Advanced Data Analytics towards Energy Efficient and Emission Reduction Retrofit Technology Integration in Shipping

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ABSTRACT

An overview of integrating two energy efficient and emission reduction technologies to improve ship energy efficiency under advanced data analytics is presented in this study. The proposed technologies consist of developing engine and propulsion innovations that will be experimented under laboratory conditions and large-model-scale sea trials, respectively. These experiments will collect large amount of data sets that will be used to quantify the performance of both innovations under the advanced data analytics framework (ADAF). Hence, extensive details on the ADAF along with preliminary data sets collected from a case study vessel are presented in this study.

KEY WORDS: Emission reduction; energy efficiency; shipping; maritime; data analytics; machine learning; artificial intelligence.

INTRODUCTION

Emission Reduction Strategy

The international maritime organization (IMO) has initiated an extensive greenhouse gas (GHG) reduction strategy that envisages a considerable reduction in the carbon intensity of the international shipping industry. This strategy consists of reducing CO2 emissions per transport work, as an average across the international shipping industry, e.g. at least 40% by 2030, and continues efforts towards 70% by 2050, compared to the 2008 levels (IMO, 2020a). Furthermore, GHG emissions due to the international shipping industry is to peak as soon as possible, therefore it is required to reduce the total annual GHG emission, at least 50% by 2050 compared to the 2008 levels. Carbon intensity based energy efficiency measures have been formulated by IMO under two main mandatory initiatives of the energy efficiency design index (EEDI) for new ships and energy efficiency existing ship index (EEXI) for existing ships (IMO, 2020b). The EEDI indicates the energy efficiency of ships compared to a baseline vessel that should be satisfied during the design phase. Hence, the required ship structural modifications to satisfy the EEDI can be introduced during the design and construction phases of the vessel. The EEXI indicates the energy efficiency of ships compared to a baseline

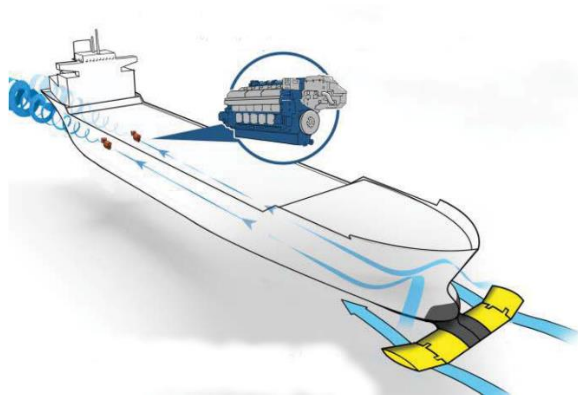

Fig. 1: Engine and propulsion innovations in the SeaTech project.

vessel that should be satisfied during the operational phase. Since major ship structural modifications cannot be introduced during this phase, the required technological innovations (i.e. ship systems as retrofitting technologies) should be introduced to satisfy the EEXI during the vessel operational phase. Therefore, the required technological innovations including alternative fuels and/or energy sources to satisfy the EEXI during the ship operational phases should be considered and their capabilities of delivering the IMO emission reduction ambitions should be investigated. The outcomes of this study will contribute to achieve those objectives, where an advanced data analytics framework (ADAF) that can quantify the performance of two selected innovative technologies with respect to the IMO emission reduction targets are developed as the main contribution.

SeaTech Innovations

The ADAF that has been developed under the SeaTech (Next generation short-sea ship dual-fuel engine and propulsion retrofit technologies) Horizon2020 project is presented in a conceptual level in this study. This project proposes to integrate engine and propulsion innovations as possible energy efficient and emission reduction technologies as presented in Fig. 1. The engine innovation consists of achieving an ultra-

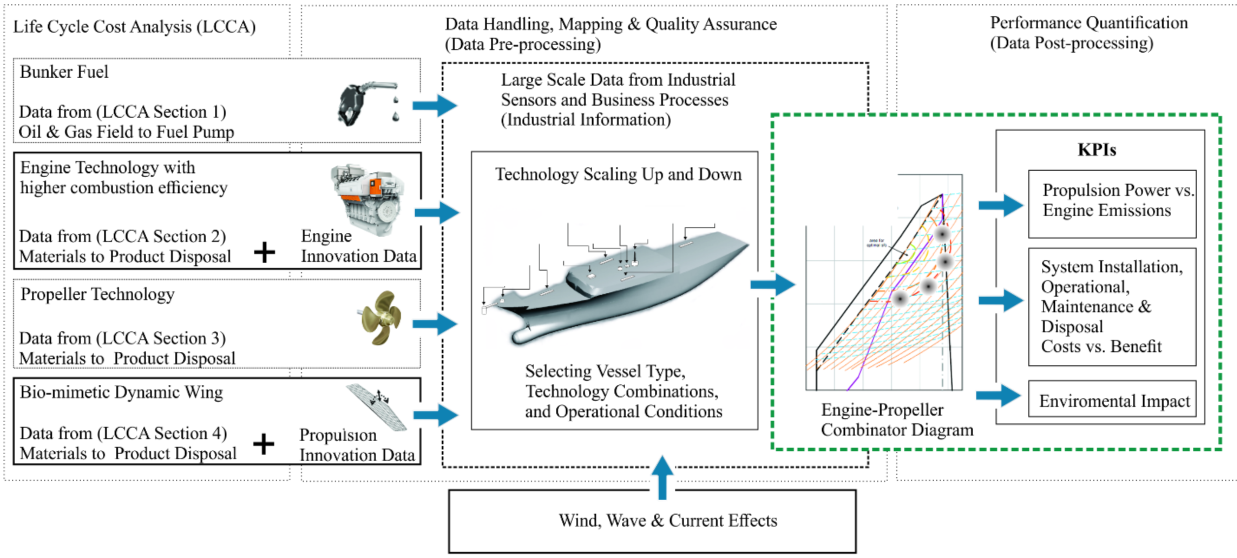

Fig 2: Advanced data analytics framework

high energy conversion efficiency by precise controlling of the combustion process of a duel-fuel (DF) engine designed by Wartsila (Wartsila, 2020), where a considerable exhaust emission reduction is expected. The renewable energy based propulsion innovation consists of an active biomimetic dynamic wing (Bowker *et al.*, 2020) mounted at the bow of a ship (see Fig. 1), to augment propulsion in moderate and heavy sea conditions by capturing wave energy, where extra thrust is produced to support ship speed, and undesirable ship motions are dampened (Belibassakis *et al.*, 2021). Due to the budget limitations of the SeaTech H2020 project, these innovations will not be evaluated under a full-scale vessel in realistic ocean going conditions. One should note that the SeaTech engine and propulsion innovations will be tested under laboratory conditions and large-model-scale sea trails (Politis *et al.*, 2014), respectively. It would be difficult to quantify the performance of both innovations in relation to ship energy efficiency as an integrated solution due to the same reason. Hence, it is proposed to argument the respective data sets collected by both innovations in a data science environment (Perera and Mo, 2017), so called the ADAF that creates the basis for engine-propeller interactions.

Innovation Impact

The initial project impact on ship emissions has been summarized in this section. It is estimated that the proposed SeaTech engine and propulsion innovations, which when combined, lead to an increase of 30% in fuel efficiency with the emission reduction levels of 99% for NOx, 99% for SOx, 46% for CO2 and 94% for particulate matter, initially (Wartsila, 2019). Since these innovations will be introduced as possible retrofit technologies, i.e. high retrofitability and maintainability to achieve the IMO 2050 emission reduction targets, the return on investment (ROI) for introducing such technologies into existing vessels has also been quantified. That has been estimated as 400% due to fuel and operational cost savings, initially (Wartsila, 2019). The above fuel and emission reductions targets and ROI will be confirmed at the end of this project under the life cycle cost analysis (LCCA) of the ADAF and that has been described in the following section.

ADVANCED DATA ANALYTICS FRAMEWORK

Data Variety

An overview of the proposed ADAF, presented in Fig. 2, and that consists of three main sections: LCCA, data pre-processing and data post-processing. In the LCCA section, the costs associated with bunker fuel, engine innovation, propeller technology and bio-mimetic dynamic wing from the respective materials to product disposal will be incorporated. That can assign an initial cost estimation for the energy efficient and emission reduction technology development, therefore ship owners can view initial estimated costs for the proposed technologies. This information along with engine and propulsion innovation data sets will be collected under laboratory conditions and large-model-scale sea trials, respectively. That will be delivered to the next section of the ADAF of data pre-processing. One should note that various data sets, i.e. data variety, will be collected under this project and that will be utilized in the following sections.

It is expected that both innovations will collect a considerable amount of data sets that will be analyzed the ADAF, as mentioned before. The selected data sets of these innovations will be shared, as open access research data with the consent of the data protection officer in this project. The respective data sharing strategy to support open innovation based applications are further described in the data management plan (DMP) (Perera, 2020) of the SeaTech H2020 project. The same document describes the respective data: what are the data sources, how it will be stored and backed-up, how and where to download, who owns it and who is responsible for different data sets. This DMP is developed accordance with this Horizon 2020 DMP guidelines. It is expected that research data sets should support the 'FAIR' principle, that is findable, accessible, interoperable and re-usable, accordance with the same guidelines (EU, 2016).

Data Pre & Post Processing

The data pre-processing section consists of the main steps of data handling, mapping and quality assurance for large-scale industrial sensors and business process data sets. These data sets will be scaled into a selected vessel, i.e. a case study vessel from the Utkilen shipping fleet, in assigned ship routes, where appropriate wind, wave and current conditions will be considered. The engine-propeller combinator diagram plays an important role in this section by providing a basis for the respective data sets. One should note that vessel engine and propeller behavior, including the respective fuel consumption and environmental conditions, can be combined in such a diagram. Furthermore, the engine and propeller optimal operational conditions with respect to various ship

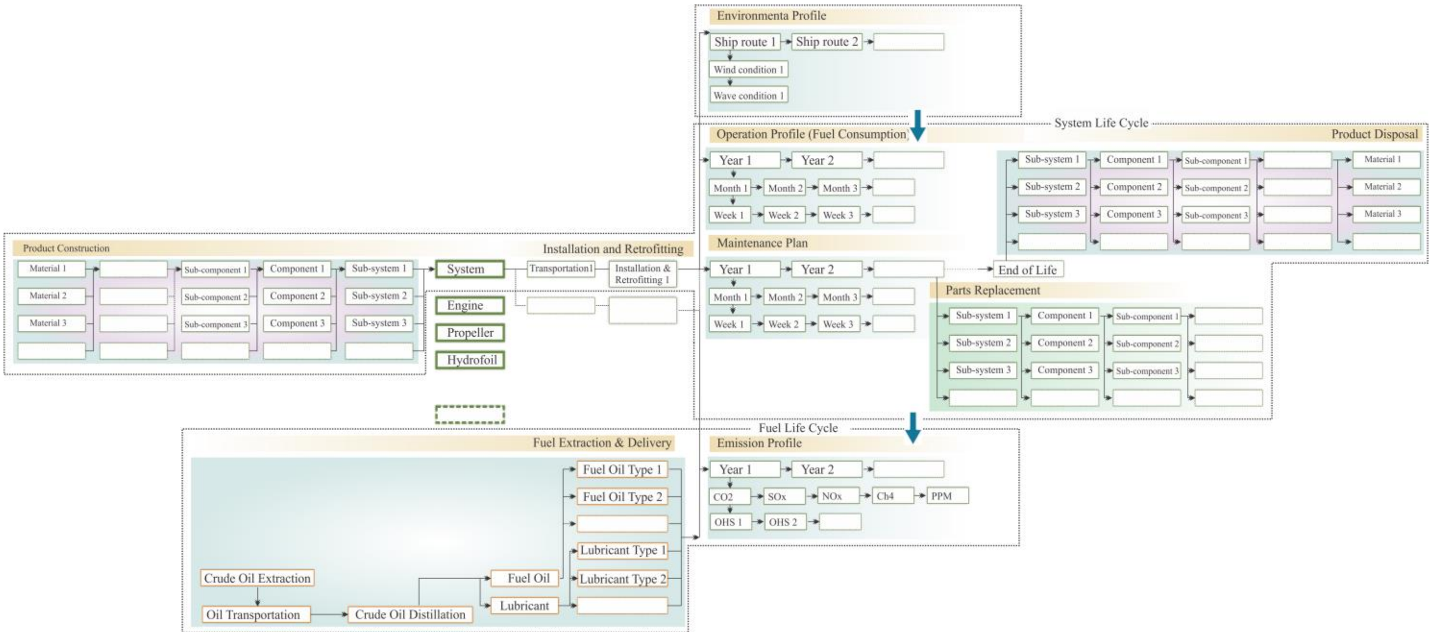

Fig. 3: The LCCA process of the SeaTech project.

operational conditions can also be identified under the engine propeller combinator diagram, where various ship performance and navigation parameters can be merged. Hence, that would be a good basis not only to estimate vessel emissions but also to utilize as a decision support system for energy efficient ship operational conditions. The required key performance indicators (KPIs) will also be derived in the engine propeller combinator diagram as a performance comparison tool. These KPIs include: propulsion power vs. engine emissions, system installation, operational, maintenance and disposal costs vs. benefits, and environmental impact. Therefore, the KPIs can be used to quantify the performance of both SeaTech engine and propulsion innovations to show the possibility of achieving the project objectives in ship emission reduction. On the other hand, the same KPIs can be used to compare other energy efficient technological alternatives that can be used to achieve similar ship emission reduction targets in the future.

Data Veracity

As mentioned previously, the quality of data sets can play an important role in the ADAF. Therefore, the respective data sets should be evaluated for possible data anomalies. Such data anomalies can be classified into two main categories of sensor faults and system abnormal events. The respective data anomalies should be separated into these categories to isolate and recover at a later stage. A process of identifying, classifying, isolating and recovering data anomalies will be introduced under the ADAF. The data anomaly detection and classification techniques that will be adopted towards this project have been extensively presented in Perera (2016a and 2016b). Furthermore, the information on various data anomalies identified during this project will be preserved, and that can be used onboard vessels, when the ADAF is implemented in ocean going vessels to support data handling processes.

LIFE CYCLE COST ANALYSIS

System Structure

The LCCA process of the SeaTech project are presented in Fig. 3 and that has divided into 9 sections: product construction, installation and retrofitting, fuel extraction and delivery, emission profile, operation profile, maintenance plan, part replacement, environmental profile, and product disposal. The total cost/price is based on each sectional cost/price and that will be considered as the total life cycle cost for operating the selected technologies and that should be compared against the energy efficiency gains of a selected vessel. However, the study is limited to the life cycle cost estimation of the main technologies of fuel, engine, propulsion and dynamic wing. These sections are considered as the main components that can play a major role in improving ship energy efficiency, i.e. by selecting appropriate fuel types, engine operational modes, and retrofitting engine and energy saving devices. Hence, these technologies are considered in this project as the main influencing factors that can be used to reduce the respective emissions in shipping.

In the product construction section of LCCA, the respective costs associated with each system from materials to the final product will be calculated and such systems can be categorized as an engine, propeller, hydrofoil, etc.. These systems consist of various energy efficient and emission reduction technologies that can be retrofitted to ocean going vessels. A tree like structure will be developed for each system and that can be expanded from a system, sub-systems, components, sub-component layers, until materials. That can introduce a technology structure for each system from its material level. Hence, that can be used to calculate the total cost for each system based on material costs. However, the market price, as a separate cost element, of each system will also be calculated during this process to compare with the system cost. These technology structures will also be used in the part replacement section to determine the respective parts that should be replaced during the maintenance activities, accordance with appropriate time intervals. Furthermore, the same technology structures will be used in the product disposal section, where that can be expanded to reproduce the respective materials, i.e. the costs associated with recycling the same materials.

In the installation and retrofitting section of LCCA, the costs associated with transporting and installing the same systems as retrofitting technologies into a selected vessel will be calculated. One should note that retrofitting of a marine engine may not replace the whole engine, but

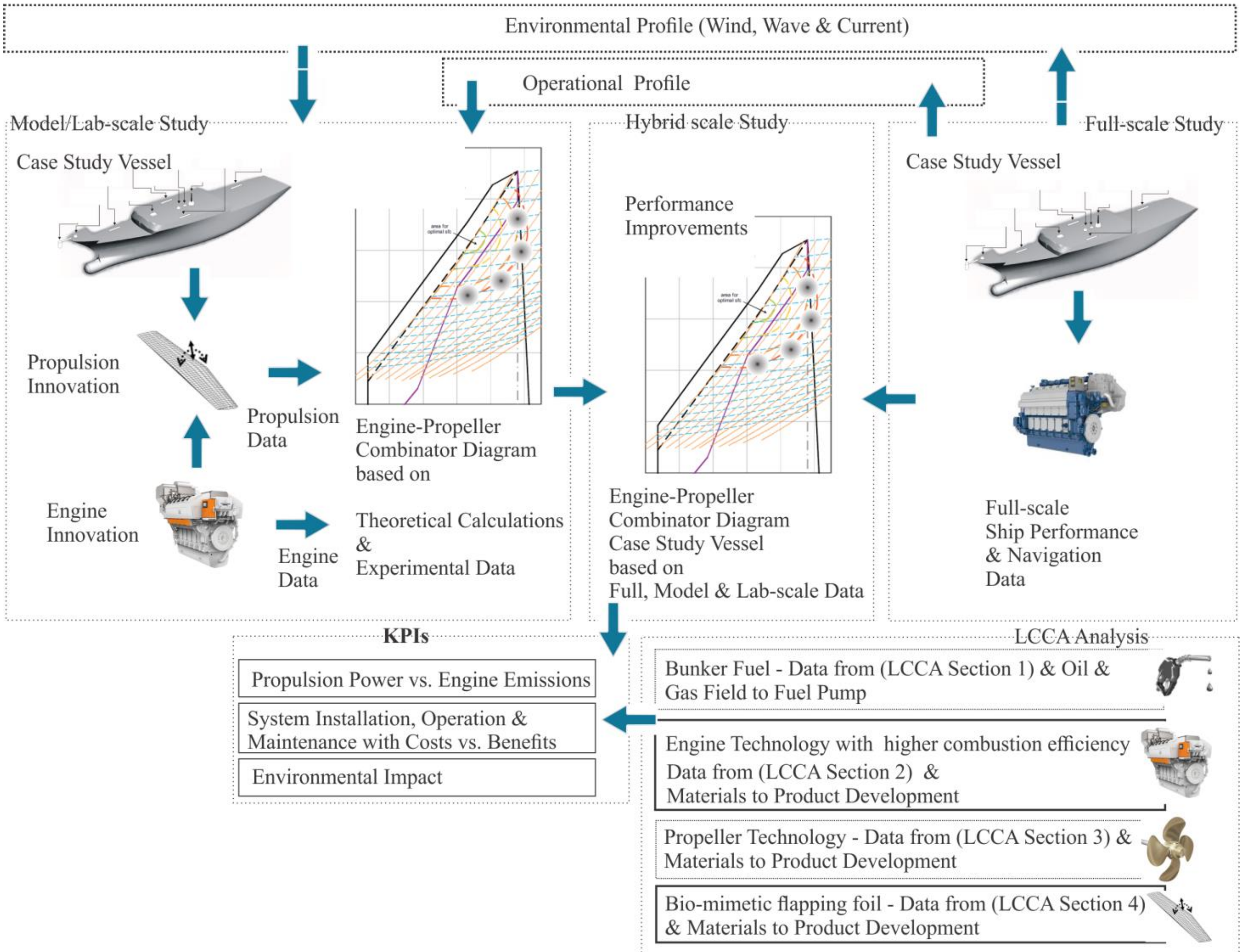

Fig. 4: Hybrid engine propeller combinator diagram development

replace some parts in the engine. Therefore, having a well documented engine technology structure can support such cost calculations by identifying appropriate systems and components that should be replaced during the retrofitting process with the required cost elements. The actual costs may not be available for LCCA in some situations, since these are novel technologies. Therefore, the respective costs will be extracted from the previous retrofitted project experiences by Wartsila.

In the fuel extraction and delivery section of LCCA, the respective costs for different fuel and lubricant oil types, i.e. to extract the same from oil fields and deliver to fuel and lubricant oil pumps, will be calculated. One should note that these fuel and lubricant oil types will be used in the SeaTeach engine in its operational profile under the laboratory conditions. The respective fuel consumption will be calculated under the same conditions and that will be compared with the fuel consumption of the case study vessel, i.e. with a similar type of duel-fuel engine and a diesel engine. One should note that a diesel engine is considered as the baseline for this project, where the respective emission reduction objective are introduced, i.e. the performance of the SeaTech engine will be evaluated, adequately.

The case study vessel in this proejct is a chemical tanker with the approximate length overall (LOA) of 130 (m), beam overall (BOA) of 20 (m) and designed draft of 8 (m). The vessel is also equipped with a Wartsila 34DF duel fuel engine with approximate rated power 4320 (kW) with rated speed of 720 (rpm). A gearbox is facilitated in between the engine and propeller with the reduction ratio of 6.9:1. The vessel has a 4-blade controllable pitch propeller with the approximate diameter of 5.2 (m).

System Operations and Maintenances

In the section of operation profile of LCCA, a general operational life of the case study vessel will be derived, based on its operation and navigation data sets. One should note that the operational profile can be divided into the time periods of weekly, monthly and yearly for these calculations, as required. It is assumed that the operational profile of this vessel will be executed by a future vessel equipped the SeaTech engine and propulsion innovations. In such a situation, the respective energy efficiency gains due to the SeaTech engine and propulsion innovations with respect to a vessel with a similar diesel engine, as the baseline, under short-sea shipping conditions can be quantified.

The same time periods of the operational profile will be considered for the system maintenance plan of LCCA, where the respective maintenance costs associated with the SeaTech engine and propulsion innovations will be calculated. These maintenance cost calculations for the SeaTech engine will also be based on the respective operational costs of the (almost similar) duel-fuel engine in the case study vessel. Similar approach will be considered for calculating the maintenance costs of the dynamic wing. In the part replacement section of LCCA, i.e. under the maintenance plan, the same technology structures, previously discussed, will be utilized, where the respective parts and their associated replacement costs of the SeaTech engine and propulsion innovations will be estimated.

Environmental Profile

In the section of environmental profile (including weather conditions) in LCCA, the respective weather and environmental conditions encountered by the case study vessel will be obtained by onboard sensors as time-series data sets and transformed into statistical distributions (Perera *et al*., 2017). These weather and environmental conditions mainly consist of wind and wave information with respect to the vessel position and time. One should note that the same weather and environmental conditions will be introduced during the laboratory testing of the SeaTech engine. On the other hand, the data collected from the model-scale sea trial conditions of the propulsion innovation will be interpolated towards the same environmental conditions. Therefore, the respective data sets from the SeaTech engine and propulsion innovations will be scaled and compatible with the weather and environmental conditions encountered by the case study vessel.

Fuel Life Cycle and Environmental Footprint

The fuel extraction & delivery and emission profile sections of LCCA, i.e. the fuel life cycle, will be complementing to each other because that can be used calculate the total life cycle costs for each fuel and lubricant oil. Therefore, that combination can be considered as the total cost estimation of the complete life cycle of each fuel or and lubrication oil. That can play an important role in the emission reduction strategy in the shipping industry, where more environmentally friendly fuels and lubricant oil types with lower associated costs can be utilized. One should note that bunker fuel will be transformed into emissions and the lubricant oil will be recycled, therefore the associated costs for such actions will also be considered into LCCA. The first part of the fuel life cycle includes the costs associated with extracting the fuel from an oil and gas field, transporting into an oil refinery center for processing of crude oil and gas into different grades, and delivering to a bunker station, i.e. an oil pump. That is categorized as the fuel extraction and delivery section of LCCA.

Emission Profile

In the second part of the fuel life cycle, the respective oil grades will be combusted through marine engines, where the chemical energy in bunker fuel is converted into the mechanical energy to drive ship propulsion systems. That has been categorized as the emission profile section of LCCA. One should note that the SeaTech engine has duel fuel modes: gaseous and liquid fuels. During the same combustion process, a portion of the bunker fuel will be converted into emissions, mainly CO2, SOx, NOx, CH4 and PPM and will be released into the environment. That would create an environmental footprint and can be considered as additional costs that can occur during the fuel life cycle. During the combustion process of a gas mode, a duel fuel engine can release CH4 into the environment, i.e. methane slip, as a part of the respective emission. One should note that CH4 is also considered as a part of greenhouse gas (GHG) emissions, therefore that can have a considerable environmental impact. However, it is also noted that the methane slip from dual-fuel engines has been reduced by 75% from its original level over the past 25 years (Wartsila, 2020) and expected to reduce further in future marine engines. One should note that CO2, SOx, NOx, CH4 and PPM can have different life spans (Howarth, 2014), therefore that should also be considered into the fuel life cycle to complete its cost calculations. Hence, the different sections of the fuel lifecycle can play an important role in LCCA, i.e. to see an overall picture on the costs savings that can be introduced under the SeaTech engine and propulsion innovations.

Product Disposal

In the section of product disposal of LCCA, the same technology structures will be flipped to formulate a transformation process of the respective systems into materials. That can be considered as the reverse engineering process of the product construction. However, the amount of materials that can be recycled during this process should be estimated, realistically and that costs can be subtracted from the LCCA calculations. On the other hand, a considerable amount of materials will not be recycled, but released into the environment. The costs associated with releasing such materials into the environment in a proper manner will also be considered in LCCA to complete the overall calculations. Hence, the final outcome can be used by the respective decision makers, i.e. ship owners, to decide proper energy efficient and emission reduction technologies that should be integrated into their fleets to improve ship energy efficiency (Bui and Perera 2019 & 2020).

HYBRID ENGINE PROPELLER COMBINATOR

Full and Model Scale Studies

The sections of operation profile, navigation profile, and environmental profile of LCCA will further be considered as a single framework to develop the ADAF. That combination is presented in Fig. 4 and consists of three studies: full-scale study, model/lab scale study and hybrid scale study. The full-scale study consists of collecting and analyzing the real-time data sets collected from the case study vessel with a duel fuel engine. These data sets will be used to extract the operation and weather profiles of the same vessel and that will be used as both time-series and statistical distributions. The data sets as both time-series and statistical distributions will be utilized during laboratory tests and sea trials of the SeaTech engine and propulsion innovations. The data sets as time-series and statistical distributions will be used to model vessel-engine operational and environmental profiles, as discussed previously. One should note that these profiles will be recreated in laboratory conditions and large-model-scale sea trials in the next stage.

Furthermore, these analyses will be done under two levels, as mentioned before. Firstly, the engine propeller combinator diagram from the theorical studies, based on ship resistance calculations, will be derived and energy saving due to dynamic wing will also be introduced. That will be done under large-model-scale sea trials based on the case study vessel with its engine-propulsion system. This approach consists of developing ship resistance calculations including the hydrodynamic coefficients (RAOs-Response amplitude operators) from the hull drawing of the same vessel, i.e. calculating the hydrodynamic parameters. Therefore, the power requirements, i.e. the engine-propulsion requirements, of the same vessel to maintain required speeds under various sea conditions will be estimated. These engine-propulsion requirements will be aligned with respect to selected operational modes and that can be considered as engine modes for an ocean going vessel. The respective engine propeller modes should be aligned with the ship

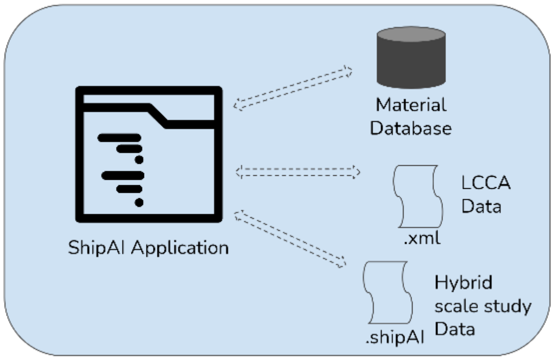

Fig. 5: ShipAI software architecture

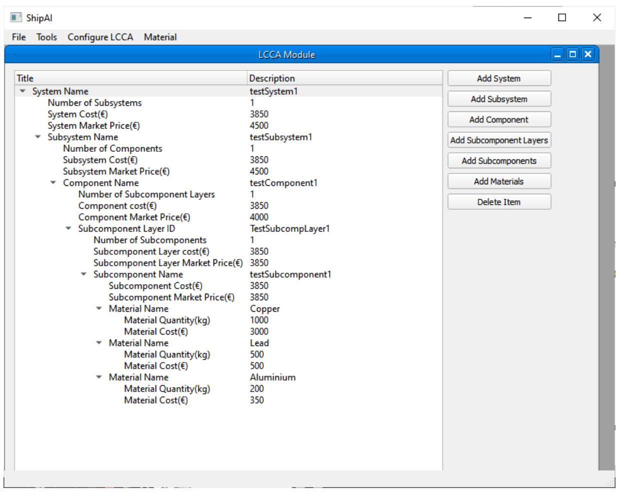

Fig. 6: LCCA tree structure

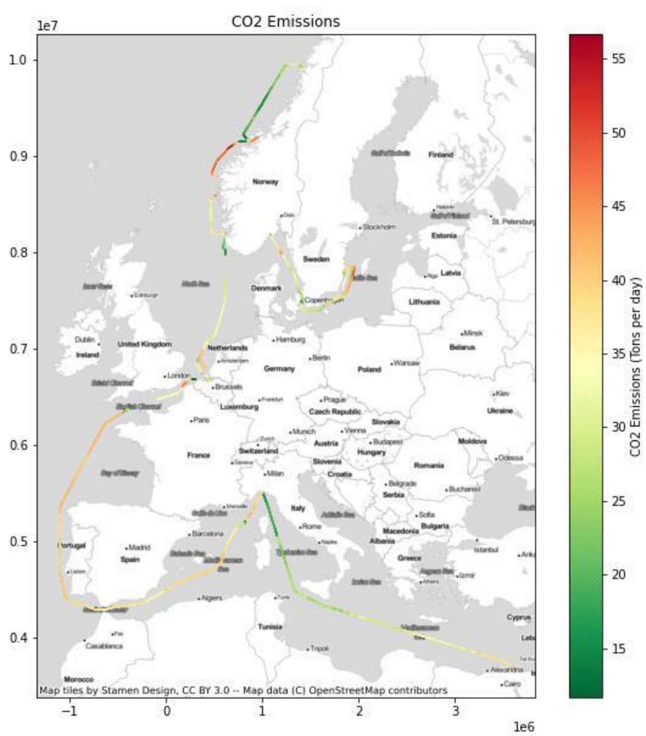

Fig. 7: Ship routes of a selected vessel

resistance models that are calculated in the previous step under selected speed constrains. Finally, the information on the engine-propulsion requirements and ship resistance calculations will be utilized to derive the respective engine-propeller combinators diagram, i.e. that is derived from theoretical calculations. These theoretical calculations should present an initial engine propeller combinator diagram for the case study vessel. As the next step, the final engine propeller combinator diagram for the same vessel with the SeaTech engine propulsion innovations, i.e. SeaTech engine and bio-mimetic dynamic wing with respect to its specific fuel consumption under various ship speeds, will be derived, theoretically.

Secondly, the real-time ship operation and navigation data sets collected from the same vessel will be projected into the engine propeller combinator diagram derived, previously. That approach can be categorized as the development of a hybrid engine propeller combinator diagram, where both theoretical and experimental information on engine and propeller interactions can be merged. Finally, the projected real-time ship operation and navigation data will be interpolated accordance with the theoretical calculations done in the previous levels. One should note that some nonlinear interpolation techniques will be used during these calculations. Hence, the respective energy savings due to the SeaTech engine and propulsion innovation can be estimated, accurately in relation to the existing engine technology. Such energy savings will be included in LCCA to complete the respective calculations. Hence, the hybrid engine propeller combinator diagram can be used quantified the performance of the SeaTech innovations based on the data sets from laboratory experiments and full and model-scale sea trials.

Hybrid Framework and KPIs

The calculations discussed in the previous section will be compared with actual data sets collected from several vessels to verify their accuracy and learn additional lessons. A more realistic hybrid engine-propeller combinator diagram will be derived during such exercises and necessary modification will be introduced through the lessons learned in this project. One should note that this diagram will reflect the energy savings introduced due to the SeaTech engine and propulsion innovations. That has been categorized as a hybrid scale study, due to the reason that both theoretical studies as well as experimental studies will be combined to quantify the SeaTech engine and propulsion innovations. It is expected, this hybrid engine-propeller combinator diagram can be used to estimate the accurate energy savings, i.e. fuel and emission reductions, under the respective KPIs.

Finally, appropriate KPIs will be demonstrated under the propulsion power vs, engine emissions, system installation, operation and maintenance with the costs vs. benefits and environmental impact, as discussed previously. That can be done by combining the outcomes of LCCA with the energy savings due to the SeaTech innovation throughout the respective technology life cycles. The combined system will be developed as a software unit with simulating capabilities for the case study vessel with the SeaTech engine and propulsion innovations under various ship operational conditions, i.e. various ship routes with selected wind and wave conditions. These simulations can be conducted under various ship systems and vessel operational conditions, therefore the respective outcomes can be utilized towards uncertainty analyses of the ADAF as an important component of LCCA. Therefore, the respective return of investment (ROI) not only on the case study vessel but also in other vessels by introducing the SeaTech innovations as retrofitting technologies can be estimated. That can be used as a good benchmark of ship owners to make required decisions and improve energy efficiency in their shipping fleets. The LCCA calculations and hybrid engine-propeller combinator diagram can be considered as two

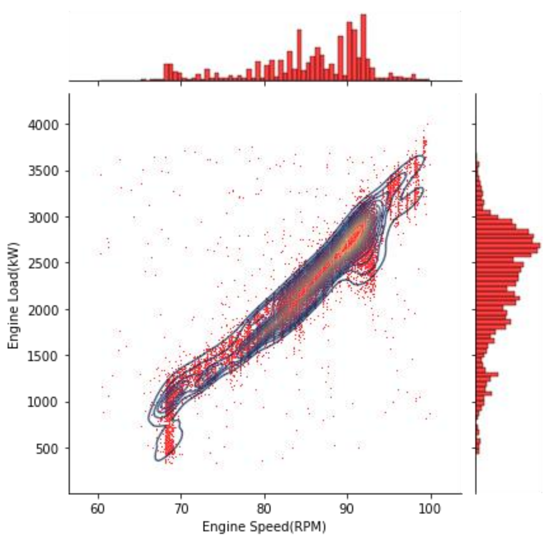

Fig 8: Engine propeller combinator diagram for a selected vessel

main contribution of this project. These two contributions will be developed as two software modules and will be combined under the ADAF. These software development steps that are in a preliminary stage and discussed in the following section.

SOFTWARE DEVELOPMENT

ADAF Development

The ADAF is under development as a software unit, named 'ShipAI' and that consists of a runtime platform of Windows with the programming language of C++. ShipAI consists of a GUI framework of Qt and a data model of XML/SQL. The software is a standalone executable file with the main function that have been discussed, previously. These functions include two main software modules: LCCA calculation module and hybrid engine-propeller combinator module. A general overview of ShipAI software architecture is presented in Fig. 5 and consists of the ShipAI application with the respective data sets of material data, LCCA data, i.e. from the LCCA calculation module and hybrid scale study data, i.e. from the hybrid engine-propeller combinator module.

LCCA Calculation Module

A general overview of the LCCA calculation module is presented in Fig. 6. That consists of a tree structure from a system to its materials. Hence, the materials make the basis for the LCCA calculation module and that consist of the information on various materials and their associated costs. The materials used for manufacturing various subcomponents, components, subsystems and systems are presented in the same tree structure. Hence, such a tree structure can be used to develop any complex technology structure from its raw materials under this software module. Furthermore, the respective software interface will have additional functions: to creating new system tree, add/remove system elements, save and open existing systems, store/retrieve and modify material data, calculate manufacturing cost and calculate market price that can replace with manufacturing cost.

Manufacturing Cost and Market Price

One should note that two important features of the manufacturing cost and market price have been introduced in LCCA due to the reason that each system can have two difference monetary values. The manufacturing cost represents the cost associated with the subcomponent, component, subsystem or system from its materials to the final product. In some situations, such calculations can be problematic due to the unavailability of manufacturing data. Therefore, the market price, i.e. the off-the-shelf price, of the respective subcomponent, component, subsystem or system can also be used in LCCA. Based on such information, LCCA can be completed under the same software module and that information will be delivered to the hybrid engine-propeller combinator module.

Hybrid Engine-Propeller Combinator Module

The general components of the hybrid engine-propeller combinator module are presented in Fig. 7 and 8. Fig. 7 consists of ship routes of a case study vessel for several months. It is expected to collect approximately two years of full-scale ship performance and navigation data sets from the case study vessel to support this project. The initial engine propeller combinator diagram based on real-time ship performance and navigation data sets for the same vessel is presented in Fig. 8. This figure represents various operational regions of the respective marine engine, where the highly dense regions, i.e. the most common operation regions, are marked by contours. These highly dense data regions represent the respective engine modes and that can be identified as data clusters by utilizing various machine learning techniques, including Gaussian mixture models and the expectation-maximization algorithm (Perera and Mo, 2017). Furthermore, the respective structure of the same data clusters should also be investigated to identify various parameter correlation. The respective structure of each data cluster can be identified by singular value decomposition (Perera and Mo, 2017). It is well known that the singular vectors represent the structure of the data cluster and the singular values represent the amount of information preserved by the respective singular vectors.

One should note that additional ship performance and navigation parameters can be introduced into the engine propeller combinator diagram under the same data clusters. Therefore, the dimensionality of the data clusters can be expanded along with its singular vectors and values. The same parameters can introduce complex correlations into each data cluster and that can be useful for identifying the optimal operational conditions of vessel navigation and ship system operations. The system operational conditions can relate to the proposed ship energy efficient and emission reduction technologies, therefore various technologies can initiate different singular vector and value structures. However, those variations in singular value decomposition can be utilized through the proposed KPIs to make proper decisions on technology selections. Hence, that will be done under the hybrid engine propeller combinator diagram to support the respective KPIs.

CONCLUSIONS

An overview of energy efficient and emission reduction technologies that will be developed under the SeaTech project is presented in this study. These energy efficient and emission reduction technologies consist of a duel-fuel (DF) engine with an ultra-high energy conversion efficiency and a renewable energy based active biomimetic dynamic wing. However, these SeaTech engine and propulsion innovations will be evaluated under laboratory experiments and large-model-scale sea trials. The ultimate objective of the project is to scale up both technologies, demonstrate them in a relevant environment with respect to a case study vessel on short-sea shipping scenarios. Since these technologies will not be installed/evaluated under a full scale vessel, the respective data sets will be combined in a data science environment, where the ADAF is introduced. The ADAF will be developed as a software unit that consists of two main modules: the LCCA calculation module and the hybrid engine-propeller combinator module.

The LCCA calculation module will also support the hybrid engine-propeller combinator module by providing the necessary information as described in this study. Hence, the hybrid engine propeller combinator module can be used to quantify the performance of the SeaTech engine and propulsion innovations based on the data sets collected laboratory experiments and large-model-scale sea trials. The LCCA calculation and hybrid engine-propeller combinator modules will complement to each other with dynamic interactions, where uncertainty analysis under the ShipAI software unit will be conducted. That approach opens a path for evaluating such energy efficient and emission reduction technologies in a data science environment even with some uncertainties, where appropriate technologies can be compared against their energy efficiency gains with respect to existing vessel technologies, specially in engine and propulsion systems. That can be done through the respective KPIs.

Furthermore, the project partners are also expected to commercialize SeaTech engine and propulsion innovations quantified under the ADAF in the European and Asian short-sea market by 2025, followed by the adjacent deep-sea market. Assuming only 10% of EU short-sea vessels would be retrofitted with the SeaTech engine and propulsion innovations, this would result in CO2 savings of 32.5 million tons annually (Wartsila, 2019). These outcomes will further be verified in a fleet level by considering the AIS data sets that are publicly available. Furthermore, the expected further impact of this project includes savings of EUR 85.2 billion in health and climate change damages due to lower emissions, the creation of +100 jobs at the project partners with a cumulative net profit of EUR 820 million in the first 5 years post-commercialization, and the indirect creation of 250 new jobs in the EU shipyard industry (Wartsila, 2019). Those can be highlighted as some of the important contributions from this project to the society, in general.

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