Mermaid Ⅱ Voyage to the future with waves

2015.08.04
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Wave Devouring Propulsor

* **Natural energy utilization**
* **Hull Stabilizer**
* **Thrust generator from waves**

  Move against waves

  Normal hull : drift by the waves

  Wave Drifting Force

 Resistance increase in waves

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WDPS

* **Thrust <= Oscillating hydrofoil**
  * **Hull motion induces hydrofoils motion**
    * **Hydrofoil relative flow generates thrust force**

* **Hull Stabilizer**
  * **Stabilized hull reduces the resistance increase in waves**

Thrust generation

Damping Force
Lift
Thrust
Flow

Relative motion

Damping Force
Lift
Relative Speed
Thrust
Advanced Speed
Flow

WDPS's overview in Tokai Univ.

* **1980：Phenomena discovered**
* **1982：Application of floating structure**
* **1989-90:WDPS actual sea trial**
* **2000：New hull design and tank test**
* **2004：Application of Mega-Float**
* **2006：Ocean going WDPS Design**

WDPS 1989

Tokai Univ. WDPS 1989-1990
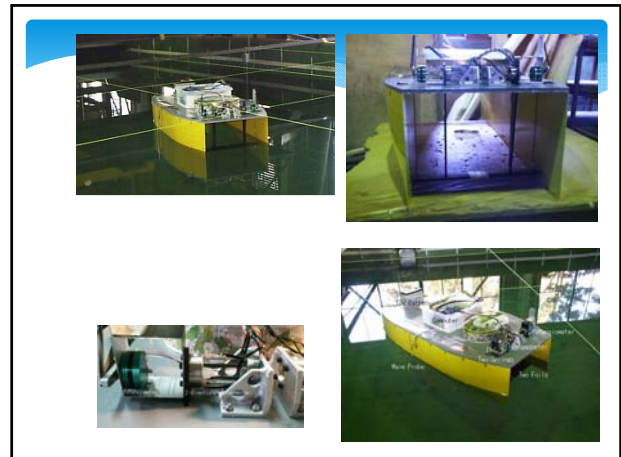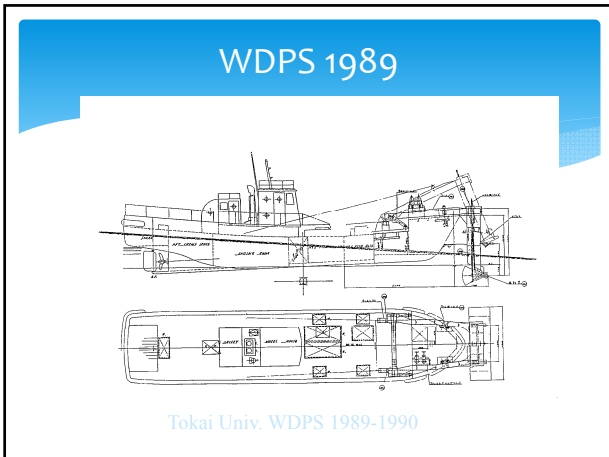
New project of ocean going WDPS

* **Sailing by the WDPS**
  * **Wave energy only**
* **Hawaii to Japan**
  * **Distance 7000Km**
* **Start of the voyage**
  * **2008 03 16**
* **Solo sailing**

Design purpose

* **Stability & Safety**
* **Speed**
  * **Max 6kts**
* **Reliability of mechanism**
  * **Simple control system**

Principal requirements

* **Single hand**
* **Long container transportation**
* **Displacement: 3ton**
* **Catamaran hull**
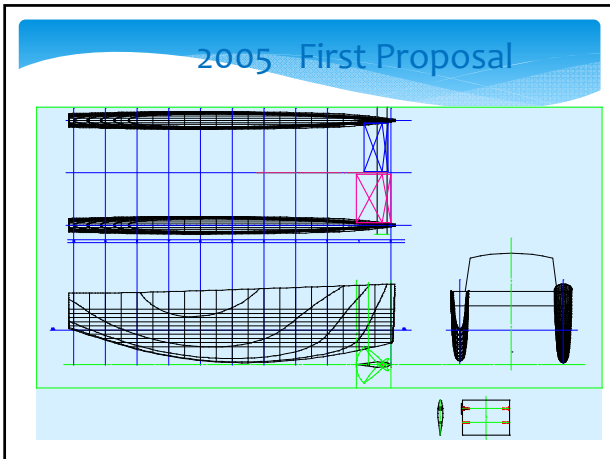* **Yacht based design for JG rule**
* **All recycled aluminum**

High performance WDPS

* **Increase wave energy absorption performance**
* **Low resistance in waves**

P=TU+E

P: Wave Power; E=0; T:Thrust, U:Forward Speed
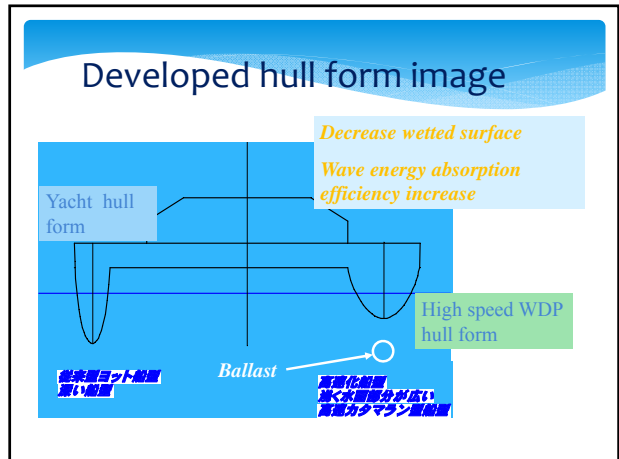
Wave energy density is high compared to the wind energy

2005 First Proposal

WDPS Hull Form Design

Optimum hull geometry for **WDPS**

>Wiglay hull series calculation

>Tank test

## Feedbacks of wave tank test results

* **Hull form change**
  * **Sailing hull form →**
                WDP hull form

  * **Hull resistance**
  * **Hull motions**

Developed hull form image

Decrease wetted surface

Wave energy absorption efficiency increase

Yacht hull form

High speed WDP hull form

Ballast

従来型ヨット船型
深い船型

高速化船型
強く水面積が広い
高速カタマラン風船型

Features of new hull form

* **Displacement is same**
  * Cp **Const**
* **Deep Hull Form→Shallow Hull Form**
  * **WDP performance increase**
  * **Foil position**
  * **Easy construction**
  * **Ballast equipment**
  * **Longitudinal strength**
  * **Course keeping performance**

Model experiment in the wave tank
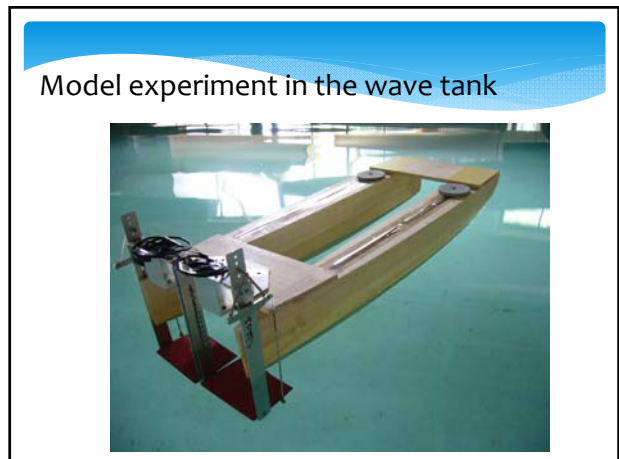
New model photo

WDPS under construction

Launching

Ballast 1ton

Shipping

Mermaid Ⅱ in Hawaii Yacht club

Support members of Horie's project

Starting ceremony

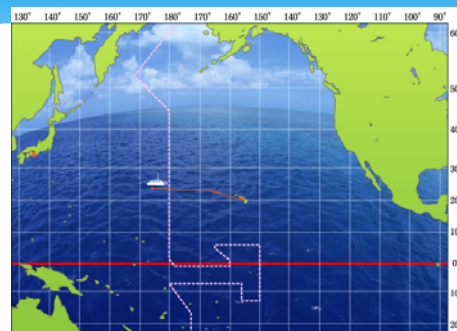## Start voyage without sails but waves and WDPS

2008/03/17 06:12 JT

Rolling angle of Mermaid

- Wave direction : Following
- Wave height : Hw=0.2m
- Wave length : 5m
- Advanced speed：2kn

- Small rolling &pitching motion
- Moving like a sliding
  - Plat forming
  - Without noise!

Photo from Escort vessel

Mermaid Ⅱ log 04/16

One day 1 deg.

Speed estimation of Mermaid Ⅱ

- ∗ Assumption：
  - ∗ Hull advanced speed is only dependent on the incident wave period, height and wave heading angle.
  - ∗ Neglect the wind & tidal effects.

Wind & tidal effects are summing up later!

Procedure

- Based on the tank test results
  - ∗ Make the Polar Diagram like sailing yacht.
  - ∗ Wave period, height and wave heading direction.
    - ∗ Many test cases must be done!
  - ∗ V is proportional to the incident wave height.
- ∗ Use ocean wave data
  - ∗ Cf. Japan Methodological Agency
  - ∗ Hw1/3→Tw1/3(Using Wilson's formula)
    - ∗ Spectrum form is decided
  - ∗ Equivalent wave height is given
- ∗ Wave heading angle is decided by the course

Speed estimation in the ocean

$H_{1/3} : given$

$T_{1/3} \cong 3.3(H_{1/3})^{0.63} : Wilson's \quad Formula \qquad (1)$
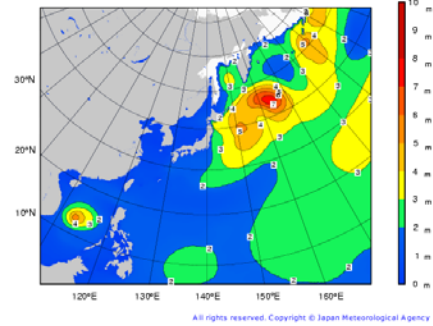
$S(\omega) : Ocean \quad Spectrum \qquad (2)$

$A_H(\omega) = \sqrt{2S(\omega)d\omega} \qquad (3)$

$v(\chi, \omega) = A_H(\omega) \bullet T(\chi, \omega) \qquad (4)$

Speed transfer function

$T(\chi, \omega) : Speed \quad Transfer \quad function$

$v(\chi)_{mean} = \dfrac{1}{\omega_1 - \omega_2} \displaystyle\int_{\omega_1}^{\omega_2} v(\chi, \omega)d\omega \qquad (5)$

Significant wave height 04/16

Ocean wave spectrum
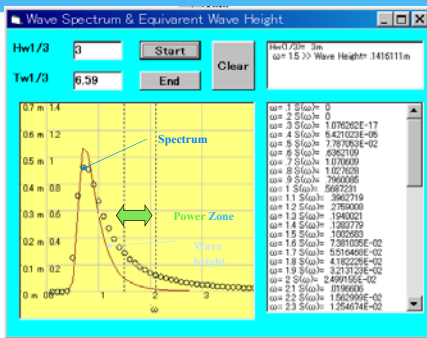
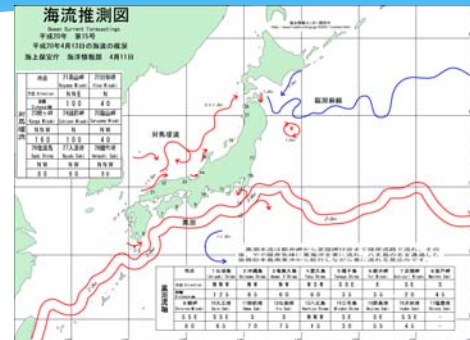## Future problems

* WDPS's performance theoretical approach
  * Based on the tank test is weak.
    * Only applicable for Mermaid 2.
    * Resistance components are still remain unclear
      * Wave making resistance
      * Frictional resistance
      * Wave drifting force
    * Scale Effect
* WDPS's data analysis.

DIY data logger for hull motion measurement

## Kuroshio, the last obstacle

Thank you for your kind attention

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* WDPS actual sea trial(1990)
  * Move against waves
  * Subsidiary propulsor
* Widen directivity(2000)
  * Model experiments
  * Beam sea is fastest
* Apply to the Mega-Float(2004)
  * Drifting force canceling devices

Drastic change of the earth environment

* Air pollution
  * Exhaust Gus
* Thermal pollution
* Chemical pollution
* Bio pollution

Human activity affects
the earth environment

Why natural energy?
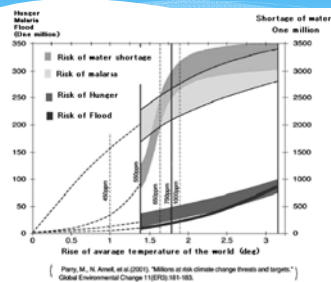
Nuclear power plant
in Japan

Natural energy

* **Subterranean heat energy**
* **Solar power**
* **Wind energy**
* **Ocean thermo energy**
* **Wave energy**
* **Tidal energy**

**Ocean
energy**