UNIVERSIDADE DE LISBOA

TÉCNICO LISBOA

# Formulations of mathematical models for manoeuvring in waves

Serge Sutulo & C. Guedes Soares

SHOPERA Meeting in Duisburg

16—17 March 2015

# Natural requirements to mathematical models for manoeuvring in waves

1. **At the zero wave amplitude/significant height the model must reduce to a normal nonlinear still-water manoeuvring model**
2. **When the ship is advancing straight without yaw and drift, the model must reduce to a normal seakeeping model enhanced with 2$^{nd}$ –order forces and combined with a resistance—propulsion model.**
3. **Obviously, the model can only be 6DOF.**
4. **The model must remain consistent at any instantaneous encounter frequency.**
5. **Desirable: the still-water manoeuvring model should be 4-quadrant .**
6. **Desirable is to have no limitations on the roll angle.**

# Implications and problems

1. **Requirement 4 ➔ the often used assumption about possibility of separation into high-frequency seakeeping motions and low-frequency/aperiodic manoeuvring motion should be avoided: the most substantial influence of waves on the manoeuvring motion takes place in long stern waves i.e. when the encounter frequency is small.**
2. **A consistent model will automatically provide estimates of additional resistance in waves (as well as all other 2$^{nd}$-order force/moment components).**
3. **Both 1$^{st}$-order and 2$^{nd}$-order wave excitation forces are approximately equally important for simulating the manoeuvring motion.**
4. **For a lower-level method the semi-linear (nonlinear Froude—Krylov+Hydrostatic & linear radiation and diffraction forces) formulation looks most attractive.**
5. **Memory effects must be accounted for**

# Double account problem

**When fusing a manoeuvring model with a seakeeping one double account of some categories of forces may occur.**

**Example: potential seakeeping theory for an advancing ship will produce the so-called Munk moment**

$$N_{MUNK} = -(\mu_{22} - \mu_{11})uv$$

**However, the Munk moment is also present in the term** $N_v v$

**If the double account is not prevented, the combined manoeuvring+seakeeping model will be structurally incorrect.**

**(See** Sutulo S., Guedes Soares C. *A Generalized Strip Theory for Curvilinear Motion in Waves,* Proceedings of the 27th Annual International Conference on Offshore Mechanics and Arctic Engineering (OMAE 2008), Estoril. Portugal, 15–19 June 2008, Paper OMAE2008-57936, 10p. **for details)**

# Characteristics of IST wave manoeuvring code

1. **Semi-linear strip method.**
2. **Empiric still-water manoeuvring part**
3. **Memory effects handled with auxiliary state variables**
4. **Double account prevented through subtracting the seakeeping part corresponding to zero frequency.**
5. **Model works at arbitrary encounter frequency.**
6. **Second-order forces are estimated:**
   - i. **Kinematical part in the natural way (varying wetted surface)**
   - ii. **Bernoulli quadratic part with the weak scatterer hypothesis (under construction)**
7. **Rectilinear motion in waves is realized either with an autopilot or through artificial kinematical restrictions.**

UNIVERSIDADE DE LISBOA

TÉCNICO LISBOA

No explicit conclusions.

Thank you for the patience!