Benefits of Carbon Composite Marine Propeller

Composite Business Dept.

Nakashima Propeller Co., Ltd.

Contents

- Characteristics of composite materials and Applications
- Approach of R&D to composite propeller
- Result of carbon composite propeller for a general merchant vessel and other delivery records
- On-going and Future R&D for CFRP propeller

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.

Application examples of composite propeller

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

Prop. Dia. Is 3.5m

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

Prop. Dia. Is 2.5m

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

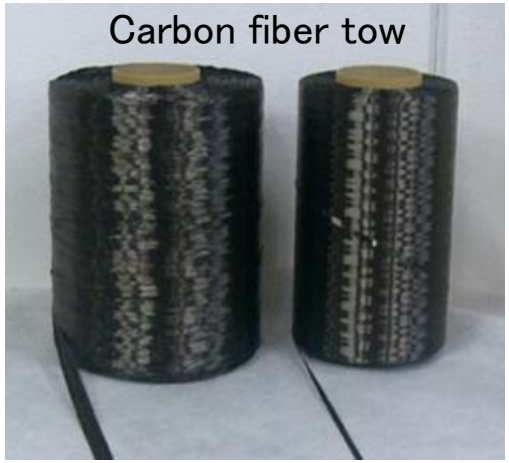
Phase 2（2009～2011）

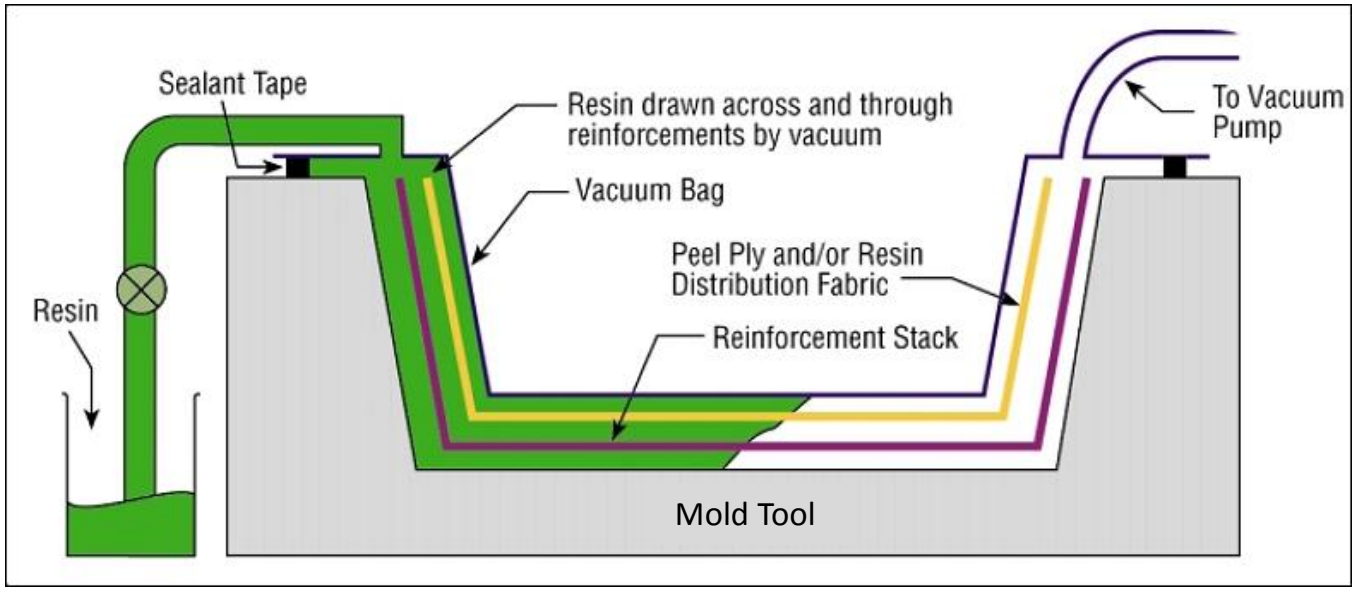
Material evaluation test, Model tank test and Actual ship test by using a small boat

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）

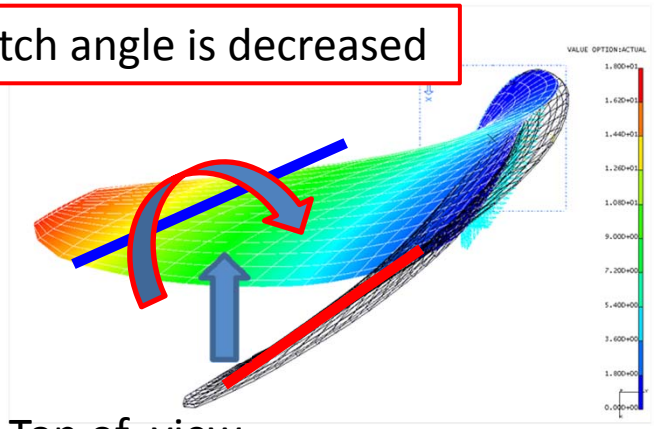
Refer to “Complete Guide to composites, Part 6”

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

Flexible Deformation of Composite Propeller

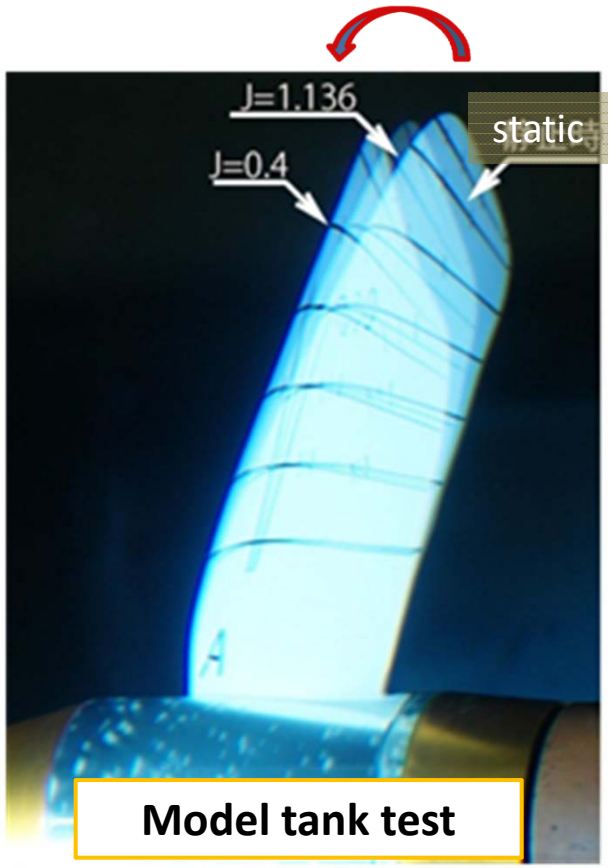
The blade is bend to the advance side

The pitch angle is decreased



Top of view

× 10 times deformation by FEA



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

Side thruster(CFRP)

Input power : 165kW

Prop. dia. : 850mm

Thrust : 25kN

installed in Sep. 2012

Main propeller(CFRP)

MCR : 735kW

Prop. dia. : 2,120mm

Retrofit in May 2014

Specifications of the propellers and the shafts

	Original (NAB, CAC703)	New design (CFRP)
Blade number	4	←
Propeller diameter (mm)	1,950	2,120
Boss diameter (mm)	363	420
Blade area ratio	0.63	0.50
Propeller weight (kg)	715	422(59%)
Moment of inertia (kg-m^2)	112	36.8(33%)
Intermediate shaft dia. (mm)	ϕ 210	ϕ 150
Propeller shaft dia. (mm)	ϕ 220	←

- 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**

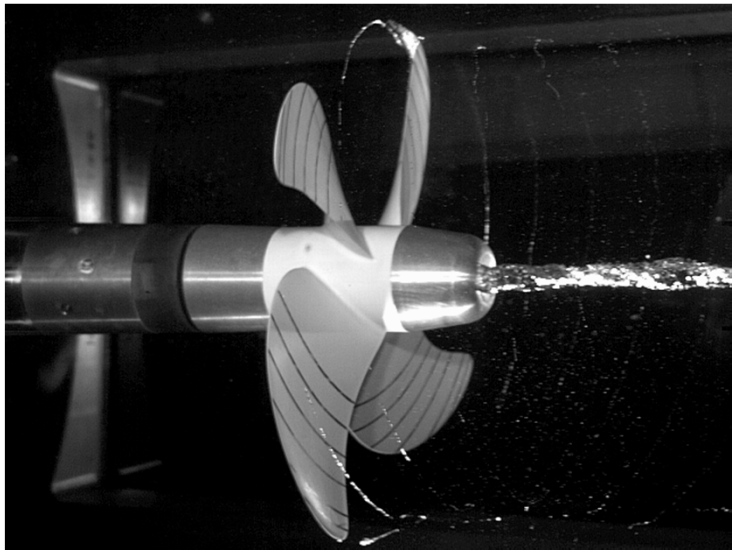
  1)Hub vortex becomes extinct,

  → Energy loss by the hub vortex is recovered

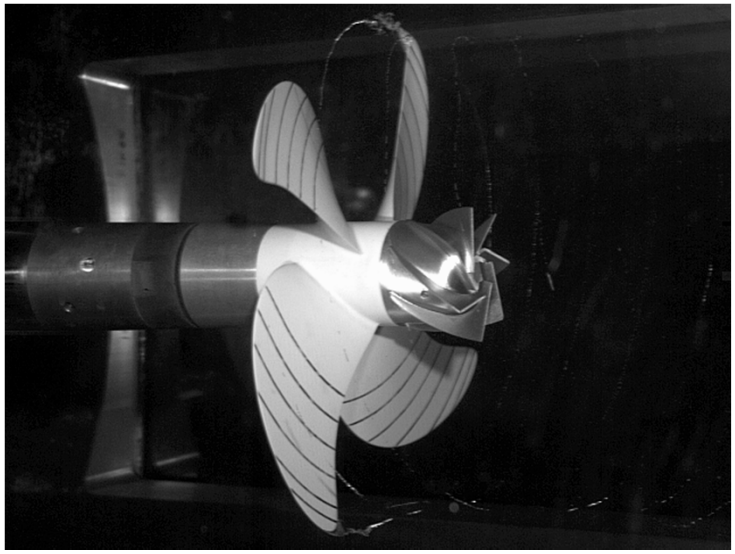
  2)The Eco-Cap fin changes negative pressure on the back end of the cap to positive pressure.

  → Propulsive force is increased

The propulsive efficiency is improved!



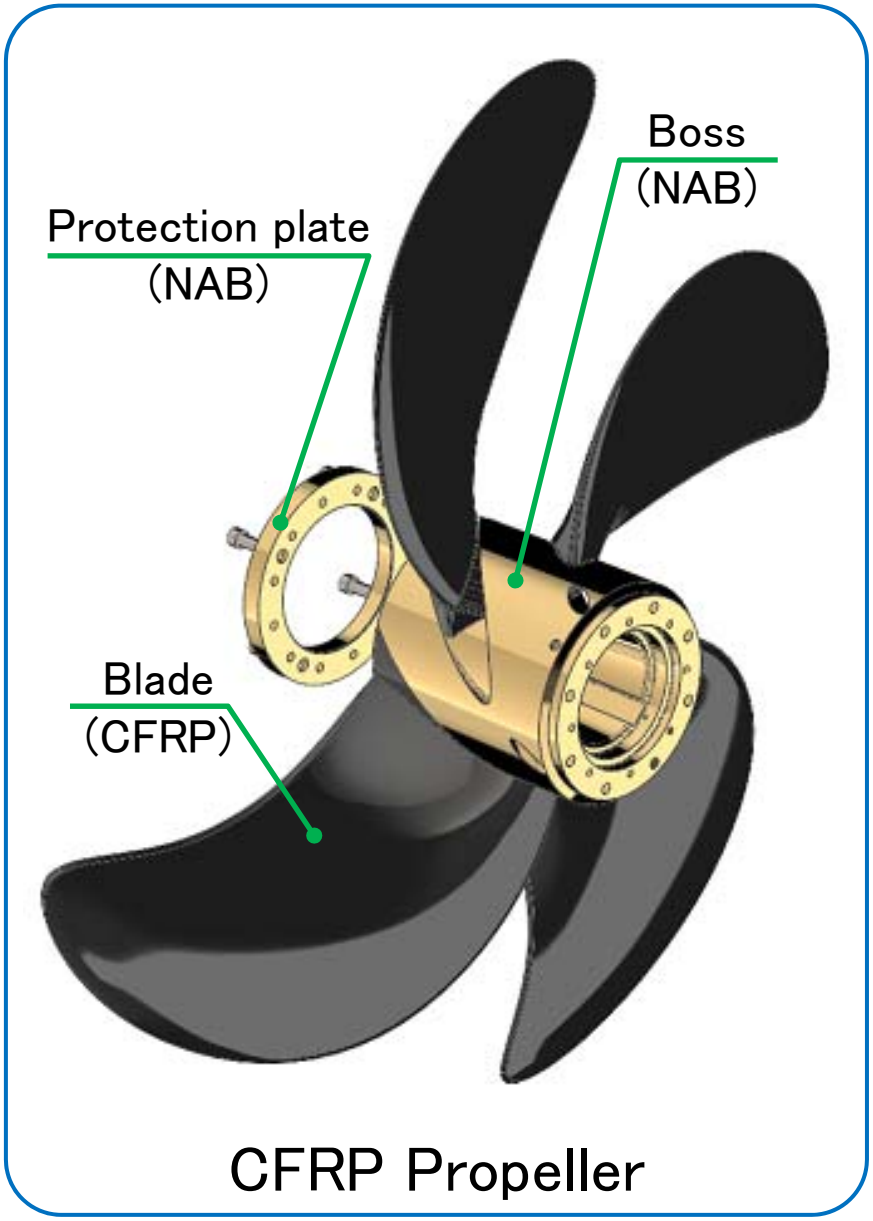
Normal cap



Eco-Cap

Installation and Sea Trial Result

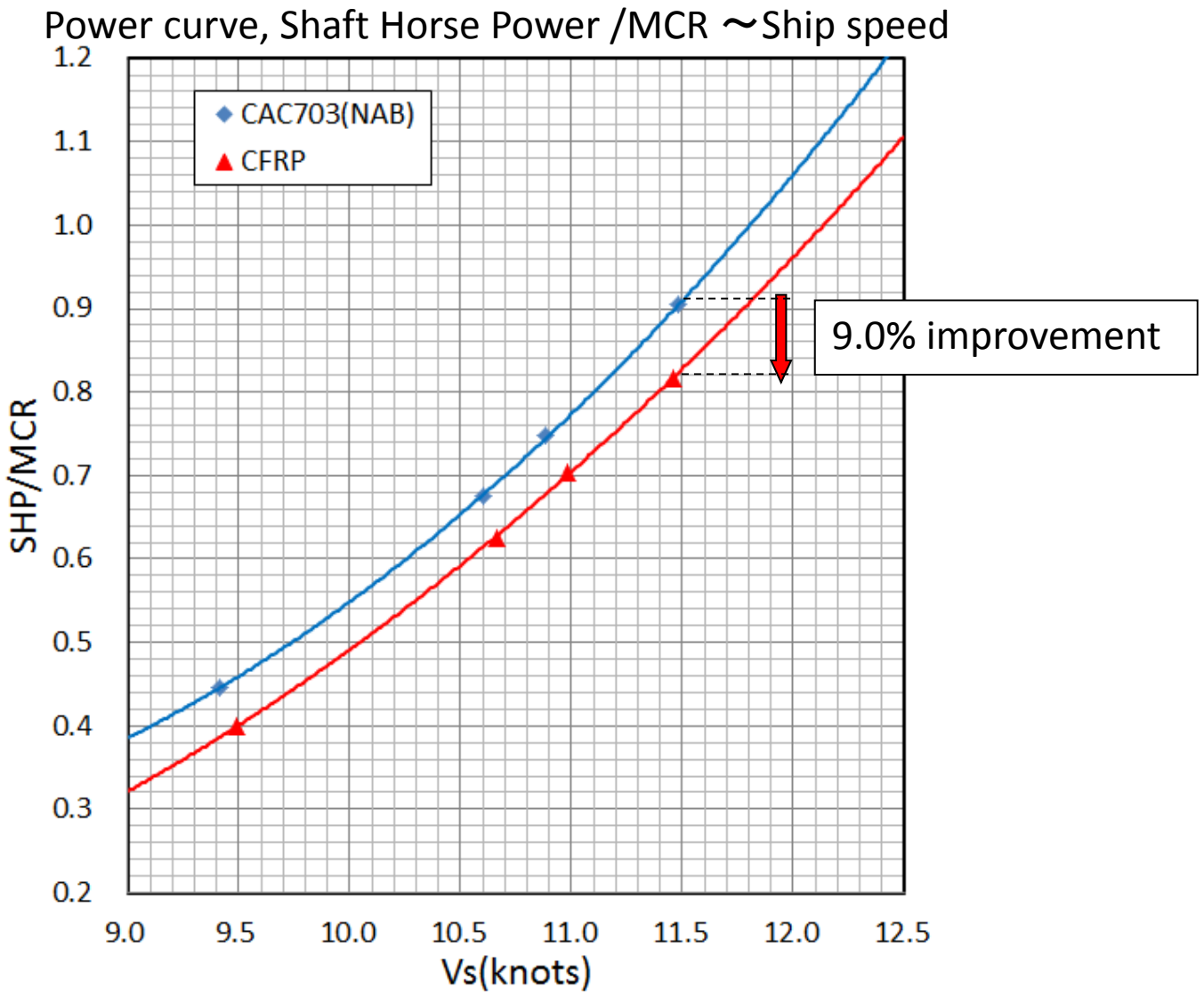
Installation of CFRP propeller



Installation completion of CFRP propeller

Result of the sea trial

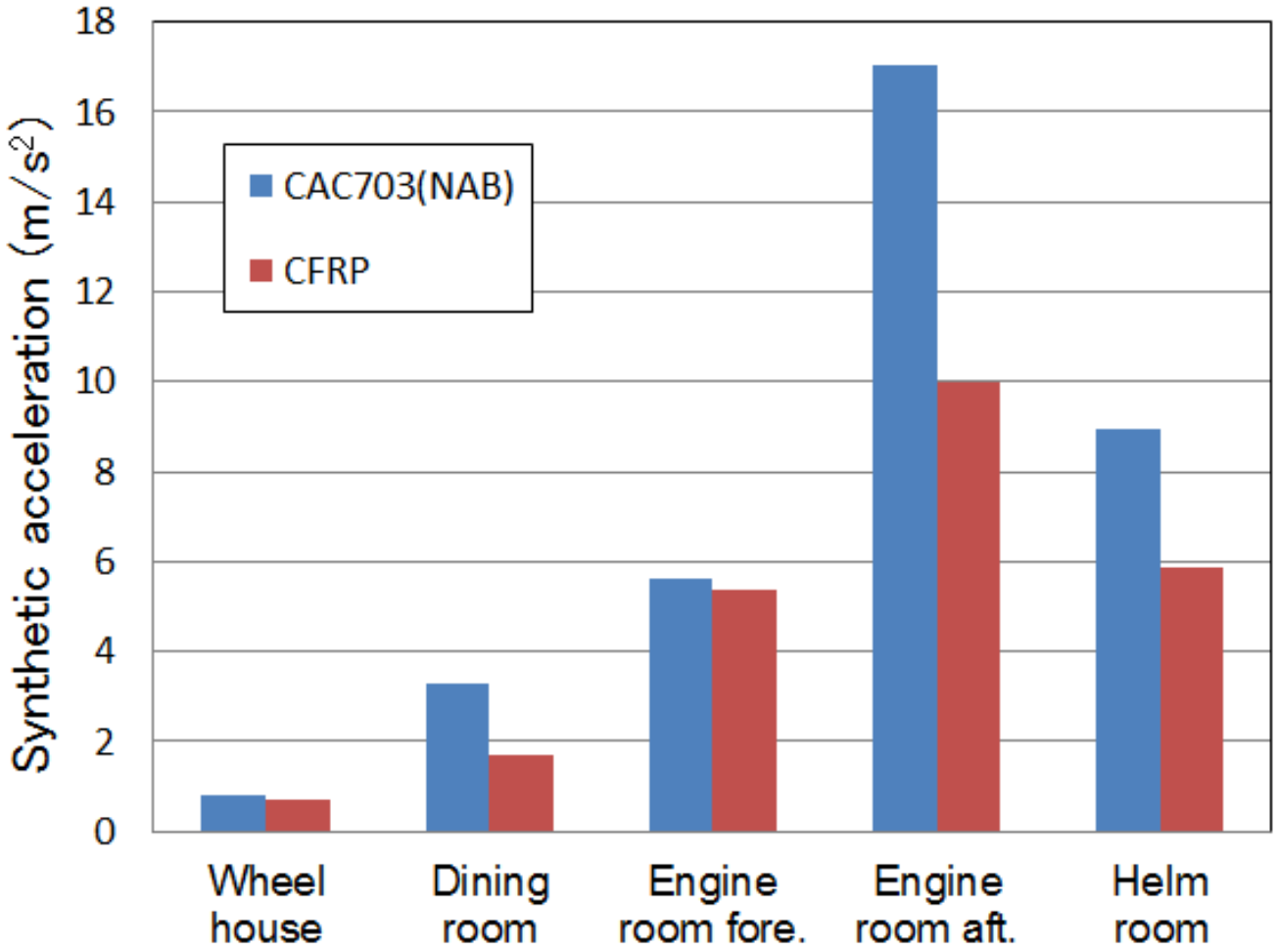
<Sea trial condition>
Ship load : Full load
Sea condition : smooth



The shaft power of the CFRP propeller was reduced 9% compare 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.

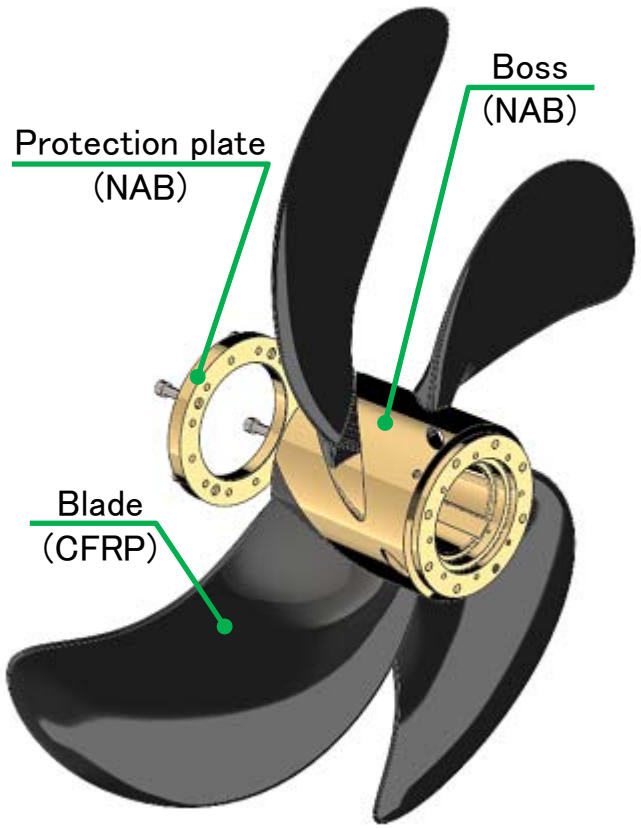
←CFRP light weight

★Cavitation inception is restrained.

←Flexible deformation

★Pressure fluctuation on ship stern is smaller.

←Flexible deformation



CFRP Propeller

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.

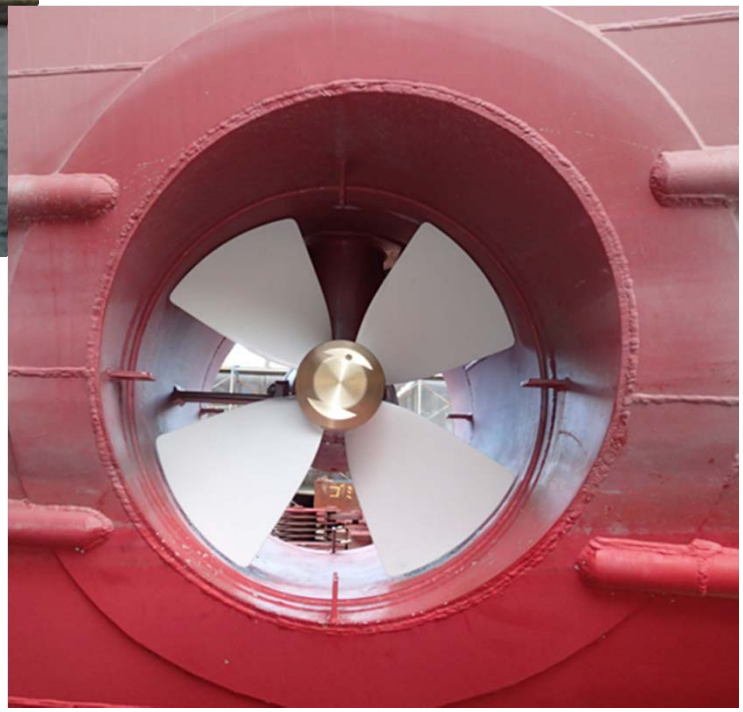
★The blade exchange is easy.

★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

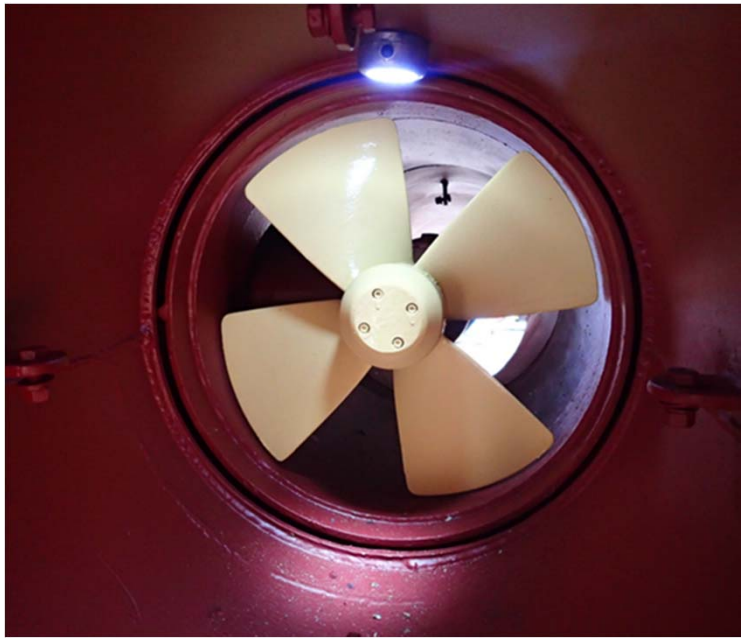


2012/8 : JG approved
2012/9 : go into service
2015/10 : repaired a blade damages by rope involvement with drift at period dock

<u>There is no problem so far.</u>

Side Thruster for Ferry

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



2013/6：go into service

<u>There is no problem so far.</u>

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
<u>There is no problem so far.</u>

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

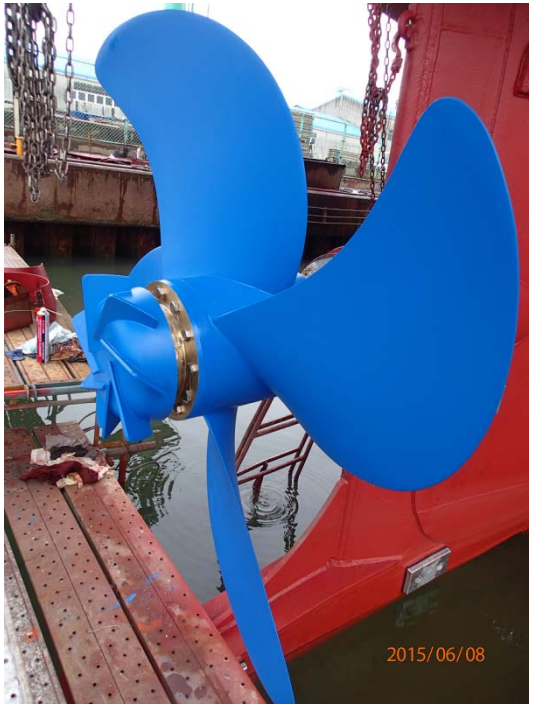
<u>There is no problem so far.</u>

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

<u>There is no problem so far.</u>

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!