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INTERNATIONAL WORKSHOP ON WATER WAVES AND FLOATING BODIES

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Report on the

TENTH INTERNATIONAL WORKSHOP ON WATER WAVES AND FLOATING BODIES

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SUMMARY

The Tenth International Workshop on Water Waves and Floating Bodies was held in Oxford from 2-5 April 1995. This short report describes the background to the Workshop, which brought together experts from most of the leading international groups of theoretical hydrodynamicists working on the interactions between waves and marine structures. The report highlights the significant areas of discussion, concentrating particularly on those relevant to the Managed Programme on Uncertainties in Loads on Offshore Structures, and on certain areas thought to be of specific interest to the HSE.

The area attracting the greatest attention at the Workshop (11 papers out of a total of 58) was that of time domain simulation of fully non-linear wave/structure interactions. Such simulations are being developed for a variety of applications, but the one attracting most current attention is the phenomenon of ringing. A further 10 papers were specifically related to development of tools for understanding and predicting this phenomenon. The report classifies these approaches, and provides brief observations of what has been achieved and some of the outstanding issues.

Another area highlighted in the report is the work presented on low frequency drift forces and responses. This subject continues to receive the attention of researchers, in view of its great importance to the performance of floating systems and some continuing areas of uncertainty in design procedures.

The report concludes with some general observations and recommendations concerning areas of interest to the HSE.

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1. BACKGROUND

The International Workshops on Water Waves and Floating Bodies were initiated by Professor D V Evans (Bristol University) and Professor J N Newman (Massachusetts Institute of Technology). The objective of the Workshops is to provide a forum for informal discussions of fundamental theoretical research, of mutual interest to both engineers and scientists, in the broad area of wave interactions with floating or submerged bodies. In addition to established experts in the field, younger workers and students are encouraged to participate. To preserve an atmosphere conducive to informal discussion, attendance is limited to the authors of accepted papers and the session chairpersons.

The technical programme is based upon concise talks which are similar in style to seminars and colloquia, except that background information which is well known by specialists working in the field is omitted. Work which is still incomplete may be presented, but material already published and widely disseminated is not reported. Papers are expected to be in the category of theoretical research, on wave interactions with floating or submerged bodies. Each speaker also provides an extended abstract suitable for distribution in a printed report of the Workshop.

This format has worked extremely well over the ten years during which the Workshops have taken place. The international spread of venues has also encouraged cooperation, and the incorporation of new blood into the research community.

The complete list of workshops to date is as shown in Table 1.

Number	Date	Venue	Organiser
1st	1986	Woods Hole USA	Prof J N Newman MIT
2nd	1987	Bristol UK	Prof D V Evans University of Bristol
3rd	1988	Woods Hole USA	Prof J N Newman MIT
4th	1989	Oystese Norway	Dr J Grue University of Oslo
5th	1990	Manchester UK	Dr P Martin University of Manchester
6th	1991	Woods Hole USA	Prof J N Newman MIT
7th	1992	Val de Reuil France	Dr R Cointe Bassin d'Essais des Carenes
8th	1993	St John's Canada	Dr J Pawlowski Institute for Marine Dynamics
9th	1994	Kuju Lake Japan	Prof M Ohkusu Kyushu University
10th	1995	Oxford UK	Prof R Eatock Taylor University of Oxford

Table 1
Lists of workshops to date

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2. OVERVIEW OF TENTH WORKSHOP

The Tenth International Workshop on Water Waves and Floating Bodies was held in Oxford from 2nd to 5th April 1995. A total of 58 papers was presented, and the 85 participants comprised the authors, session chairmen, and representatives of sponsoring organisations. The atmosphere was informal, and this together with the high level of the technical presentations ensured that the discussion (both during and outside the sessions) was deep and fruitful. This hallmark of these Workshops can undoubtedly be held responsible over the years for stimulating some major new thinking in the area of marine hydrodynamics. As usual, the papers were selected on the basis of extended abstracts. This year a record number of abstracts was submitted, and the organisers had to decline several. This is undoubtedly a sign of the good health of these Workshops and the vigour of the community they serve.

External support for the Workshop was provided by Exxon Production Research Company, Statoil, and the US Office of Naval Research. This financial support made it possible for the organisers to provide travel assistance to participants who could not otherwise have attended, and helped to defray the administrative costs of mounting the Workshop and distributing the Proceedings.

The Proceedings of the Workshop is a document of some 300 pages, containing each extended abstract (generally 4 pages long), plus a record of the discussion where this was submitted in written form. A list of the 58 abstracts with names of the authors is attached as Appendix 1 to this report. A list of all participants, with their contact addresses, is included here as Appendix 2.

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3. SIGNIFICANT AREAS OF DISCUSSION

The papers can for convenience be grouped into the topic areas shown in Table 2. In reality, of course, there is great overlap between several of these areas, and to some extent the division is arbitrary albeit indicative. For example, work described in several of the papers concerned with time domain analysis could be developed in the context of predicting ringing loads. These two areas attracted the largest share of submitted abstracts, and generated the greatest amount of discussion.

Topic	Number of Papers
Integral equation methodology	4
Time domain analysis	11
Low frequency responses	5
Wave impact	4
Ringing	10
Seakeeping and Resistance of ships	8
Multiple scattering/ many body problems	4
Non-linear waves	4
Miscellaneous	8
	58

Table 2
Categories of Papers

There is still significant interest in ship hydrodynamics and the submissions reflected that. Contributions on this topic were provided from the US, France, Japan, Russia, Germany and the Netherlands. Further developments were reported on slender-ship theory, and on progress in formulating reliable numerical methods for the Neuman-Kelvin problem (related to ship resistance). Much of the work reported on wave impact also has relevance to ships. There is clearly a great deal of work in progress internationally concerned with the development of reliable methods for time domain analysis of wave-structure interactions. Much of this has relevance to both ships and offshore structures, and the Workshop showed that there is still much to be gained by use of non-linear potential flow models in a wide range of offshore applications. Strong efforts on time domain simulation were evident in the contributions from the US and France, in addition to the developments reported from Japan, and the UK. Most of this work appears to be funded by governments, with some contributions to the US and UK programmes from joint industry projects.

4. RELATIONSHIP TO MANAGED PROGRAMME ON UNCERTAINTIES IN LOADS ON OFFSHORE STRUCTURES (ULOS)

The ULOS programme, in which the HSE is a participant, involves 11 coordinated projects in 7 UK universities, addressing the following themes related to loads on offshore structures:

- ◇ Non-linear waves and wave forces (4 projects)
- ◇ Viscous damping (4 projects)
- ◇ Wind loads (1 project)
- ◇ Mooring line dynamics (1 project)
- ◇ Experiments on a complete system (1 project)

In addition, the programme includes 4 industrially based Case Studies:

- ◇ TLP fatigue due to second order waves
- ◇ TLP extreme tether loading due to ringing
- ◇ Tanker response predictions
- ◇ Wind force predictions using CFD codes

The main overlap between the interests of the ULOS Programme and the Workshop concerns the ULOS work on non-linear waves and forces, and the first three case studies. Furthermore, 10 of the 85 Workshop participants are involved in the ULOS programme as investigators or sponsors. Two of the ULOS sponsors (Exxon and Statoil) also agreed to help sponsor the Workshop.

Areas of the Workshop which are relevant to the ULOS programme are the same areas as highlighted as being of particular interest to the HSE. Observations on these are given in the next section.

5. OBSERVATIONS ON AREAS OF INTEREST TO THE HSE IN PARTICULAR

5.1 SPRINGING AND RINGING

Two papers were given having particular relevance to the assessment of springing, both originating from the strong group in the Department of Ocean Engineering at MIT. The paper *Time-simulations of second-order forces* by Emmerhoff, Kim and Sclavounos tackled the problem of reliably predicting second order forces in random waves. It sought to overcome two practical difficulties: the interpolation of quadratic transfer functions (QTFs) to obtain adequate resolution in the bifrequency plane for spectral analysis; and the penalty of having to perform a double summation to simulate a time history using the QTFs. The solution was based on a B-spline representation of the QTF in each frequency direction, coupled with use of the Fast Fourier Transform. The authors were asked about the success of the B-spline representation for highly complex QTFs (eg. for a TLP), and answered that even in this case the number of terms in the expansion was reasonable. It should be noted, however that the emphasis of their work, and their experience with this method, was predominantly concerned with second order analysis applied to low frequency drift responses. Nevertheless, the ideas are worth exploring in the context of sum frequency springing.

In spite of the title of the paper by Sclavounos and Kim, *Third-order diffraction of surface waves by a time-domain Rankine panel method*, it is in fact also relevant to second order sum frequency loads. The approach is based on a time domain analysis, using an integral equation based on the Rankine source. This involves use of a mesh over the free surface, and the need for careful attention to provision of a beach to prevent reflections. The latter point raised a number of questions (and indeed it was a significant topic in several other presentations concerned with time domain analysis). If it can be clearly demonstrated that the beach does not corrupt the free surface pressure field which drives some of the important second order effects, this methodology could provide useful comparisons for the frequency domain analysis. Such comparisons build up confidence that reliable simulations of springing are available to industry.

The papers on ringing can be conveniently divided into those based on fully non-linear simulation of the three dimensional diffraction problem, and those using some approximations - based on a variety of applications of perturbation expansions - to deal with the non-linearity. The latter category includes the following:

(i) Two papers on slender body theory

Hydrodynamic loads on a cylinder moving unsteadily in a 3D non-uniform flow field, by Galper and Miloh, was not apparently motivated by ringing, but it is certainly relevant. The authors were dealing with a more general case than that of a slender body, but under conditions of a weakly non-linear flow their results coincide with those of Rainey for the force on a moving cylinder. The analogy with Rainey's work was further explored in the discussion.

The paper *The hydrodynamic load at the intersection of a cylinder with the water surface*, by Rainey, emphasised the progress that he and Jefferys have made in providing the reconciliation between the results of slender body theory and the FNV theory (in which wave amplitude : radius is assumed to

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be of order 1). In essence, they have discovered an additional term which has to be incorporated in the wavy lid approach, to take account of local distortion of the free surface at the intersection between the wave and a cylinder. The results are the same as those from the FNV theory in the limiting case of small waves. Rainey suggests that this means the FNV theory is essentially equivalent to what can be obtained by Stokes' expansions (where wave amplitude : radius tends to zero) and so not applicable to the case of very steep waves.

(ii) Three papers concerned with FNV theory and related analysis.

Ringing loads on gravity based structures, by Faltinsen, reviewed the FNV theory, and extended this to the case of a monotower with non-circular cross sections varying along the axis. There was an interesting discussion of experimental results, and of the apparent importance to ringing of hydraulic bores travelling around a vertical cylinder and colliding at the down-stream side when the crest is at the axis of the cylinder (similar effects have been observed in the experiments undertaken at Edinburgh University, and discussed at the ULOS Steering Committee in March). There was also some discussion of how experimental results compared with those from third order diffraction theory (as published by Malenica and Molin in Journal of Fluid Mechanics). In regular waves of frequency ω, it appears that the amplitudes of measured forces at 3ω agree well with third order results in the range $0<ka<0.4$ (where k is wave number and a is cylinder radius), but the phases are quite different (whereas both amplitude and phase agree for the 2ω components). Nor, however, are the measured phases in agreement with the results from the FNV theory. (It may be noted that the slender body theory is consistent with the third order results, in the limit of long wave length).

The paper by Newman and Lee, *Runup on a vertical cylinder in long waves,* extends the FNV theory to permit prediction of wave run-up on a vertical circular cylinder, and expressions are given to third order in wave amplitude. A comparison is also given of results from the second order expression in the long wave limit with results from conventional second order diffraction theory (The former is a very simple expression, involving only simple terms originating in the first order potential - it provides a reasonable approximation to the run-up below $ka=0.1$). It should be possible to extend the second order expression to give a simple approximation to the wave field in the close proximity of the cylinder, and thereby to permit qualitative comparison with experimental observations. This, however, has not yet been done. To improve the approximation, and extend it to higher ka, it would be necessary to incorporate the far field forcing effect which generates the second order potential. But this seems rather difficult. It is also necessary to resolve an apparent inconsistency observed between the FNV predictions of travelling waves around the cylinder circumference, and the experimental observations.

Zhu's paper, *Numerical method for nonlinear wave loads on a truncated cylinder,* is based on the fundamental assumptions of FNV, but implements them in a numerical scheme to permit extension to the case of complex geometries such as a complete TLP. Results were successfully compared with the corresponding analytical solution for a single fixed vertical cylinder. As yet, however, no results appear to have been computed for structures which can move. It was suggested in the discussion that realistic motions of, say, a TLP would substantially reduce some of the critical components of force predicted by FNV.

(iii) One paper based on numerical analysis by third order Stokes' expansion.

This is the paper by Sclavounos and Kim, referred to earlier in the context of springing. Results are in a very preliminary form, and although the possible application to ringing is clear, the accuracy of the approach still needs confirmation. It has yet to be demonstrated that the resulting algorithms would be substantially more effective than the fully non-linear approaches described next.

The objection to the above methods is that the mechanisms exciting ringing appear to be highly non-linear (precluding the use of conventional perturbation approximations); and the "fat body" effect seems likely to be important in modifying the local wave field and hence the forces. This thinking is reflected in four of the Workshop papers: one from the MIT group, one from Sirenha (France) and two from the ULOS project A3 based at London and Oxford. These are all concerned with fully non-linear simulation of the diffraction problem, and can be considered as three separate approaches.

(i) *Fully-nonlinear three-dimensional interaction between water waves and a surface-piercing body*, by Xue and Yue (MIT)

This boundary element approach had previously been applied to a study of the kinematics of steeply overturning three-dimensional waves, but substantial work was required to extend it to the case of surface piercing bodies. Some significant advances were reported, including good comparisons with the third order diffraction theory of Malenica and Molin, and some simulations of the all important circumferential waves which looked qualitatively similar to the experimental observations from tests at Marintek. The approach involves a complex matching between the non-linear flow regime near the cylinder and a linearised solution in the outer domain. Testing the validity of this approach, and gaining experience in selecting the parameters which govern the optimum matching, will require further development.

(ii) *Nonlinear wave loads and runup upon a surface piercing cylinder*, by Ferrant (Sirenha)

In this boundary element approach, the outer boundary is modelled by an absorbing beach (having similarities to that of Sclavounos and Kim, but Ferrant's approach is fully non-linear.) Again good comparisons have been obtained with the third order force results of Malenica and Molin, though the comparisons of run-up were less satisfactory. The author emphasised that the method was computationally very intensive (computations of 50 hours on a VAX 900 mainframe, which admittedly is an old machine). He highlighted an important next stage as the extension to the case of moving bodies.

(iii) The finite element approach under development in ULOS project A3 (Oxford and UCL)

Analysis of wave-body interactions using adaptive finite element meshes, by Greaves, Borthwick, Eatock Taylor and Wu

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Nonlinear wave loading on a floating body, by Wu, Ma and Eatock Taylor

The two papers highlighted the importance of adaptive mesh generation to enable the free surface and body intersection to be properly represented; and the development of a special procedure for calculating non-linear forces when the body is moving. The work is at an earlier stage than the two boundary element studies referred to above, but it is believed to have greater potential for application to a wide range of problems. This view held by the authors was confirmed in the discussion.

The great interest in non-linear hydrodynamic loading, and particularly in ringing, is evident from the above. Also evident is a willingness to exchange results, and to discuss possible discrepancies. This is especially important in the validation of new methods, and in building up confidence in their applicability. An example of this is the comparative study organised by DNV, to which several of the above authors (including the ULOS group) contributed. Further comparisons between the ULOS project, the MIT group, and the investigation by Ferrant, will bring additional benefits.

5.2 LOW FREQUENCY WAVE DRIFT FORCES AND RESPONSES

There were five papers which should be highlighted, with the emphasis being on prediction of low frequency damping (ie. wave drift damping). This is especially relevant in the context of floating production systems, FPSO's etc.

(i) *Analysis of the forces and the responses of floating bodies with a slow yaw-motion* by Finne and Grue (University of Oslo)

This extended the systematic investigations by Grue and Palm to deal with the case of a yawing vessel. The angle of yaw is assumed to be arbitrary, but the yaw rate is much smaller than the incident wave frequency (analogous to the low forward speed assumption which underlies prediction of surge drift damping). The authors had previously published the theory for the diffraction problem (at the BOSS 94 Conference), and this paper provided the complementary formulation for the radiation problem. It can be expected that this approach will be used in an industrial setting before very long.

(ii) *Interaction of freely oscillating vertical cylinders with waves and slow current* by Kinoshita and Bao (University of Tokyo)

This paper combined two approaches which had previously been used separately. One is a method for dealing with multiple wave scattering between vertical cylinders. The other is a method for solving the wave-current problem indirectly, without the need for a solution of the velocity potential term which is (at first order) proportioned to the current (or forward speed for a drifting body). No numerical results are given in the paper, but some interesting comparisons with experiments were shown in the presentation.

(iii) *Interaction of a large three-dimensional body with waves and currents by THOBEM* by Kim and Kim (Texas A & M University)

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This differed from the usual approach, in dealing with the hydrodynamic analysis directly in the time domain. The acronym stands for Time domain analysis based on a Higher Order Boundary Element Method. It is not clear that the method provides any improvement over the more conventional frequency domain approach (such as was developed in the BOFCOS programme in a project at Oxford).

(iv) *How to remove secularity in the solution of diffraction-radiation problems with small forward speed* by Malenica (Institut Francais du Petrole)

This concerned a somewhat abstruse potential difficulty in the conventional frequency domain computation of wave drift damping. In practice the difficulty is likely to be more serious for structures which are large relative to the wave length (where we are here referring to gross dimension - ie. column spacing - rather than element dimensions - ie. column diameter). Unfortunately, however, no results were given to clarify whether the difficulty causes significant errors in application of the conventional method to structures of current practical interest in, say, the UK Continental Shelf.

(v) *An epistemological innovation in water wave theory: numerical results as a benchmark for analytical results* by Aranha (EPUSP, Sao Paolo)

The background to the ironical title is the grief felt by this author that his formula for wave drift damping has not been accepted by the international community of hydrodynamicists. The reason for its rejection so far seems to be that his analytical predictions of drift damping for a body oscillating at wave frequencies disagree with independent numerical predictions based on the more conventional approach (although there is agreement for fixed bodies). The difficulty is that the theory leading to his formula has been very hard to confirm or disprove. If one assumes that it is correct, or that a corrected formula of equivalent simplicity can be obtained, this will bring considerable practical benefits to the prediction of low frequency damping. In essence, it becomes possible to compute wave drift damping simply from a first order diffraction analysis, without the need to incorporate forward speed (or current) in that analysis. The effect of forward speed is incorporated by a multiplicative factor and use of the encounter frequency.

In concluding these observations on the papers concerned with low frequency drift, it is worth remarking that there is some interaction with ULOS project B2 "Prediction of Slow Drift Damping", based at Imperial College (Prof JMR Graham). The emphasis of the latter project is on taking account of flow separation, but second order drift damping due to potential flow effects is also part of the investigation.

5.3 INTERNAL WAVES IN A STRATIFIED OCEAN

There has been spasmodic interest in this topic in previous workshops, and it might have been expected that there would have been more papers this year. Indeed more abstracts were submitted than the organisers were able to accept. The one paper presented was the following:

A time-stepping model for two-dimensional non-linear interfacial waves by Friis, Rusas, Grue and Palm (University of Oslo).

The theory is fully non-linear, and was applied to two examples. One of these allowed comparison with some published experimental results for a solitary wave at an interface between freon and water. The new theory was found to give much better predictions than other approaches based on weakly non-linear theory. The other example was relevant to a submerged obstacle in a fjord, with a thin upper layer of fresh water above a thicker salt water layer. The results showed the deformation of a solitary wave as it ran on the lower layer over the obstacle. The authors also point out the need to include additional mechanisms such as viscosity and diffusion between the layers in the case of large amplitude solitary waves, because of the sensitivity of the ideal flow solution to Kelvin-Helmholtz instability.

6. CONCLUSIONS AND RECOMMENDATIONS

It may be concluded from the above that the Workshop was highly successful, and furthermore that it covered several areas which would appear to have interest for the HSE in the context of UK offshore developments. It is probably no exaggeration to state that most of the key groups internationally undertaking analysis and numerical simulation in this area were represented at the Workshop. After the UK (23 participants) the largest number were from the US (22) followed by France (9), Norway (7) and Japan (6). It can be concluded the UK researchers would benefit considerably from attendance at subsequent workshops, to track the latest developments in this area before they are formally released for publication. Plans have been made for the next three annual workshops, as listed in Table 3.

NUMBER	DATE	VENUE	ORGANISER
11th	1996	Germany	Dr V Bertram Institut fur Schiffbau, Hamburg
12th	1997	France	Prof B Molin Ecole Superieure d'Ingenieurs de Marseille
13th	1998	The Netherlands	Prof A J Hermans Delft University of Technology

Table 3
Provisional list of future workshops

One of the areas of considerable interest in the Workshop was that of low frequency wave drift forces and responses. There has been considerable past activity in UK universities in this field (eg. at Newcastle, Oxford and Imperial College), but support for this in the UK has waned. It is clear there remains considerable international interest, and it may be expected that this continues to have a high research profile as the requirements of different types of floating production system are investigated. There still remain outstanding technical problems (eg. low frequency behaviour in directional seas), and the need for appropriate design procedures.

There was also evidence in the Workshop of very much interest, and progress being made, in the time domain simulation of non-linear waves and wave forces. This is currently perhaps of greatest relevance to the HSE's interest in ringing, but the applications are much wider. If any new hydrodynamic phenomenon is identified as being potentially hazardous (as was ringing a few years ago), it is very likely that simulations could in due course be developed to provide a major insight into its occurrence under the conditions observed. There exists a need for further work to enhance the predictive capability in this general area. A small but important part of this is to encourage the exchange of results between different research groups, so that confidence may be increased in the effectiveness of the various computational developments. This means the release of data, and support for researchers to meet together.

In the context of ringing itself, the Workshop provided the forum for a valuable debate between the protagonists of different descriptions of the phenomenon: by slender body theory, by the FNV analysis, and by full non-linear simulation. From the debate it seems clear to this writer that a complete understanding will only be obtained from the fully non-linear approach. But this may not be appropriate as a design tool. It seems vitally important to be able to delineate the range of acceptable accuracy of the simpler approaches, and steps should be taken in this direction.

A spin-off from the work on time domain simulations, and the associated work on ringing, will be better estimates of the local free surface behaviour close to structures. This is particularly important in the context of the new designs of floating platform having reduced air gap. Tools are therefore becoming available, and complementary experiments can be undertaken, which can be brought to bear on the design of such structures.

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5. **Contento, G.**: A numerical wave tank for the 2D free floating body problem

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7. **Doutreleau, Y.**: Resonances for the 3D Neumann-Kelvin problem in the case of an immersed body

8. **Emmerhoff, O.J., Kim, S. and Sclavounos, P.D.**: Time-simulations of second-order forces

9. **Evans, D.V. and Fernyhough, M.**: Edge waves along periodic coastlines

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11. **Farina, L. and Martin, P.**: Interaction of water waves with floating and submerged circular plates

12. **Ferrant, P.**: Nonlinear wave loads and runup upon a surface piercing cylinder

13. **Finne, S. and Grue, J.**: Analysis of the forces and the responses of floating bodies with a slow yaw-motion

14. **Friis, A., Rusås, P-O., Grue, J. and Palm, E.**: A time-stepping model for two-dimensional nonlinear interfacial waves

15. **Galper, A. and Miloh, T.**: Hydrodynamic loads on a cylinder moving unsteadily in a 3D non-uniform flow field

16. **Gentaz, L., Alessandrini, B. and Delhommeau, G.**: Numerical simulation in viscous fluid of a two-dimensional forced heaving cylinder on a free surface

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24. **King, A.C.**: The initial development of a jet

25. **Kinoshita, T. and Bao, W.**: Interaction of freely oscillating vertical cylinders with waves and slow current

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27. **Korsmeyer, F.T. and Bingham, H.B.**: Seakeeping computations in following waves

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31. **Malenica, S.**: How to remove secularity in the solution of diffraction-radiation problems with small forward speed

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45. **Sclavounos, P.D. and Kim, Y.W.**: Third-order diffraction of surface waves by a time-domain Rankine panel method

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51. **van Daalen, E.F.G., van Groesen, E. and Pudjaprasetya, S.R.**: Solitary wave splitting due to a mildly sloping bottom

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53. **Xue, M. and Yue, D.K.P.**: Fully-nonlinear three-dimensional interaction between water waves and a surface-piercing body

54. **Yeung, R.W. and Yu, X.**: Unsteady waves near a vertical circular cylinder in a viscous fluid

55. **Zhang, S., Storhaug, G. and Yue, D.K.P.**: Wave loads on a vertical elastic wall

56. **Zhao, R.**: Linear analyses of a 2D floating and liquid filled membrane structure in waves

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