Eco-friendly inland passenger ship for operation on the Danube in the Vukovar region

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ABSTRACT

This paper presents the eco-benefit, design and main characteristics of advanced electro-ship intended for Danube short cruising and organization of various on-board events while the ship is sailing or moored alongside pier. Advanced electric-powered 15m aluminium catamaran is designed for accommodation of 60 passengers on regular service route on Danube between Vukovar and Vučedol as well as sightseeing Danube tour in the Vukovar area. In addition to sailing functions the ship is able to serve as a multifunction space for various touristic events, cultural, artistic and entertainment happenings. For this purpose the multifunction ship superstructure is equipped with advanced audio-visual devices and lighting system suitable for various touristic applications. Highest environmental and energy efficiency characteristics are achieved by the use of sophisticated systems of energy distribution and conversion from onshore electrical grid and solar panels to the on-board battery system as a main source of energy for the propulsion as well as ship services.
Keywords: Green passenger transport, Multifunctional waterborne space, Electric powertrain

1. INTRODUCTION

The DANIBIUMBUS15 project is the result of cooperation between two SMS enterprises: Marina studio d.o.o. from Zagreb responsible for ship design and building and Panonsko more d.o.o. , shipowner from Vukovar who has great experience in tourist management service in Croatia. Financed by the Croatian Bank for Reconstruction and Development the Danubiumbus15 project started in May 2014.

2. INLAND NAVIGATION AND THE ENVIRONMENT

Greenhouse gas (GHG) emissions from shipping account today for 4% of the EU GHG emissions [1]. As increasingly stringent controls are placed on land-based sources of atmospheric emissions, there is mounting pressure to bring inland navigation ship emissions more closely within air quality policy across the European Community.

Inland waterway transport has unquestionably been the most environmentally friendly mode of inland transport for decades. However, this advantage has steadily been eroding due to the rapid improvement of emissions from other transport modes. Today, inland shipping propulsion engine systems are significantly less pollution advanced as comparable systems used in road transport. Progress achieved with the reduction of pollutant and greenhouse gas emissions in road transport is far from application in inland shipping where predominant type of engines are older types of diesel engines powered with high sulphur diesel fuel. As a consequence, inland waterway transport for certain routes, cargo types and vessel sizes, already has higher air pollutant emission levels than road transport per tonne kilometre.
Sulphur contained in fuel causes emissions of sulphur dioxide (SO_2) and also contributes to the formation of secondary particulate matter (PM) that is particularly harmful both to humans and the environment. SO_2 emissions also cause environmental problems such as acid rain affecting soil and water and damage to biodiversity.

To comply with advanced Stage III A standards [2] for inland waterway vessels (Table 1) shipping operator can choose to switch to LNG-fuelled ships, electric powertrain ships or to cut their sulphur emissions by using different exhaust gas cleaning technologies. Although using of higher cost low sulphur fuels is the easiest way of reducing pollutants from ships, application of LNG and electric energy for the propulsion of the ships offers additional benefits which for some application makes them favourable solution for the propulsion of the ships.
This specially goes for small passenger ships with low operational profile and autonomy where application of diesel electric propulsion with good characteristic of all kinds of the emissions and specially noise emissions can be achieved. For such ships which are characterized with low or seasonal operational profile where they are sporadically utilized throughout the year or with cyclic operation on the regular routes where they spent extended periods moored alongside the pier in the port, application of the electric propulsion powertrain offers significant environmental, economic and passenger accommodation advantages over standard diesel propulsion powertrain.

Table 1. STAGE III A Standards for Inland Waterway vessels [2]

Displacement dm^3 per cylinder	CO	NO_X +HC	PM
	g/kWh		
D≤0.9 P›37 kW	5.0	7.5	0.40
0.9 ‹ D ≤ 1.2	5.0	7.2	0.30
1.2 ‹ D ≤ 2.5	5.0	7.2	0.20
2.5 ‹ D ≤ 5.0	5.0	7.2	0.20
5.0 ‹ D ≤ 15	5.0	7.8	0.27
15 ‹ D ≤ 20, P≤ 3300 kW	5.0	8.7	0.50
15 ‹ D ≤ 20, P›3300 kW	5.0	9.8	0.50
20 ‹ D ≤ 25	5.0	9.8	0.50
25 ‹ D ≤ 30	5.0	11.0	0.50

The above considerations are based on the fact that standard ships generate high-localized emissions and require significant on-board power generation capacity to cover the peak power requirements of their respective on-board systems and auxiliaries which are usually idling when they are in the port. In such case the large and powerful propulsion and auxiliary motors operate even though the ship is moored alongside the pier producing harmful emissions for the environment. The fact that in reality, only very little auxiliary power is required when the ship is moored alongside a pier, offers potential for application of other types of on-board and onshore energy more suitable for such kind of ship operational scenarios.

Taking into account above reasons, application of electric energy as a main source of energy for the service as well as the propulsion needs for the small passenger ship operated on the regular service routes that are limited in time to four one hour trips from the Vukovar homeport where chosen for DANUBIUMBUS 15.

3. DESIGN FEATURES

The General arrangement plan of the DANUBIUMBUS15 is shown in Figure 1. The arrangement is based upon a number of considerations including operational requirements, equipment maintainability and aesthetics appeal. To maximize passenger contact with the environment the passenger salon is made from the glass panel mounted on the aluminium frames. The design maximizes the solar-surface on the passenger saloon roof where 10m^2 of solar cells are installed.

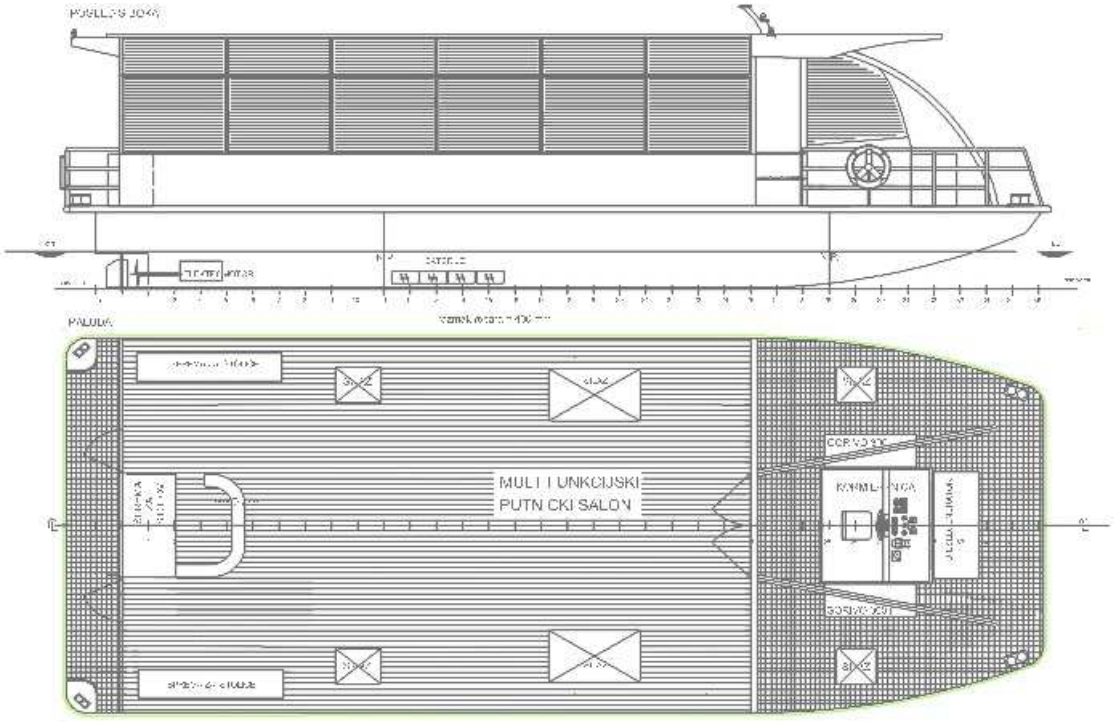

Figure 1. General arrangement plan [3]

Based on the dedicated pier equipped with electric shore connection the DANUBIUMBUS15 can recharge the batteries utilizing onshore power while it is moored alongside a pier between the regular sailing routes.

The DANUBIUMBUS15 design is based on using standard components and off-the-shelf commercial single cell batteries, electric motors, inverters, battery chargers and other electrical equipment from a variety of suppliers.

To maximise energy efficiency of the craft special attention has been given to the weight-reduction of the ship construction as well as all ship systems and equipment including the battery systems. For this reason the ship construction has been built from aluminium with catamaran configurations. Further reduced emissions goal was achieved by means of low resistance hull design with optimal L/B ratio, distance between the hulls and hull lines.

Propulsion of the DANUBIUMBUS15 is achieved by two 30kW electric motors situated in each of the hulls machinery compartment. Two watertight bulkheads divide hulls into three compartments: fore peak, battery compartment and machinery compartment. The slender hull form with a fine forward entry is optimised to generate less water disturbances and wash / wake generation.

The machinery compartments houses main propulsion electric motors with permanent magnet, inverter 96V DC / 220 V AC, propulsion shafting system, bilge pump and hydraulic steering system. For the drainage purposes each watertight compartment is equipped with an independent electric bilge pump operated by level switch.

The main ship service system is 24 volt DC supplied by four heavy duty batteries arranged in wheelhouse on the main deck. The 24 volt DC system is supplied via a distribution panel fitted with DC rated circuit breakers. The vessel is wired for AC shore supply and includes a 100A/96V battery charger. The main particulars of the boat are listed in Table 2.

Table 2. DANUBIUMBUS15 main characteristics

Length, over all	15,00 m
Length, waterline	12,25 m
Breadth	5,80 m
Draft	0,80 m
Depth	1,24
Material	Aluminium
Passenger	60
Crew	2
Propulsion power	2 x 30 kW
Propulsion motors	2 x TEMA SPM12
Propulsion battery	100 kWh / 96V
Speed, max	13 km/h

Electric powertrain battery systems are sufficient for ship consumers including the propulsion system while the ship is sailing with the speed of up to 13 km/h for a maximum of two hours.
For emergency purposes if the energy requirements of the propulsion and the auxiliaries exceeds the powertrain battery system capabilities the variable speed diesel-generator will automatically start and cover the demand. By the use of solar panel installed on the roof top the DANUBIUMBUS15 can provide near zero emissions while sailing on inland protected areas.
Considering the functional needs of the superstructure as a multipurpose space located in the centre of the city where touristic needs are broad in scope and context the superstructure of the DANUBIUMBUS15 has been designed as a multifunctional waterborne space equipped with advanced audio-visual devices and lighting system suitable for various touristic applications.

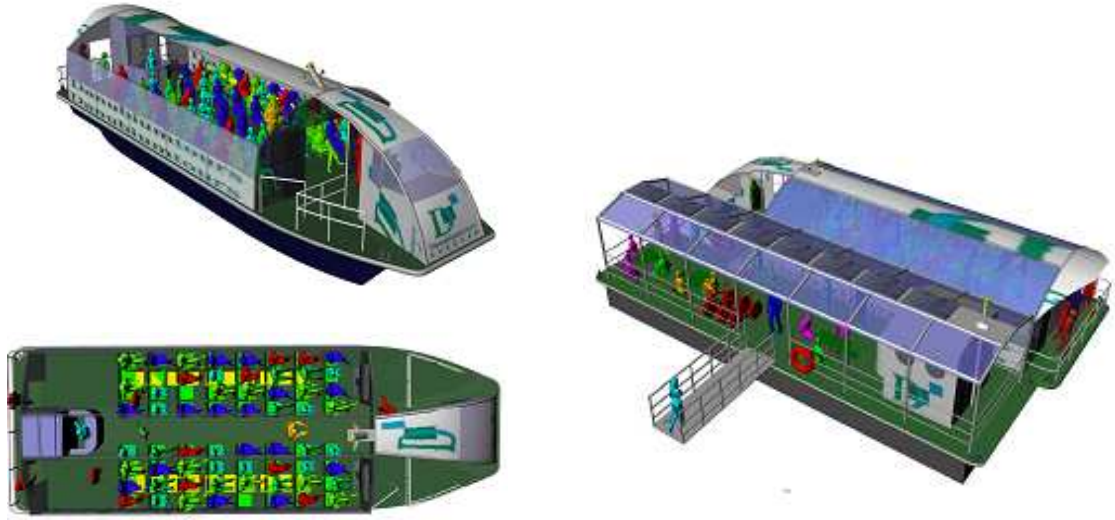

Figure 2. 3-D Model of Danubiumbus15 [3]

4. EMISSION TO THE ENVIRONMENT

DANUBIUMBUS15 high power battery system capable of operating the vessel and auxiliary equipment using electric power only, eliminate the local emission of greenhouse gases entirely and reduce harmful emissions of the NO_x, SO_x and CO and PM to the environment. This will reduce fuel consumption overall, but more importantly reduce greenhouse gases significantly compared to the standard diesel powertrain ships.
At standard diesel powertrain system 10-20% load, which is typically used during manoeuvring in port, NO_x, SO_x and CO are typically many times higher per unit of fuel consumed than under full load, while CO_2 emissions much more closely follow the direct amount of fuel consumed. This is due to the combustion temperature and pressure within the combustion chamber of the engine enabling the formation of these gases, making reduction of these by traditional means difficult.
Avoiding diesel machinery operation by using electric energy from the on-board batteries or from the onshore electrical grid enable DANUBIUMBUS15 to drastically reduce SO_x, NO_x and other PM emissions from the ship as well as the operating cost related to fuel and maintenance of internal on-board combustion engine.
Furthermore, noise emissions from the diesel engine are also improved due to better sound characteristics of the electric powertrain while sailing and exclusion of the noise while the ship is using electricity from the batteries or onshore electrical grid.
The reductions of the noise and other emissions to the environment will vary with type of application and operating profile of the ship. For a low profile operating ships with low speed such as DANUBIUMBUS15 the savings can be significant.

Depending on application/type of vessel, and operating profile, the environmental and economic characteristics of DANUBIUMBUS15 powertrain characteristics it is expected that it will allow following positive impacts:

- Reduction of abt. 80% of air pollution,
- Reduction of abt. 25% of greenhouse, gas emissions,
- Reduction of abt. 30% of fuel costs,
- Simplicity of management and minimization of maintenance operations.

These values are related to those recordable in a diesel propelled standard vessel with low operating profile on short sailing routes.

5. CONCLUSIONS

This paper bring new thinking and offer a new vision to the inland shipping industry by the presentation of the DANIBIUMBUS15 which represents attractive commercially viable passenger ship that is beyond state-of-the-art.

Commercial diesel engines are heavy and working only part of their operating time under high load. On commuter passenger ships significant portion of operating time they are idling, while the ship is waiting to load or unload passengers and while the ship is manoeuvring at slow speed close to the port. In such scenarios the diesel engine runs very inefficiently and use of electric powertrain represents better solution for environmental and economic characteristics of the ship.

Although the initial costs of an electric powertrain and battery system exceeds that of a conventional combustion powertrain DANUBIUMBUS15 has significant advantages of using the electric powertrain due to its operational scenario which enable regular use of onshore electricity for charging of the on-board battery system.

Operational scenario enables them to use pier-side electricity while it is at the port during the frequent stops between its regular navigation routes. By this way SO_x, NO_x and other PM emissions from the ship are drastically reduced as well as operating cost related to fuel and

maintenance cost. Additionally, due to lower emissions of noise, passenger comfort on electric powertrain ships are significantly higher than on conventional combustion powertrain ships.

Taking above consideration into account it can be concluded that for specific types of inland ships like passenger commuter and sightseeing ships electric powertrains represents optimal solutions for new buildings as well as for retrofitting solution on existing diesel-propulsion and combustion powertrain ships.

The authors hope that the lessons learned from this project will allow shipbuilders and ship-owners to develop and use all kinds of energy for the propulsion of the ships and that electricity will be the key to success in special types of inland navigation ships such as DANUBIUMBUS15.

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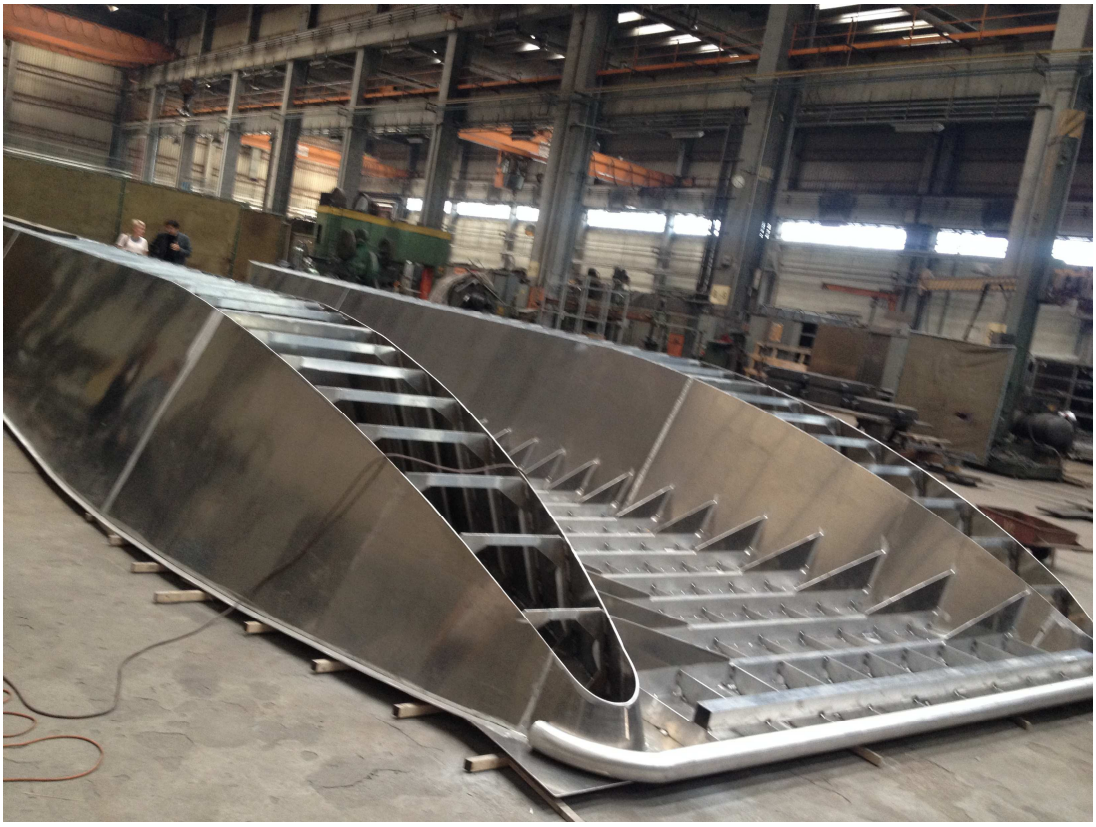


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