A Research Project on Maneuvering Motion in Waves and Minimum Power Requirement of Ships

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1. Introduction(1)

- The minimum power requirement guidelines are now under development at the IMO.
- The Japan Society of Naval Architects and Ocean Engineers (JASNAOE) started to develop a research strategy on this topic by establishing a research panel with experts in Japan.
- As a result, a physics-based prediction method of maneuvering motions of ships in adverse weather condition is indispensable as a base for developing reasonably multi-layered minimum power requirement guidelines at the IMO.

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1. Introduction(2)

We will introduce:

- A research project on the maneuvering motions in adverse condition and minimum power requirement of ships in Japan
- Research achievements on the time domain prediction method and the experimental validation for ship maneuvering in regular and irregular waves

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2. Outline of Research Project (1): members

Class NK organized to launch a collaborative research project (until March, 2016) with:

- Hiroshima University (Chairman: Prof Yasukawa)
- Osaka University
- Hokkaido University
- National Research Institute of Fisheries Engineering
- National Maritime Research Institute
- Mitsubishi Heavy Industries, Nagasaki R & D center

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2. Outline of Research Project (2): key technologies

1. Theoretical estimation of wave-induced 2nd order steady forces with ship's forward velocity and the experimental validation (Prof. Kashiwagi)
2. Modelling maneuvering motion in regular and irregular waves and the experimental validation (Prof. Yoshimura, Prof. Yasukawa)
3. Experimental technique to capture the ship model behaviors in severe and random wind and waves with limited propulsion power (Prof. Umeda, Dr. Matsuda)
4. Prediction method for ship behavior with limited propulsion power in severe and realistic wind and waves (Prof. Yasukawa)

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3. A Prediction Method(1): a policy

- **Practical tool:**
  - Reasonable computation time
  - Based on the existing methods with tank test results to ensure the reliability
- **Two theoretical methods:**
  - A time domain simulation method (like a simulator model) → *The detail will be presented here.*
  - A method based on the theory of motion dynamics and stability: checking the steady and unsteady solutions → *The detail is skipped here.*

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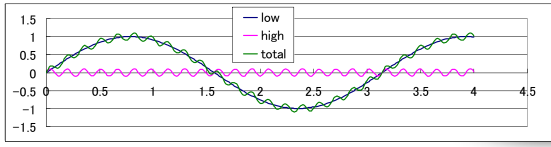
3. A Prediction Method(2): a basic idea

- Total ship motion = Maneuvering + Wave-induced motion
- Maneuvering is low frequency motion: base motion
- Wave-induced motion is high frequency motion: a linear problem based on low frequency motion



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3. A Prediction Method(3): details

1. **Maneuvering:** MMG model (4DOF) + wave drift forces
2. **Wave-Induced motions:** a linear time domain Strip Method (6DOF) on the assumption of a quasi-steady state treatment (no memory effect)
   - Change of encounter frequency
   - Change of wave direction
   - Change of speed

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3. A Prediction Method(4): cal. flow

Engine model:
- Torque rich
- Revo. control

- Ship position (X, Y)
- Heading angle (ψ)
- Ship speed (U)

1. Maneuvering model + Wave drift forces → **2. Seakeeping model**

- Motion oscillations for cal. of thrust and torque fluctuations for rudder control

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3. A Prediction Method(5): wave drift forces

- **Added resistance in waves:**
  - *Strip method* + *Prof. Maruo's far field theory* + *Fujii-Takahashi's empirical method* for diffraction wave component correction
  - An Interpolation using a data base of the added resistance coefficient for different ship speeds, wave directions and wave periods
- **Wave drift lateral force and yaw moment:**
  - The *zero speed 3D panel method*
- **Drift forces in irregular waves:**
  - Averaged value of short term prediction

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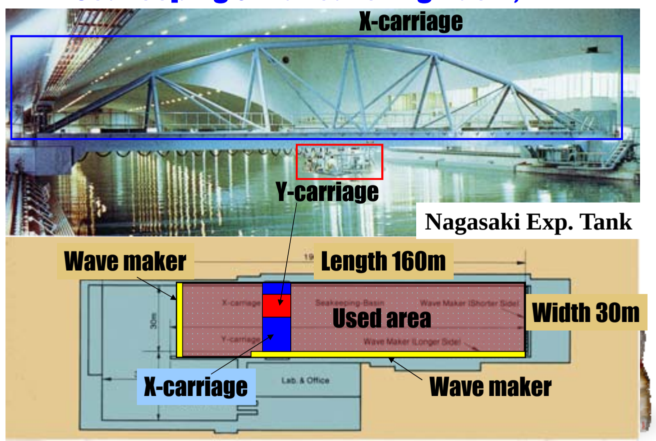
4. Free-Running Tests in Regular Waves

Seakeeping & Maneuvering Basin, MHI



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Ship Model: S-175

- L_{pp}=175m for fullscale
- L_{pp}=3.50m for model

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Regular Waves

- **Wave direction**: 0deg (heading waves)
  90deg (beam waves)
- **Wave length**: λ/L = 0.5, 0.7, 1.0, 1.2
- **Wave height**: Hw/L = 0.02
- **Froude number** of approach speed: Fn=0.15
  (Propeller revolution constant)
- **Kind of maneuvering motions:**
  ±35deg Turning; 10/10, 20/20 zig-zag maneuvers; stopping

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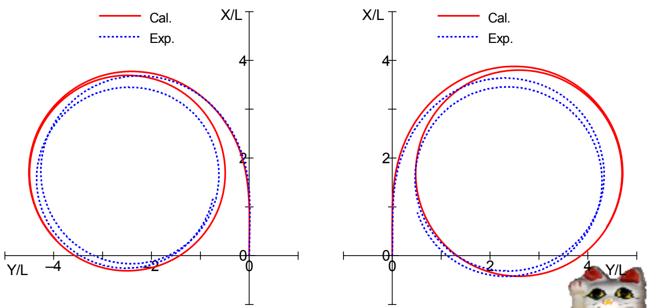
Results: Turing circle in still water δ=35deg



Maneuvering hydrodynamic forces obtained by Son and Nomoto(1982) was used for simulations.

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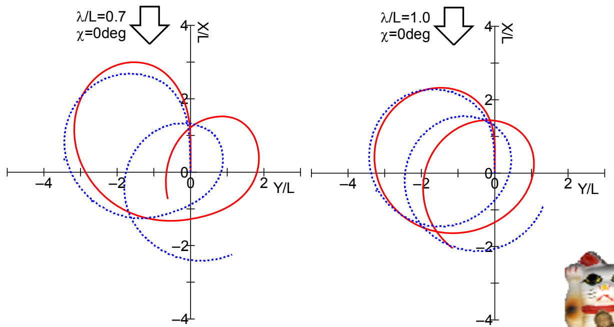
Results: Turning trajectories in regular waves（χ=0deg, δ=-35deg）



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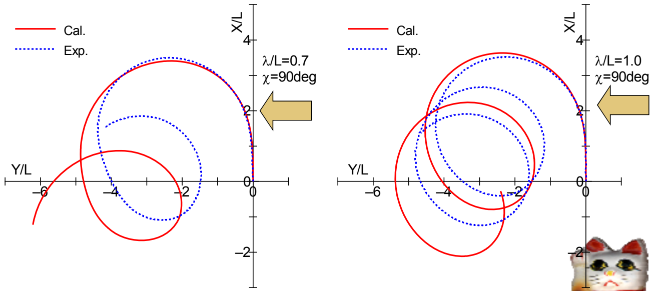
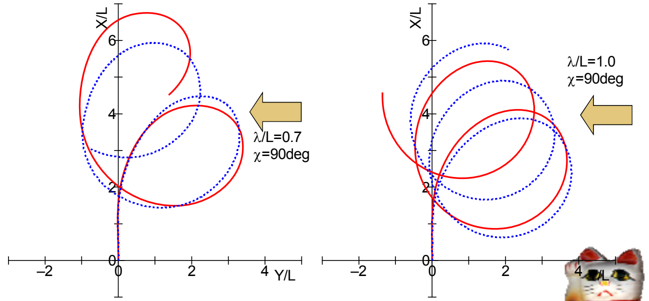
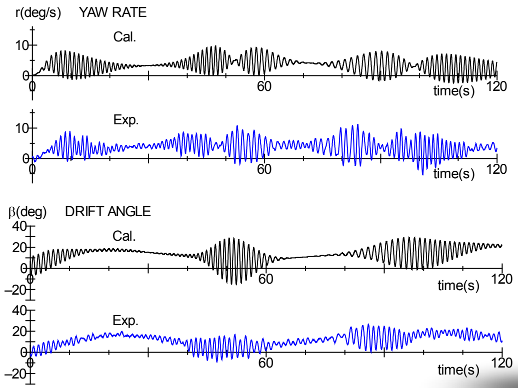
Results: Turning trajectories in regular waves（χ=90deg , δ=-35deg ）



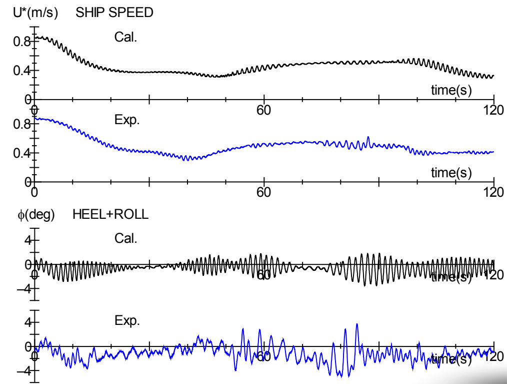
Results: Turning trajectories in regular waves（χ=90deg , δ=35deg ）



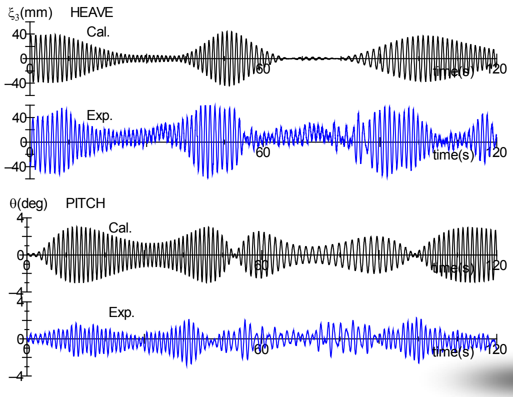
Results: Time histories of motions(1) λ/L=0.7,χ=90deg, δ=35deg



Results: Time histories of motions(2) λ/L=0.7,χ=90deg, δ=35deg



Results: Time histories of motions(3) λ/L=0.7,χ=90deg, δ=35deg



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5. Free-Running Model Tests in Irregular Waves

- Free-running tests to capture the maneuvering motions of a KVLCC model in *irregular waves*
- 35 turning trajectories and 10/10 zig-zag maneuvers in still water and irregular waves

Snake-typed wave maker at NRIFE

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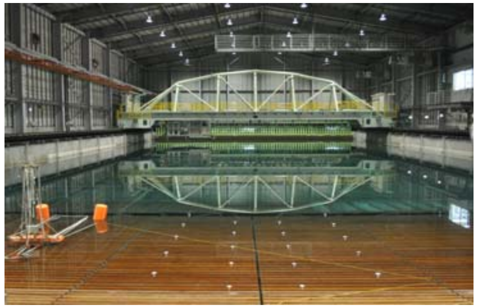
National Research Institute of Fisheries Engineering: Square Tank



Length : 60m Width : 25m Depth : 3.2m

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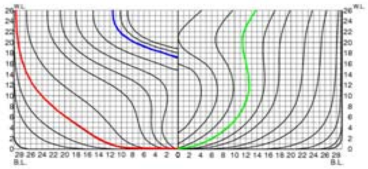
A KVLCC2 model

- L_{pp}=320m for fullscale
- L_{pp}=2.91m for model

$9\frac{3}{4}$



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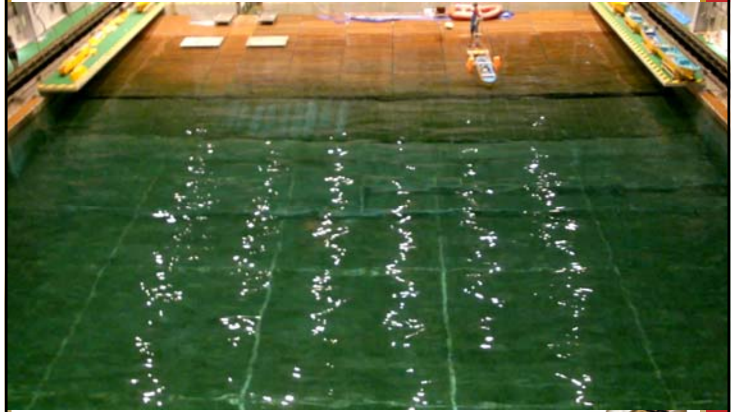
Irregular Waves

- Short crested irregular waves (directional waves)
- $\cos^2$ – function type: wave direction distribution
- ITTC Spectrum
- Head waves in ship approaching (0deg)
- Sea State 6

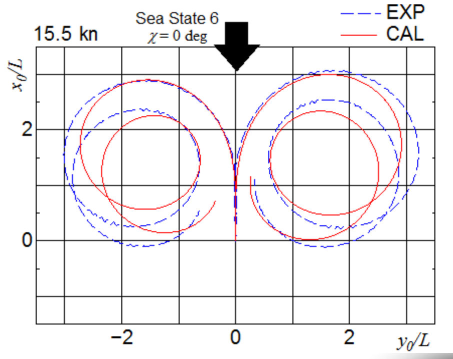
	fullscale	model
Significant waves (m)	6.0	0.0545
Averaged wave period (s)	9.46	0.902

Test was repeated 5 times with changing the random phase between elementary waves for wave generating.
(same wave height and same period, but wave patter is different)

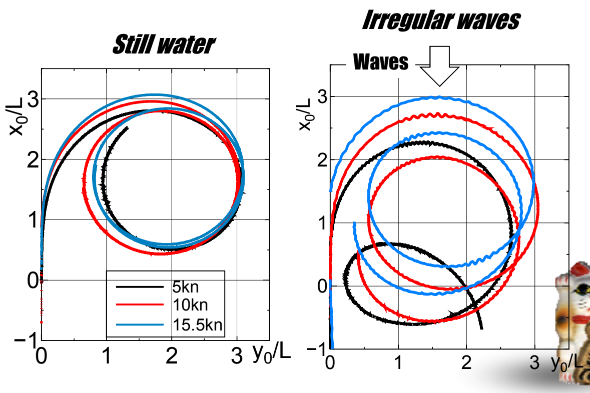
U_0=15.5kn, 35deg Turning in Irregular Waves



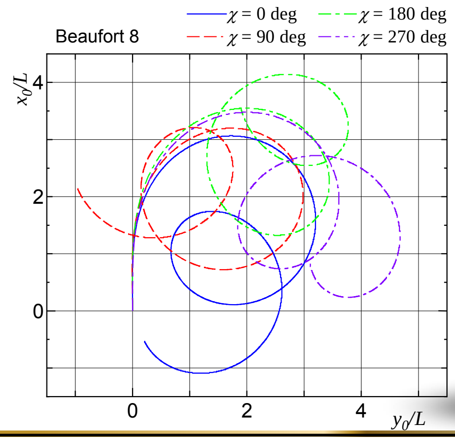
Comparison of Cal. and Exp.



Test Result:
Speed effect on turning trajectories



Cal. Results: Effect of wave direction on turning trajectories (δ=35deg)



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5. Concluding Remarks(1)

- **We introduced :**
  - **A research project** on the maneuvering motion in adverse condition and minimum power requirement of ships
  - **A time domain prediction method** of ship maneuvering in regular and irregular waves
  - **Free-running test results** of the turning motion in waves for S-175 ship and KVLCC2.
- **The present prediction method is useful** to capture the maneuvering motions in regular and irregular waves roughly.

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5. Concluding Remarks(2):

Towards the next step:

- **Improving the prediction accuracy**; wave drift forces? → ***Enhanced Unified Theory*** developed by Prof. Kashiwagi
- **Getting the validation data** for several kinds of ship ***(BC, CS, PCC)***
- **Applying to the problem related to minimum power requirement → contribution to IMO**

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Thank you for your kind attentions !

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