singularities are dealt with by a coordinate transform.

2. For the integration on the free surface, a forward prediction method is proposed for computing the second order potential in a big area. By this method the integration on the free surface for different source points is carried out outward from the body by successively subtracting and accumulating the quadratures in each forward moving step, rather than integrating on the whole free surface for each point individually. This is very significant for the calculation of third order forces, for which the second order potential is needed on the whole free surface or in a very big area.

3. Attention is also paid for dealing with the integration of singularities on the free surface. In this report, a method is proposed to add and subtract an integration of the singular kernel of the ring-source in the nearby of the source point. Thus, the infinite summation of the ring-source can be truncated at a big number, and integrations with the singular kernel can be localized to lower computing burden.

4. Numerical examination is made on the forward prediction method for functions S_1 and S_2 by comparing with the direct integration method. The numerical results show that for S_2 the forward prediction method is uniformly available; for S_1, the forward prediction method is uniformly available for its zero eigen-mode, but for other eigen-modes it can only be used in certain steps. Numerical results also show that for lower eigen-modes, the predictable distance is longer; and for higher eigen-modes, the distance is shorter.

5. A predicting and correcting method is used for computing S_1 and S_2 repeatedly, which is to predict them by the forward prediction method for a certain steps, then correct them by the direct integration method. The number of predicting steps is determined by previous numerical examination, and is different for each modes. The method can save a lot of computing effort, and can be used to compute the second order potential over the big area, including the free surface.

6. Comparison with other published results is made on second order force on different cylinders and the second order diffraction potential to validate the numerical code. Comparison shows that the present results have a good agreement with others. The program is also used to compute pitch moment on the uniform and truncated cylinders. Results show that the difference is evident between the moments on uniform and truncated cylinders in the same water depth.

7. The numerical code has been used to compute the wave elevation from second order diffraction potential around uniform and truncated cylinders in the same water depth and the same wave conditions. The results shows that at the calculation frequency, the second order wave diffractions from the two cylinders are quite different. It suggests that we should be careful to use an array of uniform cylinders as a substitution of actual TLPs when considering ringing phenomenon in long waves.

8. After getting the second order potential on the free surface by the present method for axisymmetric bodies, we can obtain the third order forcing term on the free surface. Then, the calculation of third order force is straightforward, such as by an indirect method for second order forces.

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References

1. Chau F.P. and Eatock Taylor, R., Second-order wave diffraction by a vertical cylinder, Jour. Fluid Mech., Vol.240, pp.571-599 (1992).
2. Eatock Taylor, R. and Chau F.P., Wave diffraction–some developments in linear and non-linear theory, Jour. Offshore Mech. and Arctic Engng, Vol.114, pp.185-94 (1992).
3. Eatock Taylor, R. and Hung, S.M., Second order diffraction forces on a vertical cylinder in regular waves, Applied Ocean Res. Vol.9, pp.19-30 (1987).
4. Fenton, J.D., Wave forces on vertical bodies of revolution, Jour. Fluid Mech., Vol.85, pp.241-255 (1978).
5. Huang, J.B. and Eatock Taylor, R., Semi-analytical solution for second-order wave diffraction by a truncated circular cylinder in monochromatic waves, Vol.319, pp.171-196 (1996).
6. Hulme, A., A ring source integral equation method for the calculation of hydrodynamic forces exerted on floating bodies of revolution, J. Fluid Mech. Vol.128,pp.387-412 (1983).
7. Hunt, J.N. and Baddour, R.E. The diffraction of nonlinear progressive waves by a vertical cylinder, Quart. J. Mechanics and Applied mathematics, Vol.34, No.1, pp.69-88 (1981)
8. Kim, M.H. and Yue, D.K.P., The complete second-order diffraction solution for an axisymmetric body. Part 1. Monochromatic incident waves, Jour. Fluid Mech., Vol.200, pp.235-264 (1989).
9. Kriebel D.L., Nonlinear Wave Interaction with a Vertical Circular Cylinder. Part 1:Diffraction Theory, Ocean Engineering, Vol.17, No.4, pp345-377 (1990).
10. Malenica, S., Diffraction de troisieme order et interaction houle-courant pour un cylindre vertical en profonfeur finie. PhD dissertation, Paris 6 University (in French) (1994).
11. Malenica, S. and Molin, B., Third-harmonic wave diffraction by a vertical cylinder, Jour. Fluid Mech., Vol.302, pp.203-229 (1995).
12. Molin, B., Second-order diffraction loads upon three dimensional bodies, Applied Ocean Res., Vol.1, pp.197-202 (1979).
13. Newman, J.N., The second-order wave force on a vertical cylinder, to be published in Jour. Fluid Mech., (1996).
14. Telles, J.C.F., A self-adaptive co-ordinate transformation for efficient numerical evaluation of general boundary element integrals, Intl. J. Numer. Meth. Engng., Vol.24, 959-973 (1987).
15. Teng, B. and Eatock Taylor, R., New higher-order boundary element methods for wave diffraction/radiation, Applied Ocean Research, Vol.17, pp.71-77 (1995).
16. Teng, B and Kato, S., An effective method for second order potential–towards the calculation of third order forces, 11th Workshop on Water Waves and Floating Bodies, Hamburg (1996).
17. Watson, G.N., Theory of Bessel Functions, Cambridge University Press (1966).
18. Kato,S. and et al., Ringing Response of a Tension Leg Platform -Theoretical and experimental analyses of a third order force on TLP -, Journal of Naval Architecture of Japan, Vol.180, pp.175-192 (1996)