Alternative approaches to monitoring - 'Digital Twin' of vessel performance -

24th March 2017

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MTI, NYK Group
Outline

1. Introduction of NYK/MTI
2. IoT and Big data in NYK
3. Digital Twin
4. Digital Twin of vessel performance
5. Summary
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NYK Corporate Profile

• NYK Line (Nippon Yusen Kaisha)
• Head Office: Tokyo, Japan
• Founded: September 29, 1885
• Business Scope:
  – Liner (Container) Service
  – Tramp and Specialized Carrier Services
  – Tankers and Gas Carrier Services
  – Logistics Service
  – Terminal and Harbor Transport Services
  – Air Cargo Transport Service
  – Cruise Ship Service
  – Offshore Service
• Employees: 34,270 (as of the end of March 2016)
• Revenues: $ 22.7 billion (Fiscal 2015)
NYK Fleet (as of the end of March 2016)

Containerships (including semi-containerships and others)
99 vessels / 5,820,781 DWT

Bulk Carriers (Capesize)
108 vessels / 21,248,606 DWT

Bulk Carriers (Panamax & Handysize)
269 vessels / 16,411,393 DWT

Wood-chip Carriers
47 vessels / 2,509,047 DWT

Cruise Ships
1 Vessel / 7,548 DWT

Car Carriers
119 vessels / 2,165,138 DWT

Tankers
68 vessels / 11,030,601 DWT

LNG Carriers
29 vessels / 2,176,681 DWT

Others
42 vessels / 695,974 DWT

782 vessels
62,065,769 Kt (DWT)
MTI (Monohakobi Technology Institute) - strategic R&D arm of NYK Line -


- Established: April 1, 2004
- Stockholder: NYK Line (100%)
- Number of employees: 62 (as of 1st April, 2016)
- Location
  - Head Office: 7th Fl., Yusen Building, Tokyo, Japan
  - MTI CO., LTD. SINGAPORE BRANCH, Singapore
  - MTI YOKOHAMA LAB (Transportation Environment Lab), Yokohama, Japan

NYK SUPER ECO SHIP 2030 (Concept ship for the future 69% less CO2 emissions)
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“Operation Technology (OT)” and “Information Technology (IT)” are to be bridged. The era of “transparency” where user can access the field data.

* PLC: Programmable Logic Controller
**IoT platform of NYK**

**SIMS (Ship Information Management System)**

- **Sat Com (VSAT, FBB)**
- **Onboard dashboard**
- **Motion sensor**
- **Data Acquisition and Processing**
- **SIMS unit (IoT gateway)**

**SIMS Monitoring & Analysis at Shore**
- **Operation (Tokyo, Singapore ...)**
- **Analysis report**
- **Shore Dashboard**
  - For operation
  - For ship manager

**Big data analysis**
- Operational efficiency
- Performance
- Engine & plant condition

**SIMS Data Collection Onboard**
- GPS
- Doppler log
- Anemometer
- Gyro Compass

**<Navigation Bridge>**
- VDR

**<Engine Room & Cargo>**
- Main Engine
- Power plant
- Cargo control
- Auxiliary machineries

**Sample Diagram**

**Technical Analysis (NYK, MTI)**

**Data Center**

**Operational scenario**

- SIMS IoT data + SPAS manual data

**Integrated Automation System**

- For operation
- For ship manager

**Onboard dashboard**

**Motion sensor**

**SIMS unit (IoT gateway)**

**Sat Com (VSAT, FBB)**

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### Potentials of utilizing IoT and Big data in shipping

<table>
<thead>
<tr>
<th>Role</th>
<th>Function</th>
<th>Example applications</th>
</tr>
</thead>
</table>
| Ship owner   | Technical management | • Safety operation  
                |                           • Condition monitoring & maintenance 
                |                           • Environmental regulation compliance  
                |                           • Hull & propeller cleaning  
                |                           • Retrofit & modification |
|              | New building      | • Design optimization                                                    |
| Ship operator| Operation         | • Energy saving operation  
                |                           • Safe operation  
                |                           • Schedule management |
|              | Fleet planning    | • Fleet planning  
                |                           • Service planning  
                |                           • Chartering |

Other partners in value chains, such as cargo owners, shipyards, equipment manufacturers, and class societies, have also interests in ship IoT data to improve their operational efficiency.
Energy saving hull modification

Operational profile
- Speed, RPM, Power
- Draft, trim, displacement
- Weather
- Sea margin
- Etc.

Energy saving modification
- Bulbous bow modification
- Install energy saving device (MT-FAST)
- Etc.

23 % CO2 reduction was confirmed
Utilize IoT in shipping

Target
• Prevent unpredicted downtime (owner)
• Reduce maintenance cost (owner)
• Energy efficiency in operation (operator)

Measure
• Condition monitoring
• Big data analysis
• Support service engineer
• Intelligent machinery
  – Self diagnostics

Change way of working!
NYK/MTI’s R&D activities for digitalization
- Open collaboration with industry partners -

- **Collision avoidance and autonomous ship**
- **Simulation of LNG cargo transport**
- **Cargo crane condition monitoring**
- **Multi-layered Doppler log**
- **Structural Health Monitoring**
- **Damage prevention of engine-power plant**
- **Propulsive efficiency monitoring**

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**i-Shipping: Japanese government funding projects Ship IoT for safety (2016-2020)**
Open platform for maritime industry

Onboard application
- Weather routing
- Performance monitoring
- Engine maintenance
- Plant operation optimization

Onboard data server

Data Center

Data center (operated by neutral body)

Asia

Europe

Security / access control

Weather routing

Engine monitoring

Energy management

Remote maintenance

Marketing and Big data analytics

Application / services (Competition)

Shore Service Provider

Performance monitoring

Weather routing

Engine monitoring

Remote maintenance

Marketing and Big data analytics

User

Ship operator

Ship owner

Ship Management company

Class Society

Shipyard

Engine maker

Ship equipment maker

Shipyard

Engine maker

Security / access control

Data center (operated by neutral body)

Europe

Asia

Request

Data

broadband

LAN

Ship

M/E

D/G

Boiler T/G...

VDR

Radar

ECDIS

BMS

Cargo crane

Onboard application

Onboard data server

Software agent

IoT Open platform (Industry standard)
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Engineering knowledge, simulations and tools have been used for design and production.

- Designers and engineers consider life cycle value of products
  - Manufacturability, usability, maintainability, disposability ...

```
Design       Build       Operation       Dispose
CAD, CAE     CAM         Engineering knowledge
Engineering knowledge
```

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Monohakobi Technology Institute
Era of IoT:
Engineering knowledge, simulations and tools are now demanded through life cycle of products

- Designers and engineers may provide engineering services to support operations
- IoT allow designers and engineers to access field data
- Operational efficiency will be improved by integrating existing good culture and engineering knowledge.
Digital Twin
An approach of Product Lifecycle Management (PLM) to extend computer-based engineering capabilities to operations

Reference)
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Ship performance in service

6000TEU Container Ship
Wave height 5.5m, Wind speed 20m/s
BF scale 8, Head sea @ Trans-Pacific (Oakland, US – Tokyo, JP)

@ engine rev. 55rpm

<Calm sea performance>
speed: 14 knot
FOC*: 45 ton/day
* FOC: Fuel Oil Consumption

<Rough sea(BF8) performance>
speed: 8 knot
FOC: 60 ton/day

Effecting factors
1. Weather (wind, wave and current), 2. Ship design (hull, propeller, engine), 3. Ship condition (draft, trim, cleanliness of hull and propeller, aging effect)
Model of vessel performance in service

1. **Long term analysis**
   - Degradation of hull and propeller

2. **Draft and trim effect**
   - Tank test, CFD or estimation from IoT measurement data

3. **Wind and wave effect**
   - Theoretical calculation
Continuous model to represent discrete performance data – draft and trim

Extend 3-dimensional B-spline volume to multi-dimensional volume to represent continuous data (Joint research with AIST)
Theoretical estimation of wind and wave effect (Joint research with NMRI)

Considered forces and moments
1. Resistance in still water
2. Hydrodynamic forces and moments
3. Propeller thrust
4. Rudder forces and moment
5. Wind resistance
6. Added resistance in short crested irregular waves

In-service ship performance model

<Target vessel>
6000TEU Container
Draft 12m even

Sea condition
Beaufort scale

<table>
<thead>
<tr>
<th>Beaufort</th>
<th>wind speed (m/s)</th>
<th>wave height (m)</th>
<th>wave period (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>4.5</td>
<td>0.6</td>
<td>3.0</td>
</tr>
<tr>
<td>BF4</td>
<td>6.8</td>
<td>1.0</td>
<td>3.9</td>
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<tr>
<td>BF9</td>
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0deg (wind, wave) – head sea

Wind and wave effect
Base line performance
An example of model validation

6000TEU 2012/3/21 - 4/1
Voyage: OAKLAND-TOKYO

Accuracy of vessel performance model was confirmed.

Total FOC in voyage
Actual: 961 MT
Calculation: 969 MT
Sea margin estimation
- Example of LNG carrier -

Service route

Ship performance model

Voyage simulation with past weather data

Estimation of
- Sea margin
- FOC and etc.

Combine ship performance model with weather data to optimize ship services
Sea margin estimation
- Example of cape size bulk carrier -

Simulation results show conventional sea margins are much larger than required for some routes.
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Flow of vessel performance analysis and usage

The future challenge would be how to feedback these knowledge and experience to ship design.
Thank you very much for your attention