Condition base maintenance for marine propulsion plant, CMAXS program

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1. Remote monitoring
“Remote Monitoring”

• What do we expect?
• What is the value?
Concept of CMAXS LC-A

Remote operation

Remote monitoring → Information sharing → Deeper & wider analysis by specialist

Remote operation → Remote monitoring

On board

• Measurement
• Observation

Automatic anomaly detection → Automatic diagnosis → Preventive maintenance

Automatic anomaly detection → Automatic trouble shooting support

Automatic diagnosis → Dynamic maintenance planning

Dynamic maintenance planning → Maintenance work support

Maintenance work support → Remote maintenance work (Remote control robot etc.)

Information sharing

Deeper & wider analysis by specialist

Update

Feedback

Remote operation

Algorism, parameter and contents

On board

Information sharing

Deeper & wider analysis by specialist

Feedback

Remote operation

Algorism, parameter and contents
2. Applicability of ‘Machine learning analysis’
Applicability of “Machine learning analysis”

Typical success area of “Machine learning analysis”

Point of sales system

Reference data
- Weather
- Price
- Gender, generation
- Goods

Target data to maximize
- Total payment
- Benefit

All data is in one package.

“Reference data” volume = “Target data” volume

“Machine learning analysis” can be applied, directly.
Applicability of “Machine learning analysis”

Field of condition diagnosis

Reference data
- Temperature
- Pressure
- Vibration
- Speed
- Weather

Target phenomenon to minimize

Incident

Big data
“Reference data” volume

Small data
“Target data” volume

“Machine learning analysis” can not be applied, directly!

We need different approach.
Applicability of “Machine learning analysis”

Reference data

Big data

Temperature  Pressure  Vibration  Speed  Weather

Target phenomenon to minimize

Incident

Big data analysis

(Machine learning, engineering know-how etc.)

Algorisms which is established by engineering theory, know-how, design concept etc.

“Condition Index” which indicates phenomenon
3. Concept of CMAXS LC-A

- Anomaly detection
- Condition diagnosis
- Trouble shooting
- Maintenance management support
Flow of diagnosis in CMAXS LC-A

Measurement data

Machine learning algorithm
- Anomaly index
- Regression method
- Matrix method

Know-how base algorithm
- Anomaly index

Anomaly detection
Condition Diagnosis

Safety operation
Preventive maintenance
Condition based maintenance
Trouble shooting
Optimum setting
Others

Higher value
Ex.1) Know-how base (example : 2-D mapping)

1. Two dimension map with green zone is prepared according to test result, experience, engineering theory, etc. Items for each axis can be selected from measured items according to know-how etc.
2. Measured data which is normalized are plotted, automatically.

Position in the green zone is plotted on trend graph.

Anomaly Index
It is calculated by the position on the upper and lower range. The position and anomaly index is according to preset parameter.

To condition diagnosis algorism
Ex.2) Know-how base (example: Deviation analysis)

Each green zone are defined according to load and cylinder position. So, the analysis is same as 3D map analysis.

Current data

Temperature

Green zone is not same, because it depends on position of T/C arrangement etc.

Position

Running hour

Anomaly Index

It is calculated by the position on the upper and lower range. The position and anomaly index is according to preset parameter.

To condition diagnosis algorism
Ex.4) Machine learning algorism

CMAXS LC-A applies IBM ANACONDA. It is machine learning algorism according to correlation anomaly. Wider analysis can be done easily.

Anomaly score

The score is plotted on trend graph with certain range.

Running hour

Anomaly Index

It is calculated by the position on the upper and lower range. The position and anomaly index is according to preset parameter.

To condition diagnosis algorism
The algorism and parameters are established by engineering theory, experience, design concept etc. by maker’s engineer.

When did the phenomenon start?

When does the condition reach to alarm level?

This example is condition diagnosis for air turbo charging.
Alarm from AMS
Alarm monitoring system

Anomaly Index

Condition Index
The algorism and parameters are established by engineering theory, experience, design concept etc. by maker’s engineer.

Trouble shooting function

Parts and phenomenon are automatically listed up which is estimated cause of incident. The order is according to higher possibility.

It indicates location and picture of selected one.

It shows the working procedure how to check and how to recover with many pictures. Instruction manual also linked to selected one.

The algorism and parameters are established by engineering theory, experience, design concept etc. by maker’s engineer.
- Measured record at maintenance is very important data for diagnose, and the data is applied to automatic diagnosis function.
- Recommended maintenance period can be dynamic according to diagnosis result in future.
4. Value of condition diagnosis
Value of condition diagnosis

Incident

Finding causes → Repair works → Increase FO consumption

Increase speed

Minimization of additional cost by sudden accident!

Avoidance of accident by condition diagnosis

Minimization of probability of sudden accident

Minimization of damage by preventing secondary damage

Minimization of recovering time and cost

Trouble shooting function supports quick and secure recovery.

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Maximization of parts lifetime

Earlier detection and quick recovering of condition is directly related to lifetime of parts.

For example
The lifetime is strongly related to accumulation of thermal history, especially on hot parts.
Minimization of operating cost

Continuous condition diagnosis

Each margin against unknown factors can be minimized.

CMAXS LC-A show the recommendation setting parameters according to many parameter and analyzed result.

Ex.1) **Cylinder pressure** according to CMAXS LC-A’s recommendation

Fuel Command
About 0.41% reduced through all load

<table>
<thead>
<tr>
<th></th>
<th>25%</th>
<th>50%</th>
<th>85%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOC reduction</td>
<td>△1.7%</td>
<td>△1.1%</td>
<td>△0.8%</td>
<td>△0.7%</td>
</tr>
</tbody>
</table>

Ex.2) **Cylinder oil feed rate** according to CMAXS LC-A’s recommendation

Condition of piston running behavior
Good

Cylinder oil feed rate
13% Reduction

**Scav. temperature** according to CMAXS LC-A’s recommendation

We expects about 1% FOC reduction by 10 degreeC lower scav. Temperature.
Minimization of lifecycle cost

Condition diagnosis

- Good
  - Minimization of operation cost
    - Optimization of maintenance interval
    - Optimization of operation settings
  - Optimization of operating condition
    - Reduction of operating load
    - Maintenance work will be done at earlier timing

- Not good
  - Prevention of secondary damage and severe incident.
  - Maximization of lifetime

Minimization of life cycle cost
5. CMAXS LC-A program
CMAKS LC-A program

**Vessel A**
- Machinery A
- Machinery B
- Machinery C

**CMAKS LC-A**
- Condition diagnosis
- Abnormality detection
- Trouble shooting
- Maintenance Plan

**Vessel B**
- Machinery A
- Machinery D
- Machinery E

**CMAKS LC-A**
- Condition diagnosis
- Abnormality detection
- Trouble shooting
- Maintenance Plan

**DATA BASE**
(Operated by NKCS)

**Ship owner**
Ship management company

**Support by each maker’s engineer**

- Machinery A maker
- Machinery B maker
- Machinery C maker
- Machinery D maker

- Established customer support scheme by each maker
- Provided high quality support
CMAXS LC-A program

History of CMAXS LC-A

2010 : LC-A was developed by DIESEL UNITED, LTD. and installed for field test.

2011 : LC-A was released from DIESEL UNITED, LTD. officially.

2013 : Integrated IBM ANACONDA to LC-A under ClassNK’s strong support. Then it evolved to CMAXS LC-A and start field testing on eight vessels.

2015 : All systems for CMAXS LC-A program is prepared, and it launched.

• We have more than 5 years experiences.

• More than 30 vessels apply the system, already.
CMAXS LC-A program

Evolution cycle

Install, update
CMAXS LC-A

Evolution

Experience

User’s benefit

Make it to

Artificial intelligence
6. Sensors from now
Sensors from now

Additional information will accelerate the cycle.

Sensors
Measurement point and item will increase.

Install, update
CMAKS LC-A

Evolution

Experience

User benefit

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Example of valuable sensor (TF-Detector)

On line type “TF-Detector“ can measure iron powder contents with high resolution. When “TF-Detector” apply to cylinder drain oil monitoring, piston ring sliding condition can be monitored continuously.

TF-Detector is co-developed by DIESEL UNITED and MEIYO Electric.
Example of valuable sensor (TF-Detector)

Iron powder consistency directly related piston ring sliding condition. Other monitoring methods cannot be indicated so clearly, even if big data analysis algorithms are applied.

It is very interesting data for engineers. But it is not enough for users.

We have to show schemes to produce additional benefits for users.

Seizure started from this time.

Periodical drain out
Example of visualization

The diagnosis should apply not only numeric data but also visual data.
7. Conclusion
1. We have established total support system by combination of machine learning and engineering know-how with unique approach.

2. CMAXS’s scheme drives continuous evolution of algorism, parameter and contents with every parties.

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Thank you for your attention.