Benefits of Carbon Composite Marine Propeller

Composite Business Dept.
Nakashima Propeller Co., Ltd.
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Characteristics of composites and Applications

Characteristics of composite material, FRP
- Lightness
- High strength
- High/Low elasticity
- Corrosion resistance
- Abrasion resistance
- Non-magnetism
- High damping and etc.

Examples of using FRP
- Aerospace
- Satellite
- Turbine blade for wind power
- Cars
- Boats • mine sweeper
- etc.

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Application examples of composite propeller

Carbon composite propeller was developed for German navy submarine by HDW design from 2002.

CPP type of carbon composite was developed for Dutch navy/Alkmaar mine hunter in 2010

A point of composite adoption is silence!
Approach of NAKSHIMA’s R&D to Carbon Composite Propeller
History of study on composite propeller in Nakashima

Phase 1 (2007～2008)
   Feasibility study, whether or not the composite materials are applicable to marine propeller

Phase 2 (2009～2011)
   Material evaluation test, Model tank test and Actual ship test by using a small boat

Phase 3 (2012～2014)
   In order to approve CFRP propeller by ClassNK and install the CFRP propeller to a domestic merchant vessel (joint research with ClassNK and etc.)
Molding method of NAKASHIMA

VaRTM (Vacuum assisted Resin Transfer Molding)
Refer to “Complete Guide to composites, Part 6”

① The sheets are cut to many blade outlines.
② The cutting sheets laminate on a mold tool.
③ The mold is covered by a bag.
④ The inside of the bag becomes to vacuum state by vacuum pump
⑤ Resin in the tank transfers in the bag.
→ No void in products.
Flexible Deformation of Composite Propeller

The pitch angle is decreased

Top of view

× 10 times deformation by FEA

The blade is bend to the advance side

Model tank test

The deformation by FEA corresponded with that of measurement by the model tank test.

In particular, the pitch angle of CFRP propeller decreases in the operation.

→ When sudden load changing in stormy weather, acceleration and so on, the overload of the engine becomes smaller by the blade deformation.

→ Cavitation inception is restrained.
First installation of CFRP propeller to a merchant vessel in the world!

This technology was developed with the support of ClassNK as part of the ClassNK Joint R&D for Industry Program.

Co-investigator: Class NK, University of Tokyo, National Maritime Research Institute, Imabari shipbuilding, NYK line, MTI and Nakashima propeller
499G/T Chemical tanker “TAIKO-Maru”

serviced in Sep. 2012

Main propeller (CFRP)
MCR: 735kW
Prop. dia.: 2,120mm
Retrofit in May 2014

Side thruster (CFRP)
Input power: 165kW
Prop. dia.: 850mm
Thrust: 25kN
installed in Sep. 2012
## Specifications of the propellers and the shafts

<table>
<thead>
<tr>
<th></th>
<th>Original (NAB, CAC703)</th>
<th>New design (CFRP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blade number</td>
<td>4</td>
<td>◄</td>
</tr>
<tr>
<td>Propeller diameter (mm)</td>
<td>1,950</td>
<td>2,120</td>
</tr>
<tr>
<td>Boss diameter (mm)</td>
<td>363</td>
<td>420</td>
</tr>
<tr>
<td>Blade area ratio</td>
<td>0.63</td>
<td>0.50</td>
</tr>
<tr>
<td>Propeller weight (kg)</td>
<td>715</td>
<td>422 (59%)</td>
</tr>
<tr>
<td>Moment of inertia (kg-m²)</td>
<td>112</td>
<td>36.8 (33%)</td>
</tr>
<tr>
<td>Intermediate shaft dia. (mm)</td>
<td>φ 210</td>
<td>φ 150</td>
</tr>
<tr>
<td>Propeller shaft dia. (mm)</td>
<td>φ 220</td>
<td>◄</td>
</tr>
</tbody>
</table>

- As a result of torsion vibration analysis, the diameter of shafts for the CFRP propeller can be decreased by the small moment of inertia.
- The intermediate shaft was exchanged, however the propeller shaft was not exchanged to avoid big construction in the dog.
ESD, Eco-Cap (cap with fin)

- The effects of the Eco-Cap are
  1) Hub vortex becomes extinct,
     → Energy loss by the hub vortex is recovered
  2) The Eco-Cap fin changes negative pressure on the back end of the cap to positive pressure.
     → Propulsive force is increased

The propulsive efficiency is improved!
Installation and Sea Trial Result
Installation of CFRP propeller
Installation completion of CFRP propeller
Result of the sea trial

<Sea trial condition>
Ship load : Full load
Sea condition : smooth

The shaft power of the CFRP propeller was reduced 9% compared with that of the NAB propeller at the design ship speed 11.5 knots.
Result of vibration measurement

- The vibration of the CFRP propeller becomes smaller than the NAB propeller, in spite of the CFRP propeller is larger diameter.
- The ship owner said that it became quiet so as to be able to talk each other with eating in the dining room.
Benefits of Carbon Composite Propeller

① Light weight
★ The weight is 50～60% weight of NAB
★ The shaft diameter becomes smaller.
← Moment of inertia becomes smaller 1/4～1/3

② High strength
★ The fatigue of CFRP is stronger than NAB
→ High reliability
→ High performance by thinner airfoil section

③ High performance
★ Propeller efficiency is improved by large diameter.
← CFRP light weight
★ Cavitation inception is restrained.
← Flexible deformation
★ Pressure fluctuation on ship stern is smaller.
← Flexible deformation

④ Low vibration
★ Vibrating force is declined.
← Propeller light weight.
★ High damping performance absorbs vibration on the shafting.
→ Improvement of a living environment

⑤ Overload reduction
★ The shape of the blade is deformed so that it may fit flow.
→ Overload of the engine reduces in stormy weather, acceleration and etc..

⑥ Maintenance
★ The repair is possible.
★ The blade exchange is easy.
★ When damaged, if stocking spare blades, it can exchange immediately, and the dock period can be done short.
Delivery Records of Merchant Vessels
Side Thruster for 499G/T Chemical Tanker

- Model: TFN-150S
- Output power: 165kW
- Diameter: 850mm
- Thrust: 2.5ton

2012/8: JG approved
2012/9: go into service
2015/10: repaired a blade damages by rope involvement with drift at period dock

There is no problem so far.
Side Thruster for Ferry

- Model: TFN-50S
- Output power: 90.5kW
- Diameter: 500mm
- Thrust: 1.0ton

2013/6: go into service
There is no problem so far.
Main Propeller for 499G/T Chemical Tanker

- Output power: 735kW
- Diameter: 2.12m
- Revolution: 355rpm

2014/5: ClassNK approved
2014/5: retrofit and go into service
2015/10: no damage at period dock
There is no problem so far.
Main Propeller for Ferry

- Output power: 441kW
- Diameter: 1.6m
- Revolution: 346rpm

2014/9: JG approved
2014/10: retrofit and go into service
2015/9: repaired damages by contact with drift at period dock

There is no problem so far.
Main Propeller for 499G/T Chemical Tanker

This ship owner is same as “TAIKO-MARU”
The owner is satisfied with saving fuels and becoming quiet in the ship.

• Output power : 735kW
• Diameter : 2.12m
• Revolution : 355rpm

2015/6: retrofit and go into service
There is no problem so far.
On-going and Future R&D for Carbon Composite Propeller
On-going and Future R&D for CFRP propeller

- Repairing and Maintenance method
  2014-2015, sponsored by JRTT
- Controllable Pitch Propeller for ferry
  deliver in June 2016, self-fund
- In order to approve over 4 m in diameter by ClassNK
  until March 2016, self-fund
- New Project, the ClassNK Joint R&D for Industry Program
  A target is to install a large CFRP propeller to over 60k
  DWT Bulk Carrier.
  2015-2018, sponsored by ClassNK
  The CFRP propeller will be approved in May 2017
  It will be installed to 63BC in Aug. 2017
Thank you for your attention!