INTECS
“Fleet Monitoring System” (FMOS)

Concept presentation
FMOS mission

**FMOS** – is a part of Company’s Control System, which provides continuous and complex fleet monitoring for subsequent information analysis and working out optimization decisions.

**Purpose** – the introduction of innovative technologies in automation of fleet management to reduce the cost and increase the efficiency of technical and organizational solutions, and ultimately - to increase market competitiveness.
1. Improvement of the shipping company management quality (in accordance with ISO: 9001) through automation and innovations in fleet operation.

The control function is ensured by monitoring each process in each company’s unit (head office, local offices, ships, etc.).

1. Cost optimization

Cost reduction is performed through automated monitoring of 3 main budget items:

- **Fuel** - bunkering and consumption monitoring, consumption optimization
- **Repairs** - planned and preventive maintenance, diagnostics, repairs, quality assessment, assessment of spare parts supply and service
- **Crew** - supervision over complying with internal regulations
The FMOS complex consists of following components:

• **SEEMS** – generated/consumed energy and fuel monitoring system

• “Navigation fuel optimization” modules:
  • **Optimal trim/list** (ship’s model)
  • **Optimal speed** (ship’s model)
  • **Optimal route/schedule** ("Weather routing”)

• **Equipment diagnostics** module (integrated with Repair and Maintenance system)

• **Engine emissions monitoring** (based on engine’s mathematical model)
1. Fleet operation efficiency criteria

The evaluation of voyage efficiency is performed by specified criteria as result of analysis of all the factors affecting voyage tasks performance:

- **Following the terms of cargo (passengers) transportation** (according to approved voyage plan) and **safety requirements** (including environmental);

- **Ship’s equipment normal operation** taking into account **the impact of external conditions** (hydro/meteorological factors, ice);

- **Fuel consumption**.
INTERTANKO’s Best Practice on Tanker Emissions and Energy Efficiency

1. Program for Measuring and Monitoring Ship Efficiency

2. Voyage Optimization Program
   2.1. Speed selection optimization
   2.2. Optimized route planning
   2.3. Trim optimization

3. Propulsion Resistance Management Program
   3.1. Hull resistance
   3.2. Propeller resistance

4. Machinery Optimization Program
   4.1. Main Engine monitoring and optimization
   4.2. Optimization of lubrication as well as other machinery and equipment

5. Cargo Handling Optimization
   5.1. Cargo vapours control procedure on all crude tankers
   5.2. Cargo temperature control optimization

6. Energy Conservation Awareness Plan
   6.1. Onboard/on-shore training and familiarization of company’s efficiency program
   6.2. Accommodation-specific energy conversation program
SEEMP and operational measures

3.2 The potential savings from operational measures are significant and go beyond shipboard energy management and speed reductions. New modes of co-operation between cargo owners, charterers and shipowners, as well as port-related issues also contribute. In addition, better fleet planning, large-scale improvements of vessel utilisation, and minimising non-productive ballast voyages are possible through further consolidations in the industry both on the liner and charter side. As such, operational measures to reduce the fuel consumption and CO₂ emissions can be considered in three categories:

- **Enhanced technical and operational management**: Measures include enhanced weather routing; optimized trim and ballasting; hull and propeller cleaning; better main and auxiliary engine maintenance and tuning; enhanced voyage execution and performance measurement, monitoring and reporting; efficient operation of larger electrical consumers; and deployment of cost effective propulsion, engines and auxiliary technology upgrades;

- **Enhanced logistics and fleet planning**: Measures include combining cargoes to achieve a higher utilisation rate, use of combination carriers’, optimisation of logistic chains, enhanced routeing, fewer/shorter ballast legs; larger cargo batches; adjustments for optimised arrival times and slower steaming – and changed contract formats between charterer and shipowner; and

- **Port related**: Removing restrictions on ship size (e.g. ship draft, length and beam, congestion), and limitations on quick port turn-around. Implementation requires infrastructure development and virtual arrival support. Measures can include, typically: larger port capacity; fewer restrictions on ship draft, beam or length; 24/7 port operation; quicker loading and discharging; flexible design of cargo handling equipment; and more efficient port clearance and slot time allocation.
2. SEEMS - Voyage Efficiency Analyzer (VEA) function

VEA function is BASIC part of SEEMS (as a part of FMOS complex) intended for:

- identification of "losses" and non-optimal processes;
- crew training based on voyage analysis.

The analysis of voyage efficiency is based on data automatically collected by SEEMS (with required discreteness) using specified criteria. For some functions the data recorded onboard can be supplemented with data from company’s database (through integration between servers.)
2. SEEMS - Voyage Efficiency Analyzer (VEA) function

VEA function is based on following FMOS modules and algorithms:

Voyage performance and safety
2.1. “Voyage performance efficiency” algorithm (including navigation and environment safety limitations)

Fuel consumption optimization (based on ship’s mathematical models)
2.2. “Optimal trim/list” module
2.3. “Optimal speed” module
2.4. “Optimal route/schedule” module (taking into account weather and limiting factors);

Ship’s equipment operation optimization
2.5. “Emissions monitoring / Equipment diagnostics” module (based on mathematical model and including manufacturers recommendations)
2. SEEMS - Voyage Efficiency Analyzer (VEA) function

VEA function principles:
• INDEPENDANCE from operators on the ship and in the office!
• INDIVIDUAL algorithms and modules for each series of ships (with checking each vessel on trials stage)!

Function operation:
• Voyage/period selection (can be made automatically)
• Analysis criteria specifying (set of algorithms/modules and parameters being analyzed)
• Calculation performance
• Efficiency analysis results presentation (in Graphic User Interface).

In case of analysis on fuel optimization “Voyage performance efficiency” and “Equipment diagnostic” algorithms provide limitation factors.
2. SEEMS - Voyage Efficiency Analyzer (VEA) function

Analysis results are provided in any convenient form (graphical, tabular):

<table>
<thead>
<tr>
<th>Values Type</th>
<th>ROLL</th>
<th>TRIM</th>
<th>Consumption HFO</th>
<th>Excess fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recomended</td>
<td>0.4°</td>
<td>0.2°</td>
<td>1307.7 L/H</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>0.2°</td>
<td>0.5°</td>
<td>1332.3 L/H</td>
<td>1.82 %</td>
</tr>
</tbody>
</table>
2.2. SEEMS - “Optimal trim/list” option

- “Trim Optimization” module is based on ship’s hull model
- Module calculates and recommends Trim/List values change to decrease hull resistance
- Fuel saving effect may reach 3-5% (depending on practice of using recommendations onboard)
2.2. SEEMS - “Optimal trim/list” option

Factors affecting ship’s hull resistance:

- Wave direction and force
- Wind direction and force
- Ship’s draught
- Under keel clearance
- Rudder angle
2.2. SEEMS - “Optimal trim/list” option

Technological platform:

- Hull model created based on ship’s design documentation
- Hydrodynamic mathematical model to take into account all factors making an influence on ship’s hull resistance
2.2. SEEMS - “Optimal trim/list” option

Ship’s data required (from SEEMS):

- Fuel consumption
- Inclinometer’s data
- Ship’s speed
- Under keel clearance
- Ship’s draught on fore and aft
- Wind/wave direction and force
- Main Engine power and RPM
- Rudder angle
2.2. SEEMS - “Optimal trim/list” option

Recommended Trim/List visualization (onboard and in the office):

- Current Trim/List
- recommended Trim/List
- Current fuel consumption
- Calculated fuel consumption provided recommended Trim/List applied
- Fuel saving expected
2.2. SEEMS - “Optimal trim/list” option

Project stages:

1. SEEMS installation onboard
2. Trial measurements onboard (by ship’s crew according to measurement program, under normal voyage conditions)
3. Ship’s models development (for series of ships) and trials
2.3. SEEMS - “Optimal speed” option

• “Optimal speed” module is based on individual mathematical model taking into account all factors affecting ship’s movement (propulsion characteristics, hydro/meteo conditions, voyage task specified)

• The module calculates and recommends (in real time mode) optimal values for propulsion so keep either ETA specified or optimal speed (with minimized fuel consumption)

• Fuel saving effect may reach 3-5% (depending on practice of using recommendations onboard)
Purpose and functionality:
The module parses the real-time working parameters of ME at current external conditions affecting its operation. By pressures, torque, RPM and fuel consumption it defines the load curve, which the ship’s ME is currently running on. With certain assumptions, this curve (with the current efficiency) is used to provide recommendations for speed.

Explanatory note:
Main Engine works in a very wide range of loads during its operation. Load range depends on the resistance of the vessel’s hull, therefore the “speed-fuel rate” curve is varying in wide range due to both change DG efficiency, and the non-linear external factors effect.
2.3. SEEMS - “Optimal speed” option

Explanatory note:
1. Curve on “smooth water”
2. “Weighting” the external environment (the mismatch with the curve "1" may be 15-20%) - the most common case
3. Curve with a one-way wind, no waves (rarely)

Algorithm:

- The “current position” on the curve is determined (by mathematical model)
- All parameters required for building “actual” curve (for current ME mode) are determined (efficiency, external factors)
- Building (visualization):
  - current/actual curve (optionally – with “passport” curve 1);
  - “Best Speed”/“Best Economy” extremums;
  - “current position” on the curve.
2.3. SEEMS - “Optimal speed” option

Required “static” data for model development (from ship’s documentation):
• Technical description of Main Engine;
• Ship’s fuel system (drawings);
• Cooling and turbocharger schemes and description;
• Acceptance trials results (on different ME modes);
• Shaft description;
• Fuel type and characteristics;
• Main Engine Technical File.

Required “on-line” data (from ship’s automation via SEEMS):
• ME/Shaft Power, RPM and/or torque on shaft;
• Fuel consumption on ME;
• Scav. air receiver temperature IN;
• Scav. air receiver temperature OUT;
• Scav. air receiver pressure OUT;
• Exhaust gas temperatures OUT(for each cylinder);
• Exhaust gas temperatures turbocharger IN;
• Exhaust gas temperatures turbocharger OUT;
• Turbocharger RPM.
• Others.
2.4. SEEMS - “Optimal route/schedule” option

• “Optimal route/schedule” module is based on individual mathematical model taking into account all factors affecting ship’s movement (propulsion characteristics, hydro/meteo conditions, voyage task specified)
• The module calculates fuel consumption along the planned route and monitors (in real time mode) all factors taken into account when planning route/schedule
• Fuel saving effect may reach 3-5% depending on practice of using recommendations (onboard and in the office)
2.4. SEEMS - “Optimal route/schedule” option
### 2.4. SEEMS - “Optimal route/schedule” option

**“Optimal route/schedule” module** includes the combination of several **components** intended for planning and analyzing ship’s voyages in respect to fuel consumption.

1. **Ship’s mathematical model** taking into account hydrodynamic, screw and propulsion characteristics, as well as other factors affecting ship’s movement along the route. The model for calculating fuel consumption along the route is the **SAME** as used for option “Optimal speed” (see above). The difference is only in data sources incoming to the model:
   - for “Optimal speed” the data from onboard sensors is considered;
   - for planning route the “forecasted” or “from previous voyages” data is expected. Due to use one the same model in two modes - real-time (onboard) and “Play ahead” (when planning route in the office), its accuracy will unswervingly rise!

2. **Weather forecasts** (in GRIB format) as a source of hydro/meteorological data and **Currents database**.

3. **Chart component** (or ECS/ECDIS) for plotting the route, schedule/fuel consumption calculation and data exchange with SEEMS, as well as source of depth data (from navigation charts).
2.4. SEEMS - “Optimal route/schedule” option
2.4. SEEMS - “Optimal route/schedule” option

Module functions:

1. **Planning** route:
   - Weather data extract and visualization (on navigation chart)
   - Route creation, schedule/fuel consumption calculation along the route (including comparison and data exchange with ECDIS/ECS/SEEMS)
   - Replay of ship’s movement along the route (“Play ahead”) with specified propulsion parameters (manually set or taken from previous voyage) and weather forecast data.

2. **Ship monitoring** along the route (in real-time mode)
   - Tracking “planned” and “real” (from sensors through SEEMS) parameters to determine critical difference, when system will recommend re-planning route/schedule (with new/changed parameters).

3. **Analysis**
   - Comparison planned and actual voyage results (by all factors) to define causes of the difference between planned and actual fuel consumption (SEEMS data “play back”).
2.4. SEEMS - опция “Optimal route/schedule”
2.5. SEEMS - “Emissions monitoring / Engine diagnostics” options

- “Emission monitoring / Engine diagnostics” module is based on individual ship’s Main Engine mathematical model
- Module performs 2 tasks:
  - Emissions calculation
  - Main engine diagnostics
2.5. SEEMS - “Emissions monitoring / Engine diagnostics” options

Main Engine (ME) mathematical model:

The model is developed for each ship/ME. The model describes ME working (burning) process taking into account all engine’s specifics and impact of all factors affecting its work. The model is tuned on the data from statistical analysis of ME working in different modes.

Data from documentation required for ME model development:

• S, m – piston stroke
• D, m - cylinder diameter
• I – number of cylinders
• N, kWt – ME power (cylinder)
• n, rpm – crankshaft rpm
• e - compression
• $P_e$, kPa - average effective pressure
• $P_k$, kPa - turbocharging pressure
• $b$, g/kWt-h - SFOC
• $p_a$, kPa – atmosphere pressure
• r – ratio of the crank radius to the length of the rod
• valve timing phases
• indicator diagrams on different modes of operation
• algorithm of automation operation on all control modes (including timings between modes).

“Dynamic” parameters from SEEMS (with specified discreteness):

• Current fuel consumption
• Fuel type
• RPM
• Current telegraph position
• Operation mode
• Current air consumption
• Exhaust gas temperatures IN/OUT
• Scav. air receiver temperature IN/OUT
• Scav. air receiver pressure OUT
• Exhaust gas temperatures turbocharger IN/OUT
• Turbocharger RPM.
Module purpose – information support for ship’s crew on following MARPOL requirements in respect to gas emissions.

Module functions:
- Monitoring of exceeding calculated (measured) emissions values under permitted concentration with visual and audible alarms;
- Monitoring the approach to the areas of emissions restrictions;
- Automatic reporting on emissions monitoring in accordance with MARPOL requirements.
2.5.1. SEEMS - “Emissions monitoring” option

Emissions calculation algorithm:

The calculation is performed by ME model through built-in empirical formulas summarizing passport and experimental data on emissions dependences from temperatures for a particular type of engine. At each moment the model builds working process for each cylinder detecting mode of ME operation by following «dynamic» parameters: (from SEEMS)

- RPM
- Torque
- Pk - turbocharging pressure
- Tk - turbocharging temperature
- Q – fuel consumption
- external air parameters and fuel characteristics.

Then model calculates exhaust gas parameters and emissions. The calculation results are considered correct, if “modeled” and “actual” (from SEEMS) exhaust gas parameters (temperatures/pressures) do not exceed the specified difference.
2.5.1. SEEMS - “Emissions monitoring” option

Emissions visualization in SEEMS (including data from gas analyzer):

Output parameters:
- CO2
- SO2
- NO2
- CO
- CH
- Sulphur
- Soot
2.5.1. SEEMS - “Emissions monitoring” option

Additional emissions-related parameters visualization in SEEMS:
2.5.2. SEEMS - “Engine diagnostics” option

Diagnostics is performed as follows: at each time of ME operation SEEMS collects data from sensors in “on-line” mode and transfers to the model. Based on the “real” data coming from ME the module calculates current burning process for each ME cylinder. As a result of comparing processes built by (1) “real data”, (2) collected statistical data and (3) “modeled” data, the module can identify those parameters which caused to difference and provide the operator with corresponding conclusions. When the mismatched parameters are identified, the visual and audible alarm is generated by a special diagnostic algorithms based on model and statistical data (previously collected by SEEMS).

As a result of module operation the following components and sub-systems can be checked:

- Turbocharger;
- Fuel injection equipment;
- Exhaust system.

The economic efficiency from the use of the module is based on detection of the faults during engine operation at early stages of defect, which may increase engine life by 10-25%.
FMOS economy effect

Raising efficiency from the use of FMOS modules is ensured both onboard and in the office!

The economic effect is assessed by quantitative and qualitative criteria:

- The total fuel saving from the use of ALL FMOS modules and measures prescribed by SEEMP may attain ~4% (by INTERTANKO), while according to other sources it may reach 10%.

- The additional economic efficiency is achieved from the use of SEEMS VEA function through working out the recommendations of organizational and technical solutions upon analyzing the ship’s voyages performed (useful also in accordance with ISO: 9001).
FMOS benefits

To company’s management:

• Effective FLEET MONITORING instrument as “superstructure” to existing Company Management System (including possible integration with finance system)

• Automated processes analysis on “top level”:
  ✓ Fuel consumption
  ✓ Ship’s repairs and servicing
  ✓ Ship’s operation assessment

• The use of the System during certification under ISO:9001 and SEEMP requirements
For Charterer:

- Efficient tool to monitor cargo transportation conditions
- Technical support to the contractual obligations between the Ship owner and the Charterer in respect of fuel consumption (working out rules and normative based on statistical data)
- The use of the System during certification
FMOS benefits

To company’s technical management (group engineers, superintendants):

• Effective fleet TECHNICAL MONITORING instrument (using also mobile facilities, e.g. I-pad) in following aspects:
  ✓ Bunkering logistics
  ✓ Unexpected fuel consumption increase detection
  ✓ Fuel consumption rates determination/monitoring for different ships and conditions
  ✓ Fuel consumption optimization (analysis based on statistical data)

• Automated ship’s equipment technical supervision:
  ✓ Equipment diagnostic (based on long-term statistical data recorded with high discreteness)
  ✓ Servicing quality comparative assessment (analysis of service companies, suppliers and spare parts used, servicing performed by ship’s crew)
  ✓ Working out the proposals on optimization and innovations

• Quantitative assessment of technical and organization solutions applied
FMOS benefits

To ship’s crew:

- Decreasing internal company’s reporting with regard to fuel consumption and equipment operation (due to appropriate reporting forms development and implementation)

- Efficient tool for grounding innovative ideas as well as for qualitative description of problems (if any)

- Instrument for equipment operation analysis and diagnostics (based on long-term statistical information and mathematical modelling)