Proceedings of EWTEC 2021

The 14th European Wave and Tidal Energy Conference was held from 5-9 September 2021 at the University of Plymouth. For the first time, in response to the global pandemic, EWTEC was held in a hybrid format, allowing attendees to present online as well as in person. There were 12 different thematic tracks:

- Wave resource characterization
- Wave hydrodynamic modelling
- Wave device development and testing
- Tidal resource characterization
- Tidal hydrodynamic modelling
- Tidal device development and testing
- Structural mechanics: materials, fatigue, loadings
- Station-keeping, moorings and foundations
- Operations and maintenance
- Grid integration, power take-off and control
- Environmental impact and appraisal
- Economical, social, legal and political aspects of ocean energy

From the 403 abstracts initially submitted, 236 full papers were finally selected by a peer-review process, during which 48 Track Directors requested 963 single blind reviews and 427 reviews were finally carried out. These papers comprise the present proceedings, totalling 1952 pages.

This USB flash drive contains the searchable conference proceedings.

On behalf of the EWTEC Committee, I would like once again to warmly thank all the reviewers and Track Directors for their essential and voluntary work, and all authors for their contribution to the scientific content of the 14th EWTEC.

I would also like to sincerely thank our Sponsors for their valuable support to the conference.

Professor Deborah Greaves

Chair of EWTEC 2021

1 September 2021

ISSN 2309-1983

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ISSN 2309-1983

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A post-processing technique for addressing 'irregular frequencies' and other issues in the results from BEM solvers

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Abstract—**Within the wave energy community, hydrodynamic coefficients obtained from boundary element methods (BEMs) are commonly used to predict the behaviour of wave energy converters (WECs) in response to incident waves. A number of commercially-available BEM solvers exist, with a number of open-source alternatives also available. While open-source solvers have an obvious cost advantage compared to their commercial counterparts, the results from such solvers are often susceptible to so-called 'irregular frequencies', which arise from ill-conditioning in boundary integral problems, and result in large under- or over-estimation of hydrodynamic parameters at certain excitation frequencies. Furthermore, while commercial solvers may employ techniques to suppress the effects of irregular frequencies, such solvers may, under certain circumstances, exhibit other problems in the hydrodynamic results produced. For example, the results obtained for the added mass at high frequencies, and the infinite frequency added mass for a water column, may be incorrect. The current work first focusses on an approach to remove the effects of irregular frequencies from the results obtained for the radiation damping of a particular WEC geometry. The use of radiation damping results to obtain values for the added mass, through the use of the Ogilvie relations, is then considered. The technique described herein has been implemented in BEMRosetta, an open-source tool which allows a user to view the results from various BEM solvers, as well as converting input files between solvers. The results presented in this paper have been obtained using the BEMRosetta implementation.**

Index Terms—**Boundary element methods, Irregular frequencies, Numerical modelling**

I. Introduction

NUMERICAL models of proposed WECs are an essential design tool for the development of the ocean energy industry, not least for the prediction of the likely energy generated by a WEC, and for the design of suitable model-based controllers/estimators/etc for WECs. The behaviour of a WEC may be modelled in either the frequency or time domains, and in single or multiple degrees of freedom, using the equations of motion for the WEC. The equations of motion are parameterised using frequency-dependent hydrodynamic coefficients including radiation damping and added mass. The hydrodynamic coefficients for a given geometry may be obtained from BEM solvers. A number of commercial solvers exist, including WAMIT [1], AQWA [2], and WADAM [3]. However, such commercial tools are relatively expensive, and many early-stage developers, and academic researchers, may prefer to make use of open-source BEM solvers, notably Nemoh [4], and, more recently, HAMS [5] and Capytaine [6] which can also provide satisfactory results [7]. All BEM solvers, commercial and open-source, may suffer from so-called irregular frequencies arising from ill-conditioning in the boundary integral problem, which can result in significant localised over- and under-predictions of the hydrodynamic parameters, localised at specific frequencies. It is important to note that, while this phenomenon is commonly referred to as an *irregular frequency*, (and this term is used to refer to the phenomenon throughout the current work), such localised over- and under-predictions of the hydrodynamic parameters are in no way due to the frequency, and indeed the frequency values themselves are in no way irregular. Rather it is the values for the hydrodynamic parameters around these frequencies that behave in an irregular manner compared to the adjacent values. Such over- and under-predictions, if left unattended, will result in inaccuracies in the predictions of the behaviour of a device modelled in the frequency domain in and around the irregular frequencies. Furthermore, Cummins' equation [8], often used to model WECs in the time domain, estimates radiation forces using a convolution between the velocity or acceleration of the WEC and the corresponding impulse response function (IRF) of the radiation forces. The IRF of the radiation force in the time domain is commonly determined using either the frequency-dependent radiation damping or added mass, obtained from BEM solvers, in accordance with the Ogilvie relations [9]. The process of obtaining the IRF requires integration of either the added mass or radiation damping over a range of frequencies from zero to infinity. In practice, such integrations are truncated at a suitably high frequency, but any errors in

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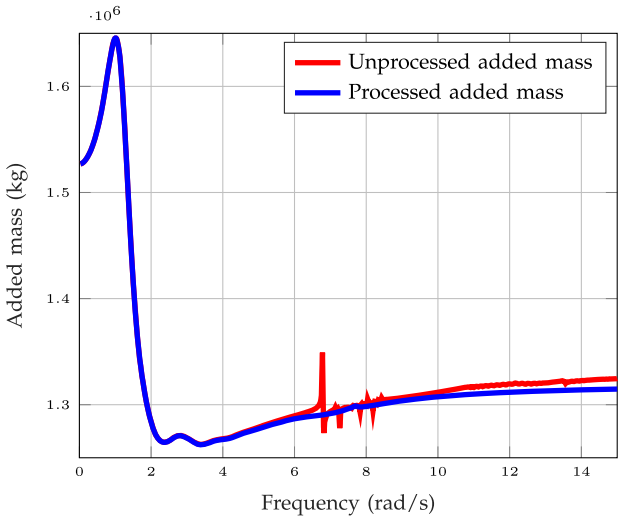

Fig. 16. Added mass curves for a cube before and after the effects of irregular frequencies have been removed.

to mitigate the effects of irregular frequencies on the exciting forces. One technique which is currently being investigated is the potential use of the 3-D Haskind relations [12] to obtain the exciting force from the radiation damping after the effects of the irregular frequencies on the radiation damping have been reduced for symmetrical bodies.

VII. Conclusion

It is the hope of the authors that the post-processing techniques described herein, and implemented in the open-source tool BEMRosetta, may prove to be of use to the wider wave-energy community. The techniques have been extensively tested on multiple data sets generated from both commercial and non-commercial BEM solvers, for a wide range of geometries, in all rigid body modes of motion. To date, the techniques have proven robust and reasonably successful in removing the effects of irregular frequencies from the hydrodynamics obtained from BEM solvers, and in addressing the high-frequency added mass issues for OWCs. Although not shown here, the techniques have also been tested on the results obtained for the coupled hydrodynamics between different modes for rigid bodies, and between multi-body systems. However, a number of critical parameters required by the algorithms are not determined *a priori*, but are based on the experience of the authors. Should users identify data sets where the techniques fail to improve the results directly obtained from BEM solvers, totally fail to remove the effects of irregular frequencies, or should any issues arise with the use of these tools, the authors would welcome correspondence on the matter.

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