</td>
</tr>
<tr>
<td>5</td>
<td>Draft, T</td>
<td>1.365</td>
<td>m</td>
</tr>
<tr>
<td>6</td>
<td>Deck Height, D</td>
<td>2.60</td>
<td>m</td>
</tr>
<tr>
<td>7</td>
<td>Volume</td>
<td>95.37</td>
<td>m³</td>
</tr>
<tr>
<td>8</td>
<td>Displacement</td>
<td>97.75</td>
<td>tonnes</td>
</tr>
<tr>
<td>9</td>
<td>Wetted Surface Area, WSA</td>
<td>188.84</td>
<td>m²</td>
</tr>
<tr>
<td>10</td>
<td>Max. cross sec area</td>
<td>5.281</td>
<td>m²</td>
</tr>
<tr>
<td>11</td>
<td>Waterplane area, WPA</td>
<td>154.13</td>
<td>m²</td>
</tr>
<tr>
<td>12</td>
<td>Prismatic Coefficient, Cp</td>
<td>0.653</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Block Coefficient, Cb</td>
<td>0.523</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Midship Coefficient, Cm</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Waterplane Area Coefficient, Cwp</td>
<td>0.829</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>LCB from amidships</td>
<td>-0.302</td>
<td>m</td>
</tr>
<tr>
<td>17</td>
<td>LCF from amidships</td>
<td>-0.794</td>
<td>m</td>
</tr>
<tr>
<td>18</td>
<td>Vertical C. Buoyancy KB</td>
<td>0.548</td>
<td>m</td>
</tr>
<tr>
<td>19</td>
<td>Vertical C. Gravity, Kg</td>
<td>0.85</td>
<td>m</td>
</tr>
<tr>
<td>20</td>
<td>Transverse Radius of Metacenter, GMt</td>
<td>5.475</td>
<td>m</td>
</tr>
<tr>
<td>21</td>
<td>Height of Metacenter, GM</td>
<td>7.424</td>
<td>m</td>
</tr>
<tr>
<td>22</td>
<td>Immersion (TPC)</td>
<td>1.662</td>
<td>m</td>
</tr>
<tr>
<td>23</td>
<td>Ship Lightweight, LWT</td>
<td>61.25</td>
<td>tonnes</td>
</tr>
<tr>
<td>24</td>
<td>Deadweight, DWT</td>
<td>36.12</td>
<td>tonnes</td>
</tr>
<tr>
<td>25</td>
<td>Total Weight</td>
<td>97.37</td>
<td>tonnes</td>
</tr>
<tr>
<td>26</td>
<td>Longitudinal Center of Gravity</td>
<td>-0.588</td>
<td>m</td>
</tr>
</tbody>
</table>

3. ASSESSMENT OF SHIP STABILITY

In this preliminary study, the computation of ship stability was done for the full load condition. The load case of those two ships are presented in Table 3. The stability of the ship is computed using Maxsurf version 13.01. The criteria that have been used are based on the IMO Code: A.749(18) Ch3 - Design criteria applicable to all ships. The results of stability computations for those two ships are presented in Table 4.

Table 3: Load Cases for Ship P250S10 and P250S11

<table>
<thead>
<tr>
<th>No</th>
<th>Item Weight</th>
<th>Weight (tonne)</th>
<th>LC from amidships</th>
<th>TCG from BW (m)</th>
<th>VCS from BL (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Passengers, Crews and Engages</td>
<td>27.030</td>
<td>13.670</td>
<td>0.00</td>
<td>6.360</td>
</tr>
<tr>
<td>2</td>
<td>Lightship</td>
<td>60.653</td>
<td>12.929</td>
<td>0.00</td>
<td>2.853</td>
</tr>
<tr>
<td>3</td>
<td>Tank 1 (F.O.T.)</td>
<td>3.617</td>
<td>2.745</td>
<td>0.77</td>
<td>0.974</td>
</tr>
<tr>
<td>4</td>
<td>Tank 2 (F.O.T.)</td>
<td>5.177</td>
<td>3.609</td>
<td>4.00</td>
<td>6.474</td>
</tr>
<tr>
<td>5</td>
<td>Tank 3 (F.O.T.)</td>
<td>1.247</td>
<td>1.583</td>
<td>0.00</td>
<td>0.000</td>
</tr>
<tr>
<td>6</td>
<td>Tank 4 (F.O.T.)</td>
<td>1.247</td>
<td>1.583</td>
<td>0.00</td>
<td>0.000</td>
</tr>
<tr>
<td>7</td>
<td>Tank 5 (F.O.T.)</td>
<td>0.193</td>
<td>0.288</td>
<td>0.00</td>
<td>0.000</td>
</tr>
<tr>
<td>8</td>
<td>Total</td>
<td>96.064</td>
<td>13.425</td>
<td>0.00</td>
<td>4.000</td>
</tr>
</tbody>
</table>

Analysing the stability values:

- The stability values of ship P250S10 is worse compared to ship P250S11.
- The stability of both ships should be improved more in order to meet some criteria of stability especially for the large angle on inclination.

4. ASSESSMENT OF THE ENGINE POWER

4.1 SHIP RESISTANCE

The ship resistance was computed by using the statistical resistance prediction method derived by Mercier and Savitsky (Lewis, 1988); Larsson (2010). This method is suitable for the semi-planning ships. The general form of the resistance equation adopted by Mercier and Savitsky is as follows:

\[
R_T/W = A_1 + A_2X + A_4U + A_5W + A_6XZ + A_7XU + A_8XW + A_9ZU + A_{10}ZW + A_{11}XW^2 + A_{12}ZX^2 + A_{13}UW^2 + A_{14}WU^2
\]

(1)
where: \( X = \sqrt[1/3]{L}; \ Z = \sqrt[3]{B^3}; \ U = \sqrt{2E}; \)
\( W = A_T/A_X. \)

The values of the coefficients \( A_1 \) to \( A_{27} \) and correction factors are presented in Lewis (1988). In addition, an approach to compute the wetted surface area is:

\[
S/\sqrt[2/3]{L} = 2.262 \sqrt{(L/\sqrt{1/3}) \left[ 1 + 0.046 \frac{B}{T} + 0.00287 \left( \frac{B}{T} \right)^2 \right]}
\]

The effective power of the ship is computed as:

\[ P_E = R_T \times V \]

where:
\[ R_T \] = total resistance and \( V \) = speed of the ship

Furthermore, the resistance of the ship was computed using the software of Maxsurf version 13.01 and the results are presented in the Table 5 and Figure 3 and 4.

### Table 5: Comparison of Total Resistance and Effective Power for P250S10 and P250S11

<table>
<thead>
<tr>
<th>No</th>
<th>Speed of Ship</th>
<th>Speed, Knot</th>
<th>Resistance of Ship</th>
<th>Resistance of Ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>19.0</td>
<td>20.5</td>
<td>21.0</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>21.0</td>
<td>22.0</td>
<td>23.0</td>
</tr>
</tbody>
</table>

### 4.2 ENGINE POWER

The engine power (brake power \( P_B \)) is computed in relation with the effective power \( P_E \) (Parsons, 2004).

\[
P_B = P_E / \left( \eta_h \eta_o \eta_r \eta_s \eta_b \eta_t \right)
\]

where:
\( \eta_h = \) hull efficiency;
\( \eta_o = \) propeller efficiency;
\( \eta_r = \) relative rotative efficiency = 1.0;
\( \eta_s = \) seal efficiency;
\( \eta_b = \) line shaft bearing efficiency;
\( \eta_t = \) transmission efficiency;
\( \eta_b = 0.97 \) for machinery amidship
\( \eta_t = 0.975 \) for medium speed diesel plant

Hull efficiency is computed as:

\[
\eta_h = \frac{(1 - t)}{(1 - w)}
\]

where:
\( w = \) Taylor wake fraction
\( = 0.5 \ C_B - 0.05 \)
\( C_B = \) block coefficient
\( t = \) thrust deduction factor
\( = 0.6 \ w \)

The maximum continuous rating (MCR) of the main engine is determined by adding a power service margin as 20% to the brake power.

\[
MCR \geq (1 + MS) P_B
\]

where: \( MS = \) power service margin

Two units for the main engines are selected for the propulsion system of the ship. It would be better to select the existing types of main engine to be used for the ship. However, as assumption for this preliminary study, the main engine and following characteristics were selected.

**Type of main engine**: MAN V12-1360

**Maximum output (MCR)**: 1360 hp

**RPM at normal Brake Power**: 2100 rpm

**Reduction ratio**: 2.0 : 1

**Fuel Consumption at rated power**: 264 l/h

**Fuel**: DIN EN 590

**Exhaust gas status**: IMO/MARPOL 73/78, EPA Tier 2, Recreational Craft Directive 95/24/EC, SAV

### 4.3 PROPELLER DATA

Two screw propeller units are used for the ship. The screw propellers were evaluated based on the propeller data from the Wageningen B-Screw Series (Lewis 1988). The propeller types of B 4-40,
B 4-55, B 4-70, B 4-85 and B 4-100 were evaluated for a range of ship speed from 19 to 23 knots. In addition, an evaluation for the cavitation of the propeller was executed based on Burril Diagram of cavitation. The trend line of suggested upper limit for merchant ship propeller is used in this evaluation. In fact, this trend line is still subjected to 2.5 % to 5% of back cavitation of propeller blade. The results of computation of the propeller parameters are presented in Table 6.

4.4 ANALYSE OF ENGINE POWER AND PROPELLER DATA

- The values of resistance or effective power for ship P250S10 is less than those for P250S11. The difference of values for a range of speed is about 3.5 %.
- The trend lines of the total resistance $R_T$ and effective power $P_E$ are almost linear for the speed range of 19 to 22 knots.
- With the similar engine power and configurations applied for those two ships, the maximum speed achieved by two ships are different.
- The maximum speed for the ship P250S10 is 21.09 knot and for the ship P250S11 is 20.36 knot. The difference value is 3.6 %.
- The decreasing of speed for ship P250S11 is caused by the increasing of resistance.

Table 6: Propeller Parameters for Ships P250S11 and P250S10

<table>
<thead>
<tr>
<th>Type of screw propellers</th>
<th>Max ship speed (knot)</th>
<th>Ratio $f_D$</th>
<th>Propeller Efficiency $\eta_p$</th>
<th>Propeller diameter (m)</th>
<th>RE/AC (required)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B 4-48</td>
<td>21.705</td>
<td>0.17</td>
<td>0.606</td>
<td>1.088</td>
<td>0.707</td>
</tr>
<tr>
<td>B 4-55</td>
<td>21.702</td>
<td>0.18</td>
<td>0.607</td>
<td>1.085</td>
<td>0.704</td>
</tr>
<tr>
<td>B 4-70</td>
<td>21.707</td>
<td>0.19</td>
<td>0.606</td>
<td>1.084</td>
<td>0.703</td>
</tr>
<tr>
<td>B 4-85</td>
<td>21.705</td>
<td>0.20</td>
<td>0.605</td>
<td>1.083</td>
<td>0.701</td>
</tr>
<tr>
<td>B 4-100</td>
<td>21.703</td>
<td>0.21</td>
<td>0.604</td>
<td>1.081</td>
<td>0.699</td>
</tr>
</tbody>
</table>

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

1. Since there is no available database for such medium-speed passenger ferry, the results achieved in this preliminary study provide some relevant initial data for our future works.

2. In addition, several modifications of the parent ship should be executed in order to find the formulations for the future optimization process.

3. The difference in the results between the two ships P250S10 and P250S11 may give an example of how the design parameters (stability and power) are changing due to the changing of ship beam.

4. In fact, the engine power required for those ships are still high and some modifications should be executed to improve the stability of and evaluated for the next design process.

5. Our future works will be to minimize the engine power of this medium-speed passenger ferry. The modification of ship layout and hull forms will play a key roles in this work. However, other factors should be taken into account as recommended there after.

5.2 RECOMMENDATION

The future works should be executed for:

- Optimizing the ship structure in order to reduce the structural weight of ship
- Optimizing the hull forms in order to reduce the ship resistance
- Rearranging the ship layout in order to increase the stability level of the ship
- Executing the model tests in order to achieve a the better results of the ship resistance
- Selecting the proper screw propeller to reduce the engine power
- Selecting the proper main engine in order to improve the performance of propulsion system.

REFERENCES


International Conference on TECHNOLOGIES, OPERATIONS, LOGISTICS AND MODELLING for LOW CARBON SHIPPING

LCS 2011
22-24 June 2011, Glasgow, Scotland, United Kingdom

PROCEEDINGS

Edited by Osman Turan and Atilla Incecik

The Organising Committee of LCS 2011 is not responsible or accountable for any statements or opinions expressed in the papers printed in the conference proceedings.

The papers have been prepared for final reproduction and printing as received by the authors, without any modification, correction, etc. therefore, the authors are fully responsible for all information contained in their papers.

Although all care is taken to ensure integrity and the quality of this publication and the information herein, no responsibility is assumed by the authors for any damage to the property or person as a result of operation or use of this publication and/or the information contained herein.
PREFACE

In many arenas there is growing concern about the environment and climate change. In 2007, international shipping contributed approximately 3% of global anthropogenic CO$_2$ emissions. For this reason, the sector needs to address these important issues, particularly as it is expected that its global share of CO$_2$ emissions will continue to increase. The industry (including users of shipping’s services, operators of ships, manufacturers of ships and equipment) has been exploring a number of ways in which it could increase shipping’s energy efficiency and reduce its CO$_2$ emissions. In addition, there have been a number of national, international and joint industry/academic activities to research the subject. Therefore, the main aim of the LCS 2011 conference is to:

- Facilitate the exchange of knowledge
- Develop new ideas
- Enhance collaboration between industry and academia.

The Low Carbon Shipping (LCS) consortium is a Research Council (UK) and industry funded collaborative project between 5 UK Universities and 15 industry and government partners (including ship operators, designers, builders, technologists, brokers, classification society, NGOs, shipping industry clubs). The LCS consortiums main objectives are to contribute to reducing the CO$_2$ emissions of the shipping industry and its high level aims are to investigate:

- The relationship between transport logistics and future ship designs
- The future demand for shipping (in relation to other transport modes)
- The impacts of technical and policy emission reduction schemes on shipping
- Implementation barriers to technical and policy emission reduction
- The allocation and enforcement of emission allowances in policy scenarios

The International Conference, ‘TECHNOLOGIES, OPERATIONS, LOGISTICS AND MODELLING FOR LOW CARBON SHIPPING’ (LCS 2011) is hosted by the University of Strathclyde in Glasgow, UK, and the Organising Committee is grateful to Lloyd’s Register, Shell UK and IMarEST for their support for the conference.

LCS 2011 brings the world’s leading experts from a mixture of both commercial and academic sectors to discuss and share the results of their work, to identify issues and find solutions to these issues with a focus on Low Carbon Shipping.

With 36 papers being presented at the conference, it is anticipated that LCS 2011 will create a world-wide network on Low Carbon Shipping. This network will focus their efforts in a concerted way, to address the Challenge of reducing CO$_2$ within the shipping industry, which is multi-disciplinary, complex and resource intensive.

Finally, we would like to thank all the members of the Organising Committee for their hard work and commitment. In addition, thanks to the participants and presenters for their contribution in making this conference a success.

We wish you a productive and enjoyable stay in Glasgow.

Osman Turan and Atila Incecik
LCS 2011 COMMITTEES

ORGANISING COMMITTEE

Banks, Charlotte (University of Strathclyde, UK)
Clelland, David (University of Strathclyde, UK)
Day, Sandy (University of Strathclyde, UK)
Fang, Ivy (Ho-Chun) (Lloyd's Register, UK)
Incecik, Atilla (University of Strathclyde, UK)
Kurt, Rafet Emek (University of Strathclyde, UK)
Lazakis, Iraklis (University of Strathclyde, UK)
McKenna, Stuart (University of Strathclyde, UK)
Mermiris, Dimitris (University of Strathclyde, UK)
Sfakianakis, Dimitris (University of Strathclyde, UK)
Turan, Osman, Conference Chairman (University of Strathclyde, UK)
Vassalos, Dracos (University of Strathclyde, UK)
Will, Thelma, Conference Secretary (University of Strathclyde, UK)
Zhou, Peilin (University of Strathclyde, UK)

LOW CARBON SHIPPING-SCIENTIFIC COMMITTEE

Atlar, Mehmet (University of Newcastle Upon Tyne)
Bertram, Volker (Germanischer Lloyd)
Bucknall, Richard (University College London)
Chang, Fai (Lloyd's Register)
Dinwoodie, John (University of Plymouth)
Gibbs, David C. (University of Hull)
Godderidge, Bernhard (Shell)
Greig, Alistair (University College London)
Groom, Julian (Rolls-Royce)
Hoeppner, Volker (Germanischer Lloyd-Future Ship)
Incecik, Atilla (University of Strathclyde)
Insel, Mustafa (Technical University of Istanbul)
Lalwani, Chander (University of Hull)
Mangan, John (University of Newcastle Upon Tyne)
Marzi, Jochen (HSVA)
McKinnon, Alan (Herriot-Watt)
Meehan, Maurice John (Maersk)
Murphy, Alan (University of Newcastle Upon Tyne)
Olcer, Aykut (University of Newcastle Upon Tyne)
Psarafitis, Harilaos N. (National Technical University of Athens)
Reynolds, Gillian (Consultants, UK)
Rigo, Philippe (University of Liege)
Smith, Tristan (University College London)
Song, Dong-Wook (Herriot Watt)
Varelas, Takis (Danaos Shipping)
Vassalos, Dracos (University of Strathclyde)
Ventikos, Nikos (National Technical University of Athens)
Wrobel, Paul (University College London)
SPONSORS

We would like to acknowledge the highly valuable support provided by the following:

Lloyd’s Register

Shell UK

The Institute of Marine Engineering, Science & Technology (IMarEST)
This conference is organised in association with RCUK ENERGY Low Carbon Shipping project partners which include:

UNIVERSITY OF STRATHCLYDE
UNIVERSITY COLLEGE LONDON
NEWCASTLE UNIVERSITY
UNIVERSITY OF HULL
UNIVERSITY OF PLYMOUTH

ATKINS
BMT
BP SHIPPING
BRITISH SHIPPING
BRITISH WATERWAYS
CLARKSONS
DAVID MACBRAYNE LTD
FISHER
LLOYD’S REGISTER
LLOYD’S REGISTER FAIRPLAY
MAERSK
MINISTRY OF DEFENCE
RCUK ENERGY
ROLLS ROYCE
SHELL
UKMPG
WWF
TABLE OF CONTENTS

SESSION 1A: SHIP ENERGY EFFICIENCY

ENERGY EFFICIENCY TARGETS

DYNAMIC ENERGY MODELLING – A NEW APPROACH TO ENERGY EFFICIENCY AND COST-EFFECTIVENESS IN SHIPPING OPERATIONS

SESSION 1B: CONTEXTUALISING THE ROLE OF SHIPPING IN A LOW CARBON SOCIETY

LOGISTICS AND LOW CARBON SHIPPING
J. Mangan, C. Lalwani, P. Rigot-Muller, D. Gibbs and M. Bennett.................................................................25

QUANTIFYING THE CLIMATE CHALLENGE FOR SHIPPING: FROM INCREMENTAL TO STEP CHANGE MITIGATION
K. Anderson, A. Bows and P. Gilbert................................................................................................................31

ACCOUNTING FOR AND INFLUENCING SHIPPING EMISSIONS AT A SUB-GLOBAL LEVEL
A. Bows, P. Gilbert and K. Anderson ................................................................................................................37

SESSION 2A: RETROFITTING TO REDUCE CARBON EMISSIONS

LOW DRAG FOR LOW CARBON SHIPPING TARGETS
J. Marzi and S. Gatchell........................................................................................................................................47

EXPLORING OPTIONS TO REDUCE FUEL CONSUMPTION
J. Knott and J. Buckingham..................................................................................................................................57

SESSION 2B: LOW CARBON SHIPPING LOGISTICS AND OVERVIEW

VESSEL OPTIMISATION FOR LOW CARBON SHIPPING
V. N. Armstrong..................................................................................................................................................69

ONBOARD DECISION SUPPORT SYSTEM FOR LOW CARBON-ENERGY EFFICIENT SHIP OPERATION
H. Cui, C. Banks, I. Lazakis, O. Turan and A. Incecik.............................................................................................81
<table>
<thead>
<tr>
<th>SESSION 4A: DESIGN AND TECHNICAL METHODS FOR REDUCING CARBON EMISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOWARDS VERY LOW CARBON SHIPPING</strong></td>
</tr>
<tr>
<td>M. Traut, A. Bows, P. Gilbert, C. Walsh and R. Wood ...........................................................................................................</td>
</tr>
<tr>
<td><strong>AN INNOVATIVE HULLFORM DESIGN Technique FOR LOW CARBON SHIPPING</strong></td>
</tr>
<tr>
<td>S.-Z. Li and F. Zhao ......................................................................................................................................................</td>
</tr>
<tr>
<td><strong>A STUDY OF HULL FORM IMPROVEMENT FOR A FISHING TRAWLER</strong></td>
</tr>
<tr>
<td>N. Xie, D. Vassalos and I. Paton ...............................................................................................................................</td>
</tr>
<tr>
<td><strong>SESSION 4B: VOYAGE PLANNING</strong></td>
</tr>
<tr>
<td><strong>TOOLS FOR THE CONTROL OF SHIP EMISSIONS AND ENERGY AND THE NEW IMO REGULATIONS</strong></td>
</tr>
<tr>
<td>J. Antunes .................................................................................................................................................................</td>
</tr>
<tr>
<td><strong>INTELLIGENCE VOYAGE PLANNING FOR EMISSIONS LOWERING</strong></td>
</tr>
<tr>
<td>T. Varelas and S. Archontaki ...........................................................................................................................................</td>
</tr>
<tr>
<td><strong>DEVELOPMENT OF A DYNAMIC PROGRAMMING METHOD FOR LOW FUEL CONSUMPTION AND LOW CARBON EMISSION FROM SHIPPING</strong></td>
</tr>
<tr>
<td>S. Wei and P. Zhou ..........................................................................................................................................................</td>
</tr>
<tr>
<td><strong>SESSION 5A: DESIGN METHODS FOR REDUCING CARBON EMISSIONS</strong></td>
</tr>
<tr>
<td><strong>LOW CARBON SHIPPING-AN OPERATOR’S PERSPECTIVE</strong></td>
</tr>
<tr>
<td>G. Taylor ..................................................................................................................................................................</td>
</tr>
<tr>
<td><strong>IMPROVEMENT OF ENERGY EFFICIENCY USING INCLINED KEEL HULL CONCEPT</strong></td>
</tr>
<tr>
<td>K.-C. Seo, M. Atlar and N. Sasaki .................................................................................................................................</td>
</tr>
<tr>
<td><strong>SESSION 5B: VOYAGE OPTIMISATION</strong></td>
</tr>
<tr>
<td><strong>IMPROVED CONTAINER TRANSHIPMENT UTILISING LOW CARBON FEEDER SHIPS</strong></td>
</tr>
<tr>
<td><strong>ON THE SPEED OF SHIPS</strong></td>
</tr>
<tr>
<td>T. Smith, M. Barrett, E. O’Keeffe, S. Parker and N. Rehmatulla ...................................................................................</td>
</tr>
<tr>
<td><strong>PRELIMINARY STUDY OF MEDIUM-SPEED MONOHULL PASSENGER FERRIES</strong></td>
</tr>
<tr>
<td>W. R. Hetharia, A. Hage and P. Rigo .................................................................................................................................</td>
</tr>
<tr>
<td><strong>SESSION 6A: KNOWLEDGE SHARING AND LIFE CYCLE CONSIDERATIONS (1)</strong></td>
</tr>
<tr>
<td><strong>INCORPORATING LIFECYCLE ELEMENTS INTO THE ENERGY EFFICIENCY DESIGN INDEX</strong></td>
</tr>
<tr>
<td>C. Walsh and A. Bows .......................................................................................................................................................</td>
</tr>
<tr>
<td><strong>EDUCATION AND TRAINING OF SEAFARERS IN LOW CARBON - ENERGY EFFICIENT OPERATIONS</strong></td>
</tr>
<tr>
<td>C. Banks, I. Lazakis, O. Turan and A. Incecik ....................................................................................................................</td>
</tr>
<tr>
<td><strong>SESSION 6B: KNOWLEDGE SHARING AND LIFE CYCLE CONSIDERATIONS (2)</strong></td>
</tr>
<tr>
<td><strong>SUSTAINABLE SHIPPING - A WAY FORWARD? DEVELOPING ECONOMIC IMPERATIVES IN AN INTERNATIONAL MARKET</strong></td>
</tr>
<tr>
<td>M. J. Landamore .........................................................................................................................................................</td>
</tr>
</tbody>
</table>
LIFE-CYCLE IMPACT ANALYSIS OF GREEN SHIP DESIGN / OPERATION ALTERNATIVES BASED ON ENVIRONMENTAL AND MONETARY ASPECTS
Y. K. K. Khoo and A. I. Ölçer ...........................................................................................................................229

SESSION 9A: POWER SOURCES FOR REDUCED CARBON EMISSIONS

FUEL CELLS FOR MARINE APPLICATIONS
G. Azqueta Gavaldon and D. Clelland ...........................................................................................................249

DEVELOPMENT OF A COMBINED CYCLE OF SOFC AND MICRO GAS TURBINE FOR MARINE POWER SYSTEMS
J. He, P. Zhou and D. Clelland .........................................................................................................................255

POSSIBLE POWER TRAIN CONCEPTS FOR NUCLEAR POWERED MERCHANT SHIPS

SESSION 9B: CARBON EMISSION BENCHMARKING AND REGULATION

PERFORMANCE INDICATORS IN BENCHMARKING OF MARITIME LOGISTICS CHAINS
W. Zhu and S. O. Erikstad ..................................................................................................................................275

THE HISTORY AND STATUS OF GHG EMISSIONS CONTROL IN INTERNATIONAL SHIPPING
G. Reynolds .............................................................................................................................................................287

INITIAL ESTIMATES ON SHIPPING’S COST IMPACTS AND EMISSIONS FOR A RANGE OF POLICY OPTIONS – A PROTOTYPE MODEL
T. Smith ...............................................................................................................................................................293

SESSION 10A: FUEL TYPES FOR REDUCED CARBON EMISSIONS

B9 SHIPS: SAIL AND VIRTUAL BIO-METHANE POWERED COASTAL VESSELS
D. C. Surplus .......................................................................................................................................................301

ASSESSING THE CARBON DIOXIDE EMISSION REDUCTION POTENTIAL OF A NATURAL GAS CONTAINER CARRIER
J. Calleya and P. Mouzakis ................................................................................................................................309

A FEASIBILITY MODEL FOR MARINE ENGINES USING ALTERNATIVE FUELS WITH THE EMPHASIS ON COST/EARNING AND EMISSION FIGURES
H. H. R. Ong and A. I. Ölçer .............................................................................................................................321

SESSION 10B: PORT AND DISTRIBUTION LOGISTICS

THE POTENTIAL IMPACT OF A LEVY ON BUNKER FUELS ON DRY BULK SPOT FREIGHT RATES
N. T. Chowdhury and J. Dinwoodie .....................................................................................................................333

THE EFFECTS OF PORT-CENTRIC LOGISTICS ON THE CARBON INTENSITY OF THE MARITIME SUPPLY CHAIN: A PRELIMINARY REVIEW
A. C. McKinnon and R. E. Woolford ..................................................................................................................339

Authors index .........................................................................................................................................................349