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SHIPS AND BERTH STRUCTURES INTERACTIONS

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1. INTRODUCTION

The advanced prediction techniques of ship behaviour at berthing facilities need to include several hydrodynamic and mechanical aspects influenced by several local structures.

2. FEATURES CONCERNING BERTHING OF SHIPS RELATED TO BERTH STRUCTURES

Some of the important features concerning berthing of ships related to berth structures, in a sense of safety, operational limits and berthing design, are: environmental short waves in the vicinity of the berthing position as a result of interactions between the incoming wave climate, the local wind (external conditions), the bottom configurations and the following harbour components:

- breakwaters
- terminal or berth lay-out
- berth or quay structure.

These aspects have to be considered during the manoeuvring operations and while the ship is moored (wave induced dynamic loading).

- long ship motions induced by water resonance inside the harbour, particularly at the nodes. They depend on the geometry and dimensions of the basins, harbour entrance, water depth, reflections on quay walls and other boundaries, berthing position and on the overall mooring and berth arrangements.
- water cushion effect between the ship I s hull and the berthing structure (open pile, vertical continuous quay).
- interactions between excitations and mooring and fendering arrangements (conventional systems and new low recoiling fenders with tension moorings based on pier or quay winches).
- stand-off actions on moored ships associated to the effect of currents running through pile-supported berthing structures (hull pressure changes, forces and moments). These actions are dependent on the berth lay-out, transverse and longitudinal pile spacings, pile diameters, current flow, ship position, underkeel clearance).
- interaction between a passing ship and a moored ship as a

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result of a close distance between the berth and a waterway.
- motion induced hydrodynamic coefficients (added mass and damping coefficients). They depend on the approaching motion history, on the distance between the ship and the quay, on shallow water effects.

3. THREE USUAL CALCULATION METHODS

In traditional calculations of berthing impact, the approaching velocity of ship V and some few coefficients account for everything which is unknown but believed to be important to quantify the effective berthing energy E. The final value depends very much on the designers skill and judgement.

For instance, the "Design Standards" referred by the "Working Group on Fender System Design of the Japanese National Section of PIANC" (1980), only consider two cases of structural situations through a berthing manoeuvre coefficient C_E (eccentricity factor, falling in 0.5 to 0.8 range):

- "wharf with a number of fenders arranged"

  $E = 1/2\ (WV^2/2g)$ W "virtual" weight of ship
- "dolphin or wharf with fenders placed at a large spacing between"

  $E = 1/2\ (WV^2/2g)\ C_E$

And the report by the "Commission Internationale pour l'Amelióration de la Conception des Systemes de Defense", PIANC (1984) considers

$E = E_C \times C_M\ C_E\ C_C\ C_S$

C_M- wharf configuration coefficient (or berth type factor) which lies in the range 0.8 (for a vertical face and a parallel berthing manoeuvre) to 1.0 (for an open pile berthing structure),

CE- added mass coefficient,

CC- eccentricity coefficient,

Cs- softness coefficient.

A purely deterministic approach is nowadays unsatisfactory to a rational design of docks, harbours and mooring facilities. So, a far better understanding of the physics and mechanics involved in the dynamic behaviour of moored ships must be a priority.

The full-scale measurements of approaching velocity, eccentricity factors and impact energies from monitored berths are so closed dependent on local conditions that such data must be widely extended to be general accepted to support statistical methods in order to provide design probability curves and risk analysis.

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It is well known that small scale hydraulic modelling is ail important design tool. But as a simplified representation of a complex real oscillating system the results and their interpretation must be considered with precautions.
Proper extensive prototype measurements would be very helpful to adjust the testing conditions, the scaling techniques and to improve levels of predictions.

4. QUESTIONS ABOUT MATHEMATICAL MODELS

Of course, we have recent advances on analytical expressions and on numerical models, which are constantly updating and work is hard in progress for further development.
But two vital questions arise about the actual applicability of such models:

— Are the available mathematical models limited, as a useful prediction technique, to the early stages in the design of a berthing/mooring system (including berth location, ship motions, fenders, mooring lines)?

— If the most sophisticated mathematical models can successfully substitute the physical models, as some of them are commercially presented to the harbour authorities, we would like to learn more about the way they actually can compute the following problems and the simplifications introduced to them, specially at more exposed locations:

-non-linear (and non-permanent) excitations:

low frequency waves and resonant harbour oscillations,
wave overtopping of breakwaters,
wave breaking,
flow separation effects,
coupling between several short waves deformations inside the harbor,
drift forces on the ship's hull (second order wave induced forces and moments, wave grouping effects).

-non-linear relations between fender excitation and compression, mooring lines loads and elongation, under cyclic loading. Multiple possibilities of mooring arrangements, including forced fendering. Interactions.

-determination of the elements of the motion induced added mass matrix, considering:

- real hull shapes,
- approaching motion including the rate of change of the berthing velocity and the distance from the ship to the quay,
- underkeel clearance,
- fender and berthing structure characteristics.

-determination of the elements of the motion induced damping matrix associated to the wave system generated by the motion of the vessel, the vortices generation and the friction forces on the ship's hull (considering viscous effects).

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To give confidence and reliability it is important to know which prototype situations or hydraulic model comparations have been considered. This is necessary to verify the accuracy and validity of such mathematical models in order to quantify the complex real excitations and induced interactions. Computer time and costs will provide a better insight.

5. SIMPLIFIED ASSUMPTIONS

In fact, the set of differential equations of motion of a moored vessel with non-linear and frequency dependent hydro-dynamic coefficients are being approached by analytical methods which consider simplified assumptions. The question is how far are those assumptions unimportant to achieve realistic results since they consider one of the options within the following items:

- some or all the six fundamental forms of ship motions (they are not equally important for different ship types and cargo operations),
- free ship or free sailing ship or moored ship,
- simplified hull shape or real hull shape,
- regular wave excitation (sinusoidal) or irregular waves,
- one wave direction or several wave directions,
- inclusion or non-inclusion of wind and current excitation forces,
- inclusion or non-inclusion of drift forces (at least for beam and head waves),
- without considering or considering underkeel clearance (at least with some of the motions),
- consideration of all the hydrodynamic coefficients or only some of them,
- uncoupled motions or coupled motions (coupled coefficients) hydrodynamic,
- linearized assumption of small amplitude of motion with constant hydrodynamic coefficients for a given form (independent of the motion amplitude and time) or frequency dependent hydrodynamic coefficients,
- considering the quay influence or without considering such influence,
- linear or non-linear behaviour of fenders,
- linear or non-linear behaviour of mooring lines.

6. COMPLEMENTARY PREVISION TECNHIQUES

As a conclusion and as far as a recent literature survey can evidence, it is more realistic and sound to defend that it will be still necessary to run model tests at least to improve the assessment of the matrix hydrodynamic coefficients for real hull shapes and local conditions.

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So, numerical models and physical models for berthing and mooring studies can be regarded as being complementary prevision techniques.
And for the design of simple situations (sheltered berths, medium size ships, conventional berth and mooring arrangements, local knowledge on the behaviour of ships and structures) it is enough to use energy probability curves including the effect of all the stated berthing factors.

REFERENCES

Bruun, P.
Mooring and Fendering Rational Principles in Design. The Dock and Harbour Authority, February. Volume 64 Number 758 (1984)

DHL
Dynamic Behaviour of Moored Ships in Harbours. Harbour Authority. February 1984

P.I.A.N.C.
(Japanese National Section). Design of Fender Systems. Japan 1980

P.I.A.N.C.
Rapport de la Commission Internationale pour I' Amelioration de la Conception des Systemes de Defense. Supplement au Bulletin 45. Bruxelles 1984

Rita, M.A.B.M.
On the Behaviour of Moored Ships in Harbours -Theory,Practice and Model Tests. Dissertation. Laboratorio Nacional de Engenha ria Civil. Lisboa 1984

Vasco Costa, F.
Moored Ships as Oscillating Systems. The Dock and Harbour Authority, February and June 1983.

E. Bratteland (ed.), Advances in Berthing and Mooring of Ships and Offshore Structures, 338-342.