E2, an advanced Ship Performance Monitoring tool

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Abstract

The paper describes the software system E2, designed to be user-friendly software in the context of the Ship Energy Efficiency Monitoring Plan (SEEMP). The software is developed using C++ programming language. The currently operational version will be soon tested on board a ropax vessel.

The usefulness of E2 software takes place during the monitoring and measurements phase with its capability to record real consumptions on board (automatic input data acquisition/manual/composite) and to calculate the corresponding fuel Key Performance Indicators (KPI’s) and emissions KPI’s. This is achieved through the E2 acquisition mode which is more dedicated to the crew usage. Other parameters can be recorded to improve the analysis. These values can be displayed either in real-time or in post-processing mode. Logged data are used to discretise the recordings into voyages, legs and steps.

Two additional modes are available for running E2 software: the simulation mode (which gives access to reference values for a given leg or voyage) and the benchmark mode, both of them being more dedicated to ship owner’s management and ship planner’s usage. The purpose of E2 benchmark mode is to benchmark, follow up and monitor the energy efficiency performance of different ships within the fleet or of one ship for different legs or voyages.

1. Introduction

The energy saving will probably become one of the most challenging topics for all the sectors of economy in the coming decades. This is really important for the transportation sector and in particular in the maritime world. In this context, the International Maritime Organization (IMO) has added a new chapter to Annex VI (resolution MEPC.203(62)), on Regulations on energy efficiency for ships to make mandatory, since January 1st 2013, the Energy Efficiency Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships.

The purpose of a SEEMP is to set up proper systems and procedures applicable to a company and/or ship for improving the energy efficiency of a ship in operations conditions. Basically, the SEEMP is built up according to four phases (planning, implementation, monitoring / measurements and self-evaluation / improvement. The use of E2 software which has been developed in this context takes place in the monitoring / measurements phase.

2. Key Performance Indicators

2.1 Definition

The setting up of a SEEMP and its deployment needs obviously the definition of Key Performance Indicators (KPIs) both for fuel consumption and emissions (CO₂ and NOx). These KPIs will be used for comparison between current situations and reference situations but also for benchmarking purpose between several voyages for a single ship or between several ships within a fleet.

The relevant KPIs include the EEDI for new ships. For all ships, the Energy Efficiency Operational Indicator (EEOI) has been defined, taking into account the operational parameters, such as loading conditions, manoeuvring phases, loading/unloading…
The consumption indexes are expressed in terms of fuel consumption/distance/transported weight. The emission indexes are expressed in the same way in terms, for example, in CO2 emissions/distance/transported weight (like EEOI).

2.2 E2 software in manual mode

2.2.1 A first answer to SEEMP requirements

The first version of E2 software which has been released (E2 version 1.2) is a basic tool usable in the context of a SEEMP. It is based on a manual acquisition of the necessary input data, and in particular the fuel consumptions (HDO or HFO). The software is developed using C++ and Fox Toolkit library.

2.2.2 Organisation of the software

The software is organized in two modules, as illustrated on Fig.1:
- the module managed by Tecnitas
- the user’s module.

The first module is accessible only by Tecnitas. It enables the setting up of the software use for a considered ship by delivering a customized database for that ship containing the ship’s particulars (ship type, dimensions, and characteristics of propulsive and electric power distributions) and all other needed input data.

The calculation of fuel consumptions KPIs and emissions KPIs depend obviously on the ship type because of the very different types of cargo (liquid cargo, bulk cargo, containers, cars, trucks, passengers). E2 is able to handle any standard type of vessel ranging from a small ferry up to a Very Large Crude Carrier (VLCC) of more than 300m length.

The second module, accessible to the user, expands the above described database by implementing the data related to the loading conditions and the definition of the ship’s voyages.

The voyages are constituted by successive legs. Regarding energy matters, the ship is encountering very different situations within a leg and consequently E2 software considers that the leg is constituted by the following sequences: navigation in calm sea or heavy sea, manoeuvring departure, manoeuvring arrival, loading/unloading, berthed, as illustrated on Fig.2.
2.2.3 The manual mode

It is of course not possible when entering manually the consumptions to take into account all fluctuations which can occur during the different operational sequences. Only averaged values can be considered. The different KPIs are calculated accordingly and they have to be considered as averaged values. However, these values can be relevant in the context SEEMP requirements as per defined by IMO.

As E2 software has been designed first to be fully consistent with SEEMP requirements, the reporting capabilities have been considered as essential since the beginning of the project. The software is able to produce automatically a report in pdf format. This report includes all relevant information for the SEEMP within a leg or a voyage, and also on a yearly basis.

Considering the limitations of the first version of E2, Tecnitas has decided that the development of E2 should be pushed much beyond the quite basic capabilities of manual acquisition mode in order to:
• provide the ship owners with a decision-making tool for operating efficiently either a single vessel or a whole fleet. Two additional modes are available for running E2 software: the simulation mode and the benchmark mode, both of them being more dedicated to ship owner’s management and ship planner’s usage. Detailed explanations about these modes can be found in sections 3 and 4 respectively,

• improve the efficiency and the accuracy of the software by developing an automatic acquisition mode using appropriate sensors and equipment on board. Detailed explanations about this mode can be found in section 5.

3. E2 software in simulation mode

The capability to simulate a voyage is particularly attractive because reference values (for a voyage or a single leg) will be obtained as a result of this simulation, and in particular the reference fuel KPIs. If the simulation is performed prior to the ship voyage, the calculated reference values could be used as target ones, if the simulation is performed after the voyage, they could be used for assessing the energy efficiency of the vessel issued from the on board observed consumptions. In any case, the simulation is part of a decision making tool for the ship planner or fleet manager. The monitoring of ship energy efficiency can be then performed on the basis of the measured efficiency of SEEMP actions and the calculated values of relevant indexes such as the yearly EEOI.

The simulation in E2 is based on the engines consumption curves and on the ship power-speed curves, taking into account hull geometry, trim and draught, an also hull cleanliness as a function of the most recent hull cleaning date.

The user should adjust the available energies on board (propulsion energy and electrical energy) reach a correct balance between them and the required energies for the considered conditions.

![Ship power speed curve](image)

Fig. 4 – Ship power speed curve / balancing between available energy on board and required energy

Once the energies have been correctly balanced, the KPIs are calculated and can be accessed by using the same post processing capabilities than for the calculated KPIs in manual mode (plots, report in pdf format).
4. Benchmarking

The capability for E2 to perform benchmarking between several voyages performed by the same ship or between different ships within a fleet represents another decision making tool for a ship planner or a fleet manager.
Once the data base(s) have been built up containing the relevant ships and voyages, the benchmarking option of E2 presents on the same tables and plots, for easy comparison, the different calculated KPIs. It is also possible to issue automatically this information on the form of a report in pdf format.

5. Automatic data acquisition with E2

5.1 Advantages of automatic data acquisition

Once E2 software using manual data acquisition has been developed, it became rapidly obvious that E2 development should be pushed ahead by implementing automatic data acquisition capabilities which will give decisive improvements in the reliability of the energy efficiency analysis performed with E2. The most significant improvements are expected to be:

- no information loss due to the lack of capture of some data by the crew,
- no error in the capture of data,
- more accuracy : possibility to take into account of the variation of the parameters during the leg instead of an averaged value of these parameters as for manual acquisition mode,
- more parameters can be recorded, enabling some extra analysis of the performance

5.2 Basic principles

The data acquisition on board is performed by relevant sensors (flow meters, GPS…) which deliver analogic or digital signals as a function of time. These signals have to be processed before proceeding to the calculations of the resulting KPIs. This processing could have been done directly by E2 but it would have been extremely detrimental for customizing E2 in a given ship environment. In fact, when sensors such as flow meters are already present on board together with a data acquisition hardware and software, it is more efficient to dedicate E2 to the calculations ok KPIs only, using the data delivered by the existing system, than to manage also the data acquisition in E2.

E2 version 2.0 has the capability to handle the information issued in real time from the data acquisition system. The transfer of information between this system and E2 software is done through an ASCII file which is written by the data acquisition system in real time and then read, also in real time by E2. This file must contain all the needed information for calculating the KPIs, basically the fuel consumptions issued from flow meters, the electric powers issued from relevant equipment and the GPS data for calculating the distances and the ship speeds. However, a lot of different signals can be recorded for use in a more refined analysis, if needed, such as wind speed, wind direction, rudder angle…
5.3 Treatment of information

The following is particularly important for the reliability of the energy efficiency analysis during ship operations:

- the integrity of the recorded information is to be ensured and it is necessary to prevent as far as possible the risk of information loss due to a hardware failure. As far as the data acquisition system is working, the ASCII file will receive the needed information in real time and this file can be regularly saved on another computer or server on board, even if the computer on which E2 is running has failed,

- the automatic definition of the different phases of a leg is not easy to implement. For example, the detection of the manoeuvring phase needs to define speed criteria which could be different from one ship to another or from one harbour to another. The possibility to use the information stored on the ASCII file even after the voyage will give the possibility to manually refine the information about legs on the basis of specific criteria and consequently the accuracy of the analysis will be increased.

The Fig. 6a shows examples of recorded signals read from the ASCII file generated by the data acquisition system and displayed by E2 in real time. As several parameters are involved in the calculations of KPIs, E2 can combine the corresponding graphs (see examples on Fig 6b) for displaying KPIs in real time.
After completion of one or several voyages, E2 can import the corresponding signals from the ASCII file for further treatments, such as:

- defining a new period constituted for example of several voyages,
- defining the legs constituting the voyage and the corresponding sequences within a leg.

The Fig. 7 illustrates these possible treatments. Of course, the KPIs can be calculated using the corresponding new signals.

![Fig. 7 – Definition of new voyages and legs for refined calculations of KPIs](image)

After a successful test phase in laboratory using a dedicated hardware able to generate real time information, E2 software is operational for the tests on board of a ro pax vessel.

6. Conclusions

E2 software has been initially developed as a tool to be used during the monitoring and measurements phase of a SEEMP.

The development of the software has been then pushed much beyond the needed capabilities within the scope of a SEEMP. The combination of manual and automatic acquisition modes, simulation mode, and benchmark mode means that E2 software is now able to deliver useful information for defining the fleet management strategy for energy efficiency.

References