Physical Modelling of Structures

Experimental Methods in Marine Hydrodynamics
Lecture in week 38

Chapter 5 in Lecture Notes
Types of structures

- Ship hull models
- Propellers
- Offshore structures
- Miscellaneous
General Principles

• Geometric similarity (same shape)
  – Typical Limitations:
    • Only the part of model in contact with water
    • Simplification of small details
    • Hybrid models (where a part of the model is omitted and the effect calculated into the results)

• Dynamic Similarity
  – Correctly scaled mass (and mass distribution)
  – Correctly scaled stiffness (if hydroelasticity matters)

• Kinematic Similarity
  – Select scale to allow the required speed, within facility constraints (which means carriage speed)
  – If flow is turbulent in full scale – ensure turbulent flow also in model scale
Selection of scale

• Big model:
  – to avoid (or minimise) scaling problems
  – to carry all instrumentation within the specified weight

• Small model
  – to avoid (or minimise) blockage and wave reflection problems
  – to allow the maximum speed to be tested within the maximum carriage speed
  – To allow testing at correct water depth (offshore testing)
  – To reduce costs

• Other factors:
  – Size of available instruments
  – Size of available stock propellers
Requirements for ship hull models

- Very accurate, doubly-curved surfaces
  - Numerical milling is increasingly used for production
- Very smooth surface
  - Friction forces are important
- Size of conventional ship models is usually determined by size of model propellers
  - Shall not be smaller than 200 mm due to risk of scale effects
- Size of high-speed models often determined by carriage speed and minimum required model weight
Materials for manufacture of hull models

• Paraffin wax
  – Re-usable material -> cheap and environmentally friendly
  – Easily deformed
  – Must be stored in water
  – Can only be applied for calm water testing

• Wood
  – Changes shape due to water entrainment in the material
  – Relatively heavy models
  – Dust from the manufacturing is a health hazard

• Foam
  – Lightweight, very stable material
  – Expensive to buy material
  – Creates a lot of waste

• Glass Reinforced Plastic (GRP)
  – Very expensive to make (requires a plug and a mould)
  – Very stiff and lightweight – used mainly for high-speed models
Wax model manufacture
Dynamic ballasting of models

- Required for seakeeping
- Requirements:
  - Total mass
  - Position of Centre of Gravity
  - Moment of inertia:
    - Pitch (and roll and yaw)
  - If internal loads shall be measured:
    - The mass distribution must be modelled
Dynamic ballasting – how to do it

- Aim: To find CoG and mass moment of inertia
- Use a tilter
- Oscillate the model in the tilter and measure the natural period $T$ to find the natural frequency $\omega$

$$\omega^2 = \frac{mgh}{I_0 + mh^2}$$

Two unknowns: $I_0$ and $h$. Vary either $I_0$ or $h$ and repeat the measurement.
Dynamic ballasting of platforms

Moving the point of rotation

$h_{ref}$

Platform

Stiff support frame
Dynamic ballasting of ship models
Elastic models

- Used in cases where the elastic deformations are important:
  - Marine risers (bending stiffness)
  - Loading hoses (both bending and axial elasticity)
  - Tethers for Tension Leg Platforms (TLP) (both axial and bending)
  - Mooring lines (axial stiffness)
  - Springing and whipping of ships
  - Floating bridges
  - Fish farming plants
  - Seismic cables

- Direct geometric scaling with the same material as in full scale gives a model that is $\lambda$ times too stiff
Measurement of global loads – with modeled global elasticity

- **Purpose:**
  To determine the design loads, used for dimensioning of the ship structure

- **Modeling alternatives:**
  - Backbone model
  - Fully elastic model
  - Segmented model

*Backbone model*:

*Fully elastic model*:

- Divinycell foam
- Glassfibere resin

*Strain gauges*
Segmented model of bulk carrier
Segmentation of models

- Hinge
- Feather rod
- 3-comp. force transducers
- Movable fastening block
- Aluminium frame
Location of segmentation cuts

- Depends on what you want to measure
  - Midship bending moment ⇒ midship
  - Shear force due to slamming ⇒ stern quarter

- For flexible models, it also depends on the number of flexible modes
Segmented Catamaran model

Diagram showing the segmented catamaran model with annotations for aluminium beams, stiff hull segments, wetdeck plates, and springs. The diagram also includes indications for 5 dof's transducer and vertical force transducer.
Segmented Catamaran model

a) Mode 7: Longitud. bending  
\[ \omega = 17.1 \]

b) Mode 8: Prying  
\[ \omega = 20.7 \]

c) Mode 9: Torsion  
\[ \omega = 23.5 \]

Fig. 4 First three elastic modes of vibration. Nondimensional eigenfrequencies \( \omega \sqrt{L/g} \), measured in air, are indicated
Materials for Manufacture of propellers

- Nickel-Aluminium-Bronze and similar alloys
  - Good, but expensive

- Tin and aluminium
  - Inexpensive
  - Easy to shape
  - Not strong enough for cavitation tests
  - Aluminium is used when a lightweight propeller model is needed

- Stainless steel
  - Very difficult to shape
  - Very strong
  - Rarely used

- Plastic and composite
  - Only used for hydroelastic models
  - Expensive, because a mould is needed
  - Plastic propellers might be 3-D printed!
Propeller model manufacture