Predictive Maintenance Using Diagnostic System for Work Vessel Equipment

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Background of Development

Issue of Work vessel

➢ Aging work vessel ( decrepit work vessel )
➢ Increase maintenance costs
➢ Increased risk of serious trouble

Diagnostic System For Work Vessel Equipment
(System to monitor the bearing and the gear)

Predict the exact repair timing !!
Reduction of maintenance cost !!
Prevention of equipment accident !!
Predict the replacement timing !!
Characteristics of Work Vessels

Main equipment of work vessel

- Cutter suction dredger
- Floating crane
- Grab dredger
- Cement deep mixing barge
- Sand compaction pile barge
- Remotely operated vehicle
- Pneumatic soil transfer vessel
- Dredge pump
- Spud system
- Lifting winch
- Lifting winch
Characteristics of Work Vessels

Trouble case - 1

- Abnormal wear of gear

<table>
<thead>
<tr>
<th>Type</th>
<th>Cutter Suction Dredger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>Ladder Lifting Winch</td>
</tr>
<tr>
<td>Damaged parts</td>
<td>The Sun gear of the planetary reduction gears</td>
</tr>
<tr>
<td>Material</td>
<td>SCM21</td>
</tr>
<tr>
<td></td>
<td>(Chromium molybdenum steel)</td>
</tr>
</tbody>
</table>
Characteristics of Work Vessels

Trouble case - 2

Broken gear

- Type: Cement deep mixing barge
- Equipment: Lifting Winch
- Damaged parts: Pinion gear of winch drive shaft
- Material: S45C (Carbon steel)
Predictive Maintenance Technique

Predictive Maintenance of Rotary Machines by Vibration Measurement

- General measurement item
  - Vibration, noise, temperature, distortion

<table>
<thead>
<tr>
<th>Mode</th>
<th>Unit</th>
<th>Frequency band</th>
<th>Feature of abnormality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement (DISP)</td>
<td>μ</td>
<td>0~10Hz</td>
<td>Mild vibration of structure</td>
</tr>
<tr>
<td>Velocity (VEL)</td>
<td>cm/s</td>
<td>10Hz~1kHz</td>
<td>Imbalance, misalignment, faulty foundation, backlash, loosening of foundation bolt, heavy damage to antifriction bearing</td>
</tr>
<tr>
<td>Acceleration (ACC)</td>
<td>G</td>
<td>Above1kHz</td>
<td>Damage to antifriction bearing, faulty lubrication, damage to gear</td>
</tr>
</tbody>
</table>

Simple diagnosis ➔ Abnormal sign ➔ Precise diagnosis
Predictive Maintenance Technique

Predictive Maintenance of Rotary Machines by Vibration Measurement

- **Simplified diagnosis**
  - Compared with the reference value of the vibration level

- The relative determination method
- The mutual determination method
- The absolute determination method

Using determination method two or more
Predictive Maintenance Technique

Predictive Maintenance of Rotary Machines by Vibration Measurement

- Precise diagnosis
  - Analyze the periodicity in the vibration
  - The estimated cause and location of damage

- Analyzed using the FFT
- To evaluate the spectrum
Predictive Maintenance Technique

Introduction to the work vessel

Points to be noted

➢ Large winch of work vessel
  - Low-speed (10 rpm below)
  - Collision energy of damage is small
  - High noise

Vibration measurement is not suitable

- Introduction of AE (Acoustic Emission) measurement
- Can measure the bearing of 150 rpm or less
Predictive Maintenance Technique

Predictive Maintenance of Rotary Machine by AE Measurement

- **Principle of Acoustic Emission (AE)**

  - Detector: AE sensor
  - Elastic wave (AE) emission
  - Progress of crack

- Detecting of elastic wave by AE sensor
- Evaluating the fracture process of the material
Predictive Maintenance Technique

Predictive Maintenance of Rotary Machine by AE Measurement

- Typical diagnostic parameter: E_area

- Measurement results of damaged bearing
- Measurement results of normal bearing

- Amplitude of AE signal
- Most frequency amplitude
- Asymmetric Frequency distribution of amplitude (E_area)

- To quantify asymmetric distribution
- Comparing the normal value and E_area
Predictive Maintenance Technique

Predictive Maintenance of Rotary Machine by AE Measurement

- Typical diagnostic parameter: E_ratio

1. Average Amplitude
2. Setting The Detection Level
3. AE Amplitude more than the set detection level (Noise)

- Ratio of AE amplitude more than the set detection level
Predictive Maintenance Technique

AE Measurement

Diagnostic parameter

➢ ① E_area : To quantify the asymmetric frequency distribution of amplitude.

➢ ② E_ratio : Ratio per revolution of AE amplitude of more than a setting the detection level

➢ ③ E_peak : Maximum AE amplitude per revolution

➢ ④ E_ave : Average amplitude per revolution

➢ ⑤ Peak : Maximum amplitude per revolution

➢ ⑥ Ave : Average of AE amplitude that omitted the part deviates from the normal waveform.
Introduction of Predictive Maintenance Technique to AJIA MARU No.3

Outline of ASIA MARU No.3

- Cutter suction dredger

<table>
<thead>
<tr>
<th>Principal particulars</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of build</td>
<td>1979</td>
</tr>
<tr>
<td>Length</td>
<td>78.0m</td>
</tr>
<tr>
<td>Breadth</td>
<td>19.5m</td>
</tr>
<tr>
<td>Depth</td>
<td>5.5m</td>
</tr>
<tr>
<td>Draft</td>
<td>4.1m</td>
</tr>
<tr>
<td>Fully equipped engine output</td>
<td>10,830kW</td>
</tr>
<tr>
<td>Dredging pump output</td>
<td>5,880kW</td>
</tr>
</tbody>
</table>
Introduction of Predictive Maintenance Technique to ASIA MARU No.3

Measurement points

- Total of 48 points

Equipment:
- Ladder lifting winch
- Ladder Swing winch
- Spud winch
- Stern winch

Bearing:
- Electric motor
  (gear)
- Reducer
- Pinion
- Winch drum

Vibration: 15 points
AE: 33 points
Introduction of Predictive Maintenance Technique to ASIA MARU No.3

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Introduction of Predictive Maintenance Technique to ASIA MARU No.3

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Introduction of Predictive Maintenance Technique to ASIA MARU No.3

Measuring instruments

- **Vibration meter**
  
  Manufacturer: JFE Advantech Co., Ltd.
  
  Model: MK-210HE II
  
  Characteristic: Trend management, Deterioration prediction, FFT

- **AE meter (Slow rotating bearing diagnosis instrument)**
  
  Manufacturer: JFE Advantech Co., Ltd.
  
  Model: MK-560
  
  Characteristic: $E_{area}$, $E_{ratio}$, $E_{peak}$, $E_{ave}$
Introduction of Predictive Maintenance Technique to ASIA MARU No.3

Result of measurement

- Example of vibration measurement result
  (Port swing winch reduction map)
  ➢ Damage were not observed
Introduction of Predictive Maintenance Technique to ASIA MARU No.3

Result of measurement

- Example of AE measurement result (Port spud drum bearing)
  - $E_{\text{area}}$ and $E_{\text{ratio}}$ were found normal
  - Signal without periodicity was observed in the AE waveform
  - It seems not due to damage.
Plans for future

➢ Continue the data acquisition

➢ Introduction of remote automatic measurement by the online system

➢ Introduction of fatigue degradation monitoring technology by distortion measurement

To plan further improvement of the maintenance efficiency
Thank you for your attention.
Predictive Maintenance Technique

Predictive Maintenance of Rotary Machines by Vibration Measurement

- **Simplified diagnosis**
  - Compared with the reference value of the vibration level

- **Determination method**
  - ① The relative determination method
    ⇒ Trend management
  - ② The absolute determination method
    ⇒ Absolute value determination (ISO or Maker's own)
  - ③ The mutual determination method
    ⇒ Comparison between the same type machine

Using determination method two or more
Introduction of Predictive Maintenance Technique to ASIA MARU No.3

Introduction costs

- **Purchase cost of instrument**
  - Vibration measuring instrument (including client software)
  - AE measuring instrument

- **Cost of system introduction**
  - Installation work for measurement pickup base
  - Software production (AE data analysis tool for PC)
  - Work of data entry
  - Guidance system introduced
Introduction of Predictive Maintenance Technique to ASIA MARU No.3

Result of measurement

Example of AE measurement result (Port spud drum bearing)

- $E_{\text{area}}$ and $E_{\text{ratio}}$ were found normal
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