Super Eco Inland Vessels
Line –Shaft Contra Rotating Propellers with Diesel Electric Propulsion System

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Manager
Ecological Engineering
IHI Marine United Inc.
IHIMU is promoting Contra Rotating Propeller combined with Diesel Electric System to the Inland Vessels.

- IHIMU have delivered 14 vessels with CRP combined with diesel electric system.
- CRP efficiency of 10% is expected.
- Additional fuel saving by diesel electric system is expected.
What is In-line Contra Rotating Propeller (CRP) system?
Principle of Contra Rotating Propeller

**Single Propeller**

Rotational stream energy after propeller doesn’t work for propulsion

**CRP**

Rotational stream energy is recovered by aft propeller

**Improve 10% Efficiency**

Rotational stream energy after propeller doesn’t work for propulsion

Rotational stream energy is recovered by aft propeller
## CRP Application

<table>
<thead>
<tr>
<th>Environmental Footprint Fuel</th>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO2 $\Delta$ 10%</td>
<td>CO2 $\Delta$ 20 $\sim$ 30%</td>
</tr>
<tr>
<td></td>
<td>NOx $\Delta$ 10%</td>
<td>NOx $\Delta$ 90%</td>
</tr>
<tr>
<td></td>
<td>EN590</td>
<td>PM $\Delta$ 90%</td>
</tr>
</tbody>
</table>

**Convert**

LNG

Displace the generator engines to gas engines. Constant speed engine is more reliable for gas fuelled

**Driven by**

Two electric motors

Displace the main engine to gas engines.

**or**

Displace the main engine to gas engines.

**Driven by**

One diesel engine

No engine displacement. Further investment for gas engine is necessary in case direct coupling with FPP

**Twin Drive for Diesel Electric System**

Delivered 14 vessels

**Single Drive for Mechanical System**

Delivered 3 vessels

**Environmental Footprint**

**Current**

- CO2 $\Delta$ 10%
- NOx $\Delta$ 10%
- EN590

**Future**

- CO2 $\Delta$ 20 $\sim$ 30%
- NOx $\Delta$ 90%
- PM $\Delta$ 90%

**Drive**

- Diesel Engine
- Dual Fuel Engine

**Delivered**

- 14 vessels
- 3 vessels
Inline Contra Rotating Propeller

Inner prop. shaft→drive to aft propeller
Outer prop. shaft→drive to fwd propeller

Contra Rotating Gear
(Parallel Shaft Type Reduction Gear)

Electric Motor
(2sets)
### Reference of similar size

<table>
<thead>
<tr>
<th></th>
<th>Nadeshiko-Maru</th>
<th>Kokuho-Maru</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name</strong></td>
<td>Nadeshiko-Maru</td>
<td>Kokuho-Maru</td>
</tr>
<tr>
<td><strong>L × B × D</strong></td>
<td>69.95x11.5x5.25m</td>
<td>76.9x12.2x5.80m</td>
</tr>
<tr>
<td><strong>Cargo Volume</strong></td>
<td>abt. 2,200m³ Product</td>
<td>abt. 2,500m³ Chemical</td>
</tr>
<tr>
<td><strong>Service Speed</strong></td>
<td>12.0kt</td>
<td>13.0kt</td>
</tr>
<tr>
<td><strong>Propulsion Motors</strong></td>
<td>600KW × 2sets (Inverter)</td>
<td>745KW × 2sets (Inverter)</td>
</tr>
<tr>
<td><strong>Main Generators</strong></td>
<td>410KW × 4sets</td>
<td>700KW × 3sets</td>
</tr>
</tbody>
</table>

**Super Eco Ships in Japan**

CRP with Diesel Electric
Application to Inland Navigation
110m size Chemical Tanker

Aft machinery room

Conventional space is enough

Nozzle is applicable for low speed operation
This tank test was carried out to confirm the CRP efficiency with nozzle using the existing CRP for coastal vessel, which is not optimized for duct application.
Tank Test Result - Shallow water & Nozzle -

Efficiency of CRP and nozzle is not influenced by shallow water.

Performance of the nozzle propeller can be predicted by the present design tool accurately.
Benefits of Super Eco Inland Vessel (SEIV)

Why CRP with Diesel Electric Propulsion System?
Comparison with conventional plant
Plant Comparison with conventional Single Shaft

Conventional

Total Diesel Engine Power; 2,360kW
5 Types of Engine

Total Diesel Engine Power; 1,720kW
Only 1 Type of Engine
(27% less power and unified engine type saves initial and maintenance cost)

CRP+DE

1,350kW x 1200 rpm
Plant Comparison with conventional Single Shaft

For Environmental Economy

• Less FO Consumption by CRP with power management
• Less Emission (NOx, CO2, SOx, PM) by Less SFC

Total Diesel Engine Power; 2,360kW
5 Types of Engine

Total Diesel Engine Power; 1,720kW
Only 1 Type of Engine
(27% less power and unified engine type saves initial and maintenance cost)

CRP+DE

For Environmental Economy

60kW x 1800rpm

100kW x 1800rpm

175kW x 1800rpm

2,360kW

1350kW x 1200 rpm

400kW x 1800rpm X 4 sets

500kW

Bow Thruster

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For Environmental Economy

- **Less FO Consumption**
  by CRP with power management
- **Less Emission(NOx, CO2, SOx,PM)**
  by Less SFC

**Total Diesel Engine Power; 2,360kW**

5 Types of Engine

**Total Diesel Engine Power; 1,720kW**

Only 1 Type of Engine

(27% less power and unified engine type saves initial and maintenance cost)

For Safety

- **Higher Redundancy**
  by DE(Power Plant)+ CRP(Propellers)
- **Better Maneuverability**
  by Rich Torque Operation at Low Speed+Bigger Thrusters
- **Flexible Arrangement**
  for reliability by multi location

Plant Comparison with conventional Single Shaft
Why Diesel Electric for Inland Vessels?

110m Chemical Tanker

- **Torque Rich** operation At Shallow Water
- **Min Low Load** operation For over speed
- **Cargo Pump** operation
- Rotterdam
- Ludwigshafen

Source: Inland Navigation Europe
## Operation

<table>
<thead>
<tr>
<th></th>
<th>Mechanical</th>
<th>Diesel Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Going Up Stream</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Navigation</strong></td>
<td>No control</td>
<td>Power Management</td>
</tr>
<tr>
<td><strong>Shallow water</strong></td>
<td>Poor Torque</td>
<td>Rich Torque</td>
</tr>
<tr>
<td><strong>Cargo Handling</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pump operation</strong></td>
<td>Load Control</td>
<td>Inverter Control</td>
</tr>
<tr>
<td><strong>Going Down Stream</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Min. load operation</strong></td>
<td>30%</td>
<td>10%</td>
</tr>
</tbody>
</table>

### Diesel Electric
Keep good fuel consumption to control no. of running D/G
### FOC Simulation for example

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Navigation</th>
<th>Maneuvering</th>
<th>Total (1round trip)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Up Stream</td>
<td>Down Stream</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal</td>
<td>T. Rich</td>
<td></td>
</tr>
<tr>
<td><strong>Mechanical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Engine</td>
<td>kW</td>
<td>1350 (90%)</td>
<td>750 (50%)</td>
<td>450 (30%)</td>
</tr>
<tr>
<td>SFCR</td>
<td>g/kWh</td>
<td>203</td>
<td>255</td>
<td>222</td>
</tr>
<tr>
<td>Time</td>
<td>Hr</td>
<td>41</td>
<td>29</td>
<td>70</td>
</tr>
<tr>
<td>FO Cons</td>
<td>ton</td>
<td>11.2</td>
<td>5.5</td>
<td>7.0</td>
</tr>
<tr>
<td><strong>CRP + Diesel Electric</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/G Engine</td>
<td>kW</td>
<td>1276 (90%)</td>
<td>567 (50%)</td>
<td>284 (20%)</td>
</tr>
<tr>
<td>SFCR</td>
<td>g/kWh(e)</td>
<td>225</td>
<td>226</td>
<td>226</td>
</tr>
<tr>
<td>Time</td>
<td>Hr</td>
<td>41</td>
<td>29</td>
<td>70</td>
</tr>
<tr>
<td>FO Cons</td>
<td>ton</td>
<td>11.8</td>
<td>3.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>

- CRP efficiency: 10%
- Energy loss (Inverter-Motor): 5%  

\[ \Delta 16.5\% \]
Evaluation
Bunker Price

Rotterdam MGO Price & BWI

SOURCE: Bunkerworld
Bunker Price

Current EN590 (Sulfur <10ppm) Price

750〜950EUR/ton

- Fuel Consumption: 860 ton / year
- Fuel Cost: 645,000〜817,000 EUR / year

Fuel Cost Saving by CRP
64,500〜81,700 EUR / year

In case of 110m Chemical Tanker

SOURCE: Bunkerworld
Pay Back Calculation

Pay back time = \frac{(CRP \text{ price} - \text{Initial saving} - \text{subsidy})}{(\text{Fuel saving cost})}

CRP efficiency : 10%

Assuming 10% of investment cost is covered by subsidy.
### Cash flow for 110m class

#### Annual cost

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Tanker</th>
<th>Dry Cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>Base</td>
<td>Base</td>
</tr>
<tr>
<td></td>
<td>DE CRP</td>
<td>ME CRP</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>+11%</td>
<td>+10%</td>
</tr>
<tr>
<td>Labor</td>
<td>Same condition</td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>+11%</td>
<td>+10%</td>
</tr>
<tr>
<td>Other</td>
<td>Same condition</td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>-(10+α)%</td>
<td>-10%</td>
</tr>
<tr>
<td></td>
<td>-10%</td>
<td>-10%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>&lt;97.9%</td>
<td>97.9%</td>
</tr>
<tr>
<td>NPV[MEUR]</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>For 20yrs</td>
<td>1.0&lt;</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

#### Conditions:
- Fuel Price: 750 EUR/ton
- With subsidy (10%)
Return on Investment

Corporate Social Responsibility Appeals

Less Environmental Footprint
Higher Safety
Higher Redundancy

Investment

- Less footprint
- Fund condition
- Insurance
- Advertisement
- Better charter condition

Direct Cost Saving

Return

Risk Hedge

- Offset Cost from conventional vessel
- Carbon Tax
  - Crew
    - Fuel
    - Lub.
    - Maintenance
- Shafting System
  - Main Engine
  - D/G Sets
- CRP
  - For Diesel Electric

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Business Paradigm Shift

Economy Business

New Market Fundamentalism

Green Economy Modal Shift

Issues

Earth Warming, Low Carbonize
Growth of Developing Countries (Energy/Foods)

Mechanism

Carbon Tax, Cap & Trade
ISO 26000 (Social Responsibility)

Competence Competitiveness

Reduce CO2 Emissions
Corporate Social Responsibility
Conclusion

• IHIMU have been delivered **14 vessels** with CRP combined with diesel electric system.

• CRP efficiency of **10%** is expected.

• Additional fuel saving by “Diesel Electric System” should be studied and validated on board.

IHIMU will help to realize Super Eco Inland vessels for the inland navigation with sustainable competence.
Thank you very much for your attention!

Hartelijk Dank
Vielen Dank
Je vous remercie beaucoup
ありがとうございました。

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