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Review paper

Analysis of Technical Properties of Small Passenger Ships in the Mediterranean Sea with Overview of Future Market Needs – Environmental and Comfort Issues*

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Abstract: Coastal shipping is nowadays a very important research topic, where the emphasis is mainly on the improvement of ship energy efficiency (reduction of fuel consumption) and its environmental performance. In line with this, the ship design procedure is being more complicated aiming to offer competitive products with high level of comfort for both crew and passengers, low operative costs and minimum environmental footprint. This paper reviews the technical properties of existing small passenger vessels in countries in the Mediterranean and future market needs for these vessels considering more stringent habitability criteria and future emission reduction targets. It represents an important step of a novel design procedure for small passenger vessels for Mediterranean, based on the modular principle. Analysis of technical properties of existing small passenger vessels has been made from data available in the IHS Fairplay database. Beside overview of design requirements related to ship environmental friendliness and comfort, available countermeasures are reviewed.

Keywords: passenger vessel, Mediterranean Sea, market analysis, regulatory framework, technical measures

1. Introduction

Ship design process is determined by technical complexity, long exploitation life of the final product, high unit cost and production in small series. Designing of a ship in a way that it performs its missions effectively for a lifetime of 25 years or longer is quite demanding. Small passenger vessels for short-sea shipping, mostly build in small shipyards, are often based on previous concepts with low-cost design and low energy efficiency, but relatively high lifetime costs and harmful environmental impact [1]. Decisions made during the early design stage have a large impact on the direction of

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the design process and the product performance, since the freedom to make changes will rapidly decreases [2]. Nowadays, ship design is strongly influenced by regulations on emissions [3], owners of all kinds of ships are seeking higher standards of comfort for both crew and passengers, while economic criteria are continuously important. On the other hand, due to market uncertainty, it is difficult for ship designers to design a vessel that has the right size and capabilities for use over multiple decades [4]. Vladimir et al. [5] illustrated the design procedure for small passenger vessel in the Mediterranean using modular approach, where the ship is virtually assembled from three predefined modules. In that paper the lifecycle CO_2-eq emissions and costs of small passenger vessel with capacity of 250 passengers for diesel, electricity, methanol, liquefied natural gas, hydrogen, ammonia, and biodiesel power system configuration are investigated, and it is found that electrification is the most environmentally friendly and most cost-effective powering options among those considered. This paper sheds light on some aspects of the overall procedure given in [5], that are not explained very detailed. Therefore, in the next section IHS Fairplay database is outlined, while third section deals with the analysis of technical properties of the selected ships. Future design requirements and available solutions are dealt with in fourth section, while concluding remarks are drawn in the fifth section.

2. IHS Fairplay database

The first step in the analysis of technical properties of existing vessels is to limit the range of vessels according to some criteria. Passenger ships - usually defined as ships carrying more than 12 passengers - on international voyages must comply with all relevant IMO (International Maritime Organization) regulations, including those in the SOLAS (International Convention for the Safety of Life at Sea) and Load Lines Conventions [6]. There are different criteria according to which the ship can be designated, such as the length, capacity, gross tonnage, etc. The source of the data used in this paper is IHS Fairplay database, [7], which is the largest maritime database in the world, evolved from the Lloyd's Register of Ships, covering ship characteristics, movements, ports, casualties, and research (Fig.1).

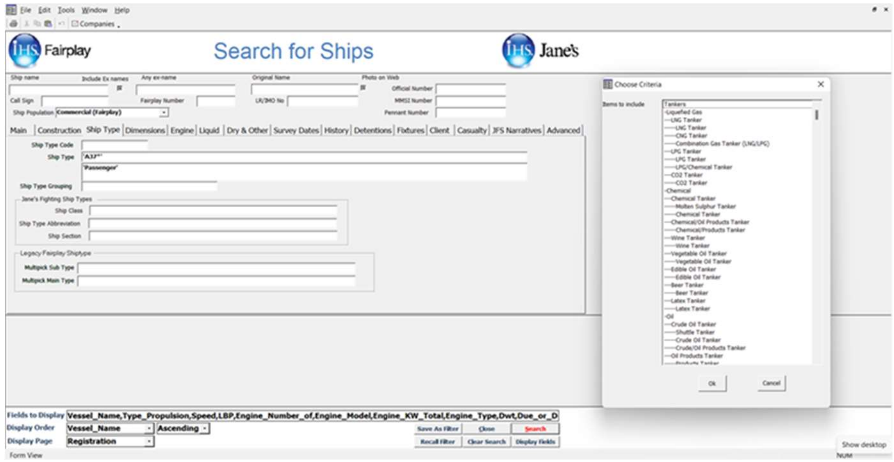

Fig. 1 – *World register of ships, IHS Fairplay database.*

In this investigation, the length is selected as the relevant quantity and technical properties of all passenger ships registered in the Mediterranean countries, Fig. 2, with a length below 100 m are extracted from the IHS Fairplay database. The rules that are relevant to small vessels take the upper length boundary very differently. In this sense, according to the International Association of Classification Societies (IACS) small ships are those below 24 m, while depending on the context they can be up to 65 m in length (Bureau Veritas) or even up to 100 m (Det Norske Veritas), [8].

Fig. 2 – *Mediterranean countries [9].*

3. Technical properties of small passenger vessels in the Mediterranean

The ship characteristics are obtained for 692 small passenger vessels sailing under the flag of one of Mediterranean country (Albania, Croatia, Cyprus, Egypt, France, Greece, Italy, Malta, Montenegro, Morocco, Spain, Tunisia, Turkey), build between 1999 and 2015. While obtaining data, the maximum length overall (LoA) of 100 m is set as a limit. Using obtained data relationship is derived between ship characteristics and illustrated on Fig. 3. With respect to the power system, it is found that diesel engine serve as prime movers in about 97 % cases. Most of the vessels is equipped with fixed pitch propellers, Fig. 3 d).

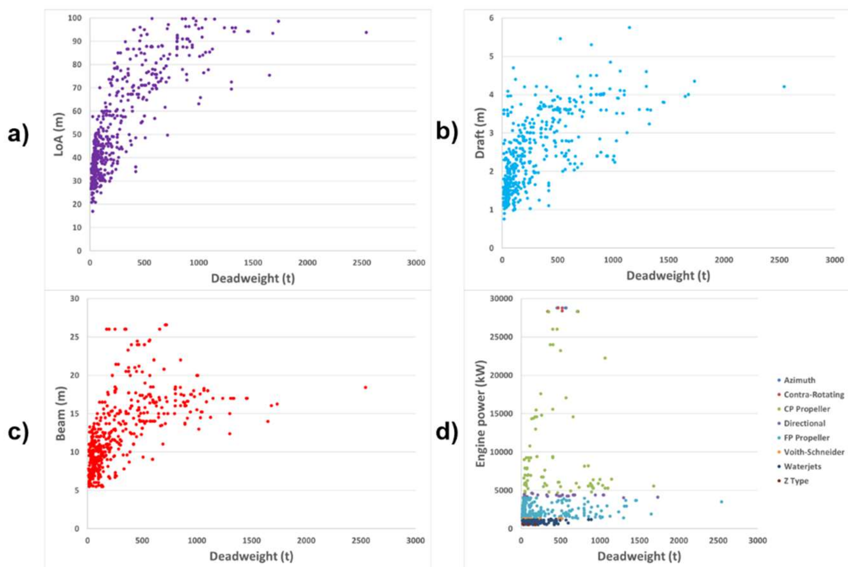

Fig. 3 – *(a) Deadweight vs Length overall, (b) Deadweight vs Draft, (c) Deadweight vs Beam, (d) Deadweight vs Power with Type of Propulsion.*

Taking into consideration that capacity of passengers and speed are important parameter for passenger ships relationship between deadweight and length overall, and number of passengers and speed is illustrated in Fig. 4.

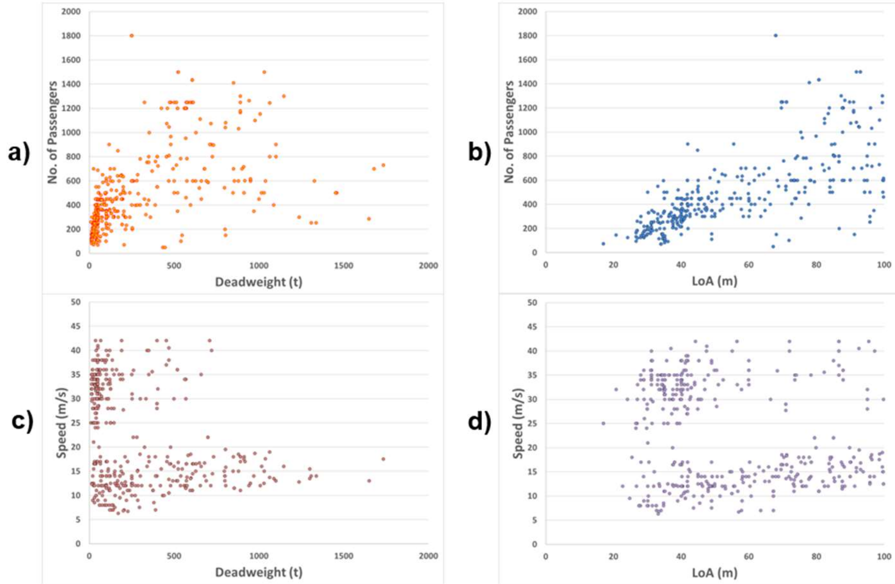

Fig. 4 – *(a) Deadweight vs Number of passengers, (b) Length overall vs Number of passengers, (c) Deadweight vs Speed, (d) Length overall vs Speed.*

Relationships between parameters shown on Fig. 3 and Fig. 4 do not give better understanding into ship particulars relation therefore further analysis are needed.

4. Overview of future design requirements and available solutions

Beside technical properties, the environmental regulations and the comfort requirements are mandatory to be considered in the design phase.

A Environmental regulations

The reduction of emissions generated by internal combustion engines represents one of the most important research topics in the marine sector. Exhaust gases released from the combustion of fossil fuel in marine engines consist of different components, such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_X), sulphur oxides (SO_X), hydrocarbons (HC) and particulate matter (PM), and their negative effects on the environment and on people are more pronounced when ships spend greater time near populated areas. The Paris Agreement is an international response to climate change, which aims to keep the global temperature rise below 2 °C, in comparison to pre-industrial level [10]. The shipping sector aims to reduce its Carbon Footprint (CF) by 40% by 2030, and by at least 70% by 2050 compared to 2008 [11]. CF is a relative measure of the total amount of CO_2 or

CO_2-eq emissions caused by indirect or direct activity or is accumulated over the life cycle of a product [12].

The International Maritime Organisation (IMO) decarbonization strategy defines three levels of measures to achieve the required GHGs reduction goal: short-term, mid-term and long-term measures [13], Fig. 5.

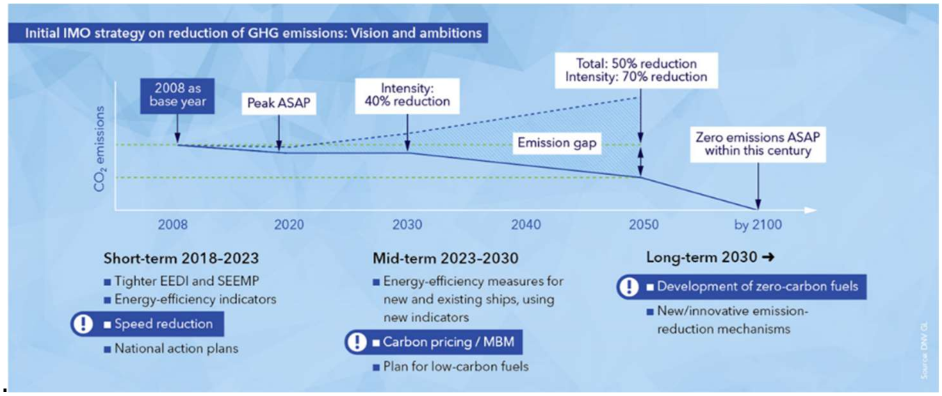

Fig. 5 – *The IMO strategy for the reduction of GHG emissions [14] (reproduced with the permission of Det Norske Veritas (DnV)).*

In the maritime sector, SO_X and NO_X emissions are controlled in Emission Control Areas (ECAs), in which emissions requirements are stricter than out-side these areas [15]. While SO_X emission is limited with the allowed content of sulphur in fuel, NO_X emission are regulated depending on the engine maximum operating speed [16]. Maritime sector has various technical and operative measures at disposal to reduce emissions. Bauman et al. [17] conducted extensive literature review on technologies, measures, and potential for reducing GHG emissions from shipping, Table 1. With combination of these measures, required emission reduction will be achieved thus fulfilling required environmental regulations imposed by IMO. The ships of the future intended to operate in this area should be designed to cope with these requirements. It is worthy to mention studies performed by the authors dedicated to the alternative powering options for small short-sea [18],[19],[20],[21], and inland [22], [23], [24], vessels, trying to identify those ones that will comply to future regulation framework.

Table 1 – *Measures and potential effect on energy efficiency and emission reduction (CO2) [17]*

Type of measure	Main measures reviewed	Potential for CO_2 reduction
Hull design	Vessel size	4-83 %
	Hull shape	2-30 %
	Lightweight materials	0.1-22 %
	Air lubrication	1-15 %
	Resistance reduction devices	2-15 %
	Ballast water reduction	0-15 %
	Hull coating	1-10 %
Power and propulsion system	Hybrid power/ propulsion	2-45 %
	Power system/ machinery	1-35 %
	Propulsion efficiency devices	1-25 %
	Waste heat recovery	1-20 %
	On board power demand	0.1-3 %
Alternative fuels	Biofuels	25-84 %
	LNG	5-30 %
Alternative energy sources	Wind power	1-50 %
	Fuel cells	2-20 %
	Cold ironing	3-10 %
	Solar power	0.2-12 %
Operation	Speed optimization	1-60 %
	Capacity utilization	5-50 %
	Voyage optimization	0.1-48 %

B Comfort regulations

Noise and vibration problems are inherent to all ships due to a number of engines and devices needed for their operation [25], Figs. 6 and 7:

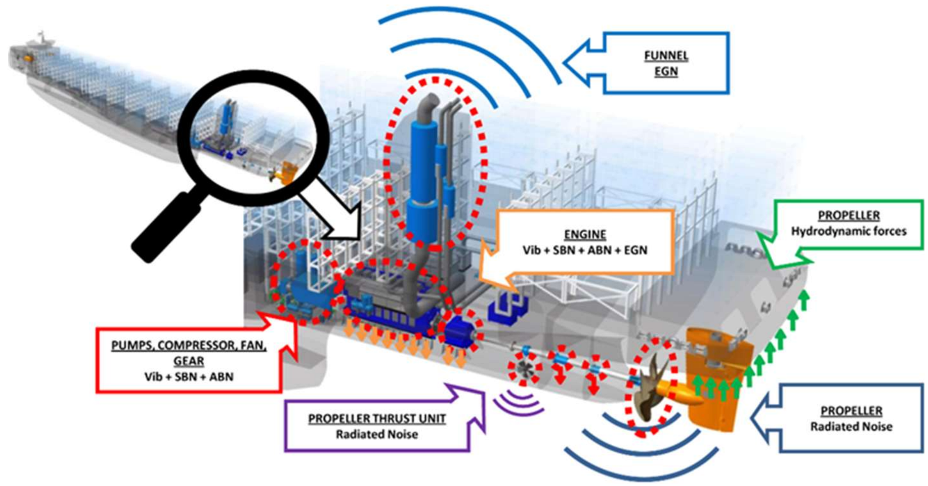

Fig. 6 – *Main noise sources on board [26].*

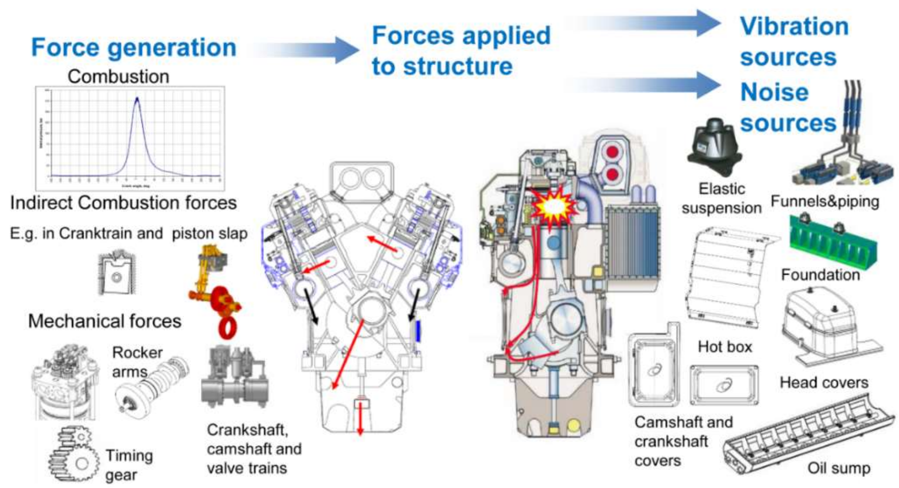

Fig. 7 – *Excitation forces generated by the engine interacting with ship structure external emitters [26].*

Classification Societies have included in their rules, comfort classes for passengers and crew accommodation. Passenger comfort is very important and subjected to penalties if ship does not fulfil requirements. Table 2 provides ratings requested by Classification Societies from 1 to 3, where 1 stands for "high" and 3 for "acceptable" comfort. Table 3 shows comfort class criteria related to sound installations for passenger cabins [27].

Similarly, to noise, classification societies have vibration standards associated with the comfort class notation.

Table 2 – *Sound pressure levels (DB(A)) in passenger accommodation [27]*

Location	DNV			BV			LR	
	CRN (1)	CRN (2)	CRN (3)	1	2	3	1	2
Top grade	44	47	50	45	50	50	45	50
Standard cabins	49	52	55	50	55	55	45	50
Public rooms	55	58	62	55	60	65	55	60
Open decks	65	65	70	65	70	75	65	70

Table 3 – *Comfort class criteria related to sound installation RW (DB)*

Location	DNV	BV	LR
Between top grade cabins	46	42	45
Between standard cabins	41	40	45
Between cabins and standard public rooms	55	55	55
Between cabins and show rooms	65	65	-

Noise and vibrations can be controlled by altering source of noise and vibration, conveying medium, and receiver. By employing appropriate software in design phase, noise levels based on sound propagation from machinery, propeller, and wave slap sources via air-borne and structure-borne paths, can be calculated and evaluated, and various treatment options can be explored, including resiliently mounting equipment, adding absorptive insulation and/or damping materials, etc [5]. Regarding vibrations, by implementing different technologies on the source (engine) and increasing its quality (and simultaneously cost) vibration velocity can be reduced thus increasing comfort class [5].

5. Concluding remarks

In the current practice, the ship design is generally approached with the aim of keeping building-cost at the minimum, often forcing low-cost designs and low value-added market solutions. This is particularly true for small passenger vessels designed for short-sea shipping. Small shipyards cannot sustain the high costs of innovation. In this paper, the length is selected as the relevant quantity of all passenger ships registered in the Mediterranean countries, and by utilizing IHS Fairplay database, technical properties of selected ships are obtained and analysed. After conducting analysis of technical properties of small passenger vessels in the Mediterranean, it is found that there is relatively high scattering between ship dimensions, capacity, and power systems among the analysed vessels. As explained in the paper, it is important to take into account stricter regulations regarding emissions and comfort at design phase. Environmental requirements can be fulfilled increasing ship energy efficiency by employing technologies, and measures for reducing harmful emissions from shipping, which regularly impose additional investment costs. Noise and vibrations, produced by ship engines and devices needed for ship operation, are restricted by comfort regulations. In order to get the best possible comfort in passenger spaces both excitation source and transmission path must be included in investigation and results would be most satisfactory if mitigation technologies would be applied upon both of them.

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