

Computations of heave added mass and damping coefficients of some axisymmetric bodies using WAMIT

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18 November 2013

The heave added mass and damping coefficients of some axisymmetric rigid bodies are computed using the three-dimensional radiation/diffraction code WAMIT [7], which is based on the boundary element method.

The higher-order panel method is used, whereby the velocity potential on the body is represented by B-splines in a continuous manner. In most applications, this provides a more accurate solution compared to the low-order method, whereby the geometry of the body is represented by an ensemble of flat quadrilateral panels, and the velocity potentials are approximated by piecewise constant values on each panel.

The panel models are prepared using the CAD program MultiSurf [6]. The geometry is imported directly from MultiSurf into WAMIT by linking to the MultiSurf kernel during execution of WAMIT. The link between WAMIT and MultiSurf allows the user to override floating-point values in the definition of any entity in the model. This allows a single model (parametrically constructed) to be analysed in a wide variety of configurations without opening the model and making any changes in MultiSurf.

The option to remove the effects of irregular frequencies is used. Also, cosine spacing is used to provide better resolution in regions with high gradients. Patches are automatically subdivided into panels such that the maximum length of each panel is approximately equal to a specified parameter. By decreasing this parameter, systematic convergence tests can be made easily without changing any other parameters or inputs.

Hemisphere

Results are given in terms of standard non-dimensional added mass μ and radiation damping λ values, which are defined as

$$\mu = \frac{m}{\rho V} \quad (1)$$

$$\lambda = \frac{R}{\rho V \omega}, \quad (2)$$

where m and R are the dimensional added mass and radiation damping coefficients, ρ is the density of sea water, V is the displaced volume, and ω is the angular frequency.

In Figure 1 the computed values are plotted against non-dimensional wave number ka , where $k = \omega^2/g$ and a is the radius of the hemisphere. Also plotted in the same figure are the values calculated by Hulme [3]. The agreement is found to be excellent.

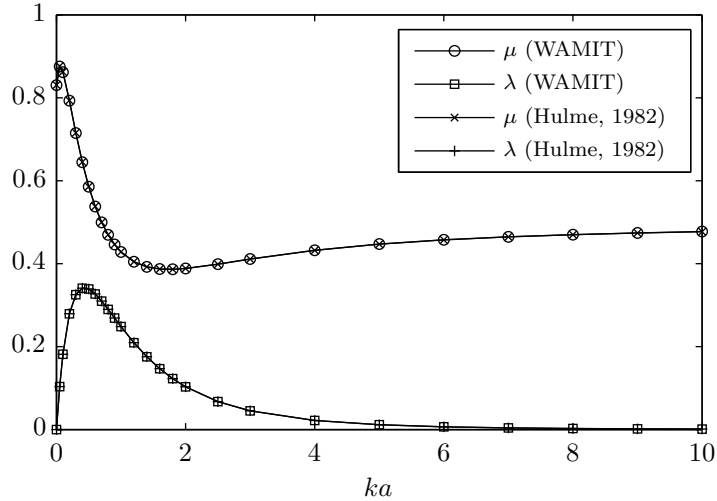


Figure 1: Comparison of non-dimensional added mass and radiation damping coefficients for a floating hemisphere.

Bullets

By bullets we mean vertical cylinders with hemispherical bottoms. We compute the added mass and damping coefficients for a series of bullets with different ratios of cylinder height to radius. Results are compared with those computed by Chaplin [1] using the semi-analytical theory of Fenton [2] and Isaacson [5], and are plotted in Figures 2 to 7. They are generally in very good agreement, but with increasing ratio of cylinder height to radius, it is noticed that the added mass values start to differ, especially at large ka . Results are compared also with those of Hulme [4], for cylinder height to radius ratio of 1.055 (Fig. 8). They are shown to be in very good agreement, except for minor discrepancies at low ka , which is suspected to be interpolation error.

Cones

Similar comparisons are shown in Figures 9 to 16 for cones with different half angles. The agreement found for the cones are not as good as compared to the bullets. With increasing half cone angle, less agreement is found between the two sets of data.

Results are also compared with those of Hulme [4], for a cone with wall gradient of 6, which is equivalent to cone half angle of 9.46 degrees. The results are plotted in Fig. 17. Suspecting the disagreement is due to the pointed base of the cone, we also perform the computations for the same cone truncated at

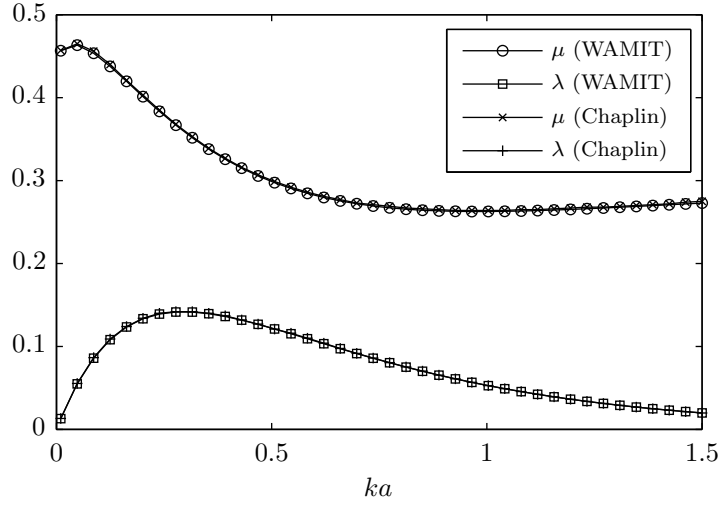


Figure 2: Comparison of non-dimensional added mass and radiation damping coefficients for a bullet with cylinder height to radius ratio of 0.5.

the base. The comparison is shown in Fig. 18 for cones truncated 1/10 from the base and 1/5 from the base. No significant differences are observed for the WAMIT results, however, except that the added mass and damping values are slightly higher than those of the full cone, which is expected.

Fig. (19) shows the comparison of Hulme’s and WAMIT results for the same cone, where the two additional WAMIT results are obtained using low-order panel method with two different number of panels. The added mass and damping values obtained using the model with higher number of panels agree well with those obtained using the higher-order panel method. As the number of panels is reduced, the values become lower, and are in fact closer to the values obtained by Hulme.

References

- [1] J. R. Chaplin, personal communication, 2013.
- [2] J. D. Fenton, “Wave forces on vertical bodies of revolution,” *Journal of Fluid Mechanics*, vol. 85, pp. 241–255, 3 1978. [Online]. Available: http://journals.cambridge.org/article_S0022112078000622
- [3] A. Hulme, “The wave forces acting on a floating hemisphere undergoing forced periodic oscillations,” *Journal of Fluid Mechanics*, vol. 121, pp. 443–463, 1982.
- [4] —, “A ring-source/integral-equation method for the calculation of hydrodynamic forces exerted on floating bodies of revolution,” *Journal of Fluid Mechanics*, vol. 128, pp. 387–412, 1983.
- [5] M. d. S. Q. Isaacson, “Fixed and floating axisymmetric structures in waves,”

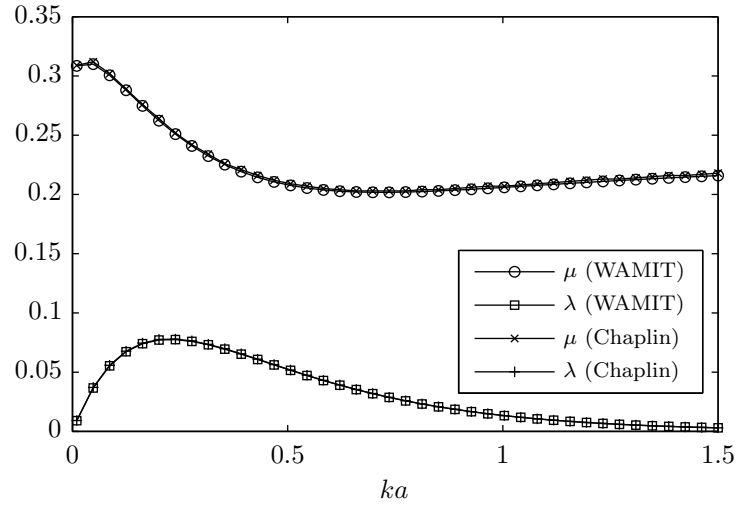


Figure 3: Comparison of non-dimensional added mass and radiation damping coefficients for a bullet with cylinder height to radius ratio of 1.

Journal of the Waterway Port Coastal and Ocean Division, vol. 108, pp. 180–199, 1982.

- [6] MultiSurf, AeroHydro, Inc., Southwest Harbor, Maine, 2013, version 8.5. [Online]. Available: <http://www.aerohydro.com>
- [7] WAMIT, WAMIT, Inc., Chestnut Hill, MA, 2013, version 7.0. [Online]. Available: <http://www.wamit.com>

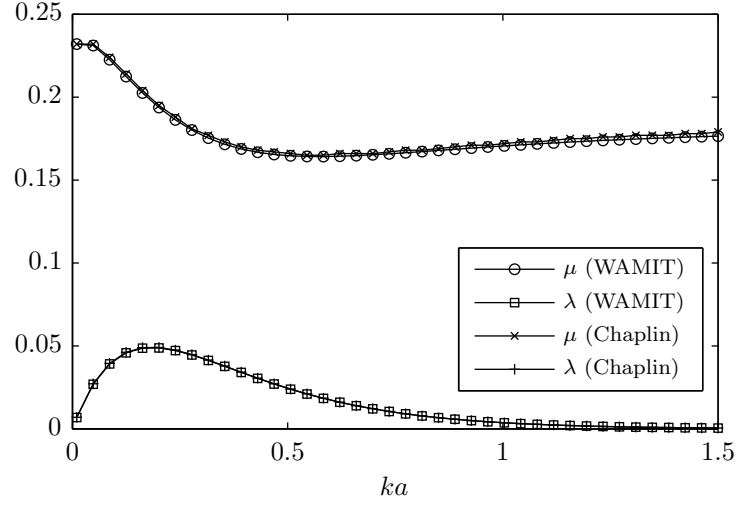


Figure 4: Comparison of non-dimensional added mass and radiation damping coefficients for a bullet with cylinder height to radius ratio of 1.5.

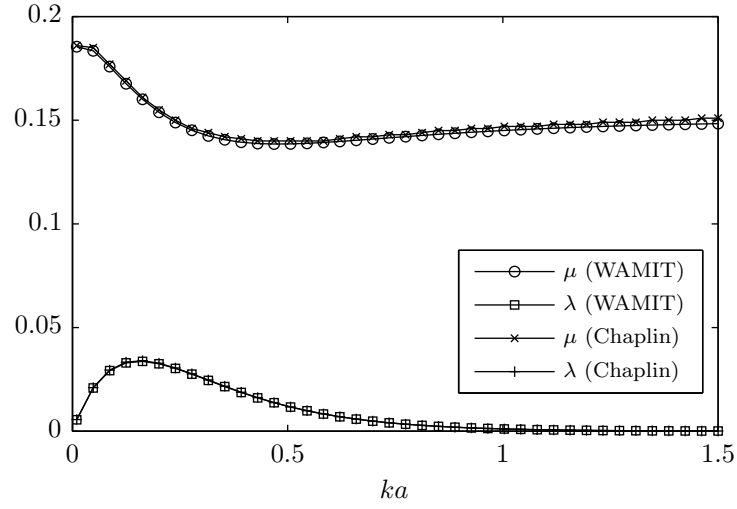


Figure 5: Comparison of non-dimensional added mass and radiation damping coefficients for a bullet with cylinder height to radius ratio of 2.

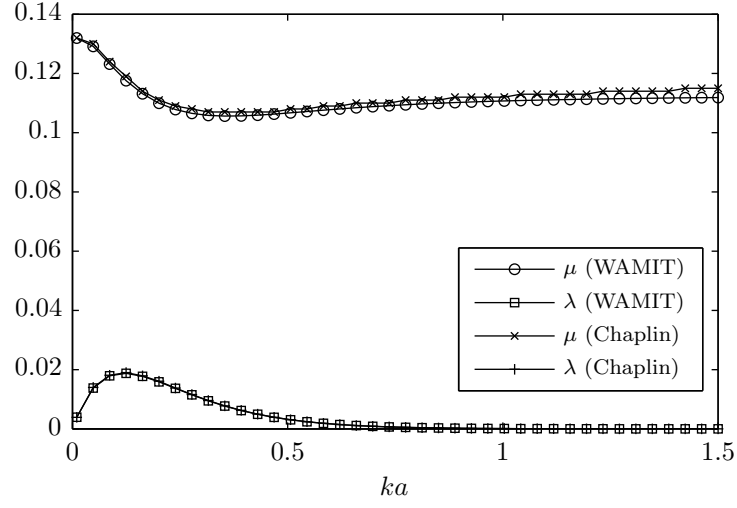


Figure 6: Comparison of non-dimensional added mass and radiation damping coefficients for a bullet with cylinder height to radius ratio of 3.

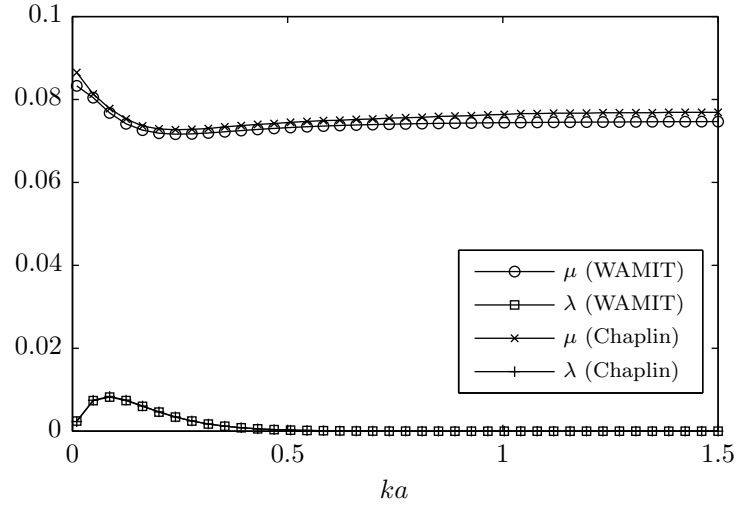


Figure 7: Comparison of non-dimensional added mass and radiation damping coefficients for a bullet with cylinder height to radius ratio of 5.

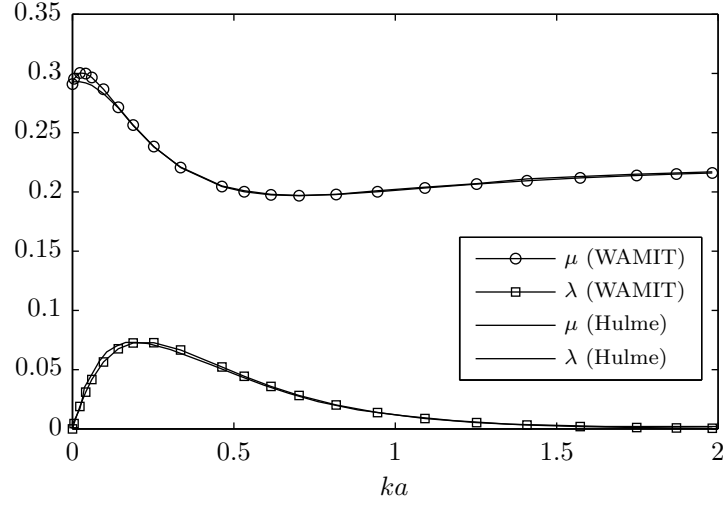


Figure 8: Comparison of non-dimensional added mass and radiation damping coefficients for a bullet with cylinder height to radius ratio of 1.055.

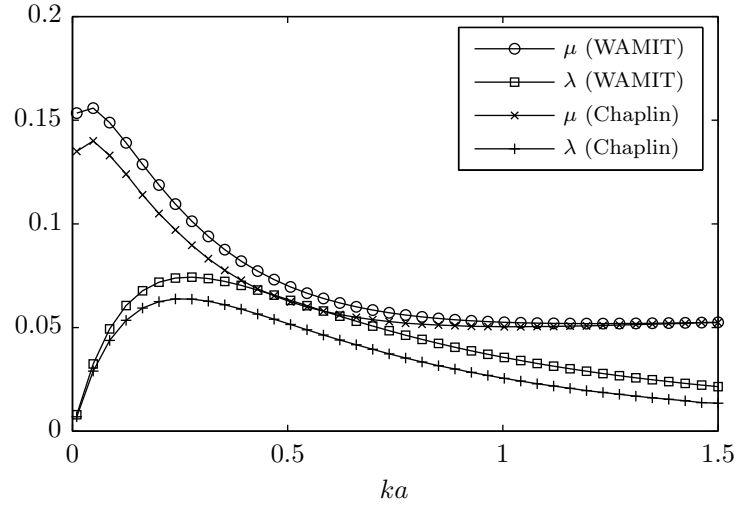


Figure 9: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with half angle of 10 degrees.

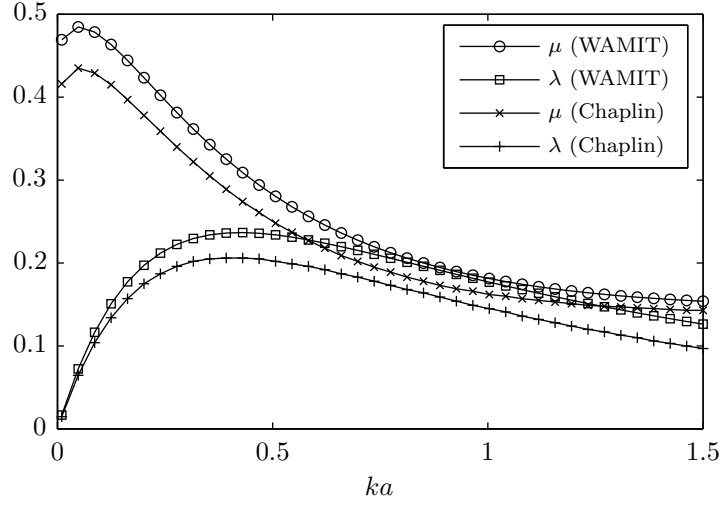


Figure 10: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with half angle of 20 degrees.

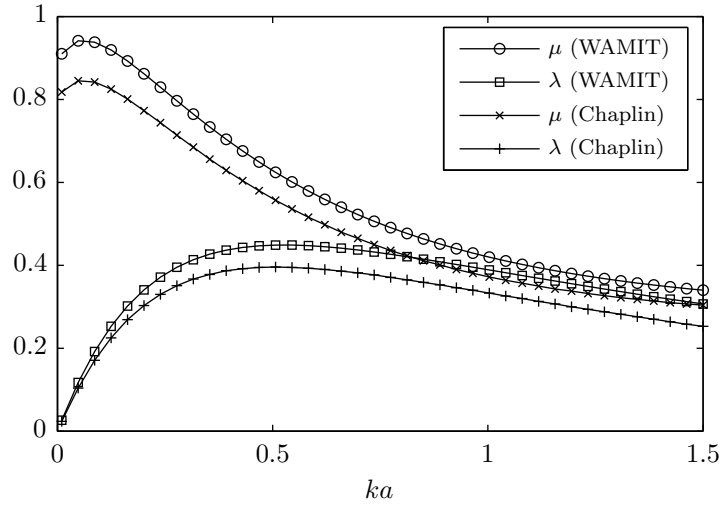


Figure 11: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with half angle of 30 degrees.

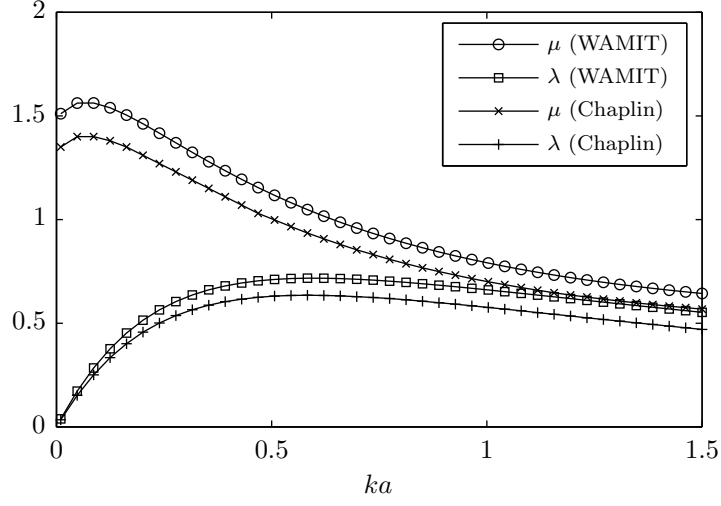


Figure 12: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with half angle of 40 degrees.

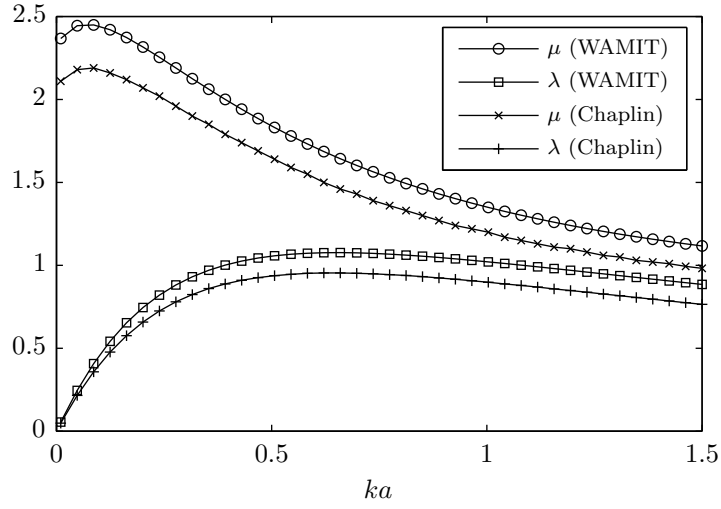


Figure 13: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with half angle of 50 degrees.

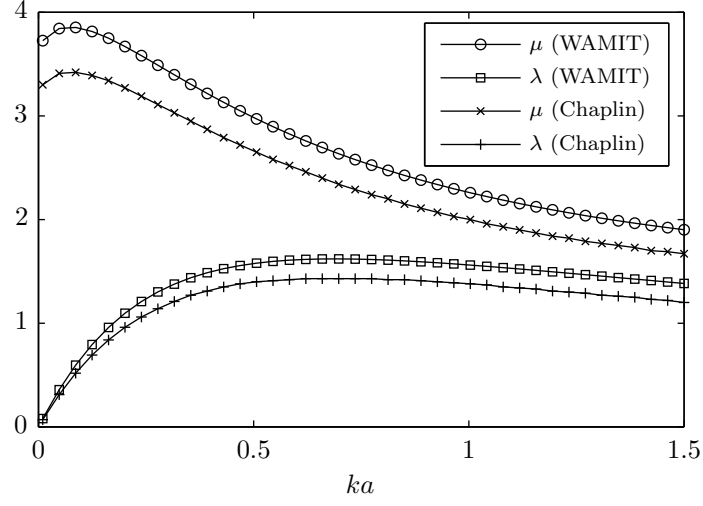


Figure 14: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with half angle of 60 degrees.

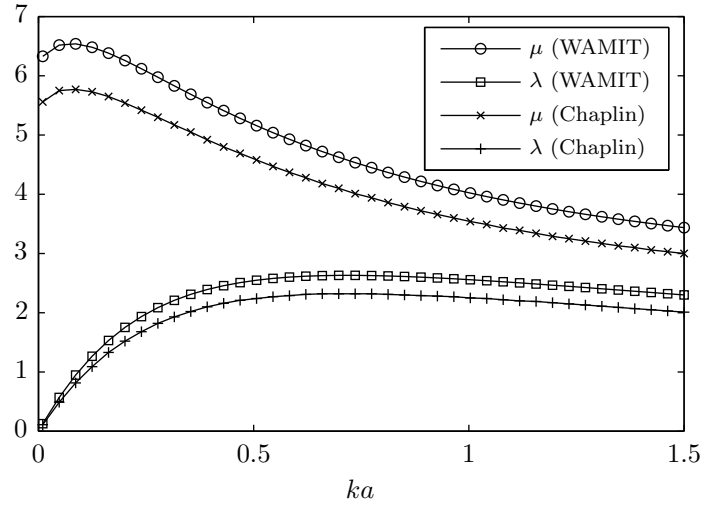


Figure 15: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with half angle of 70 degrees.

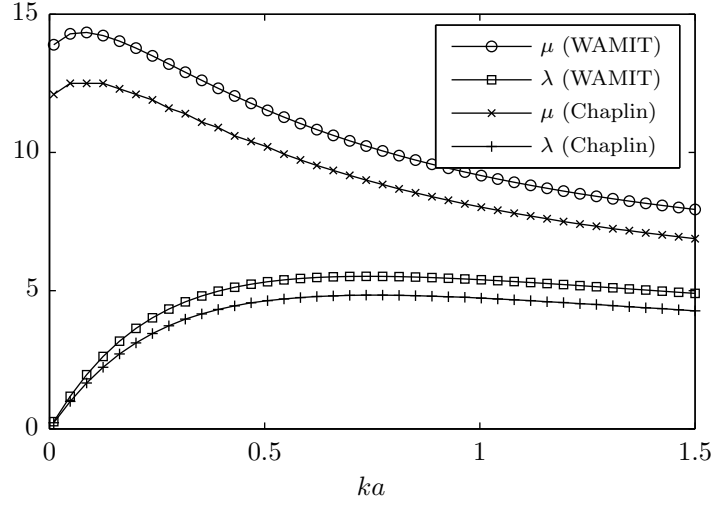


Figure 16: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with half angle of 80 degrees.

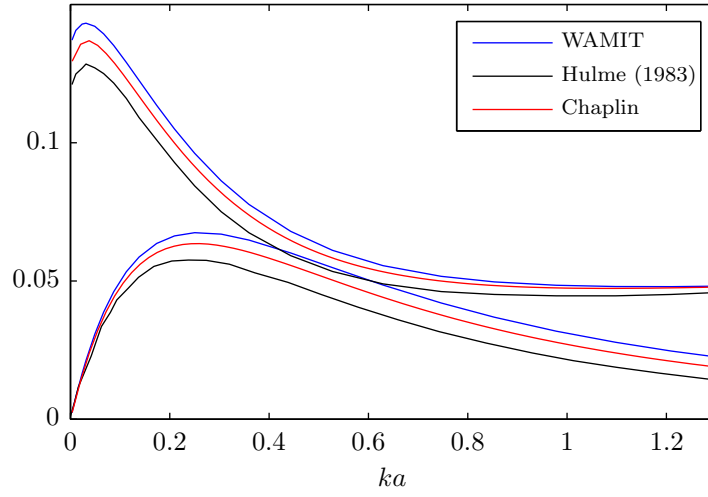


Figure 17: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with wall gradient of 6.

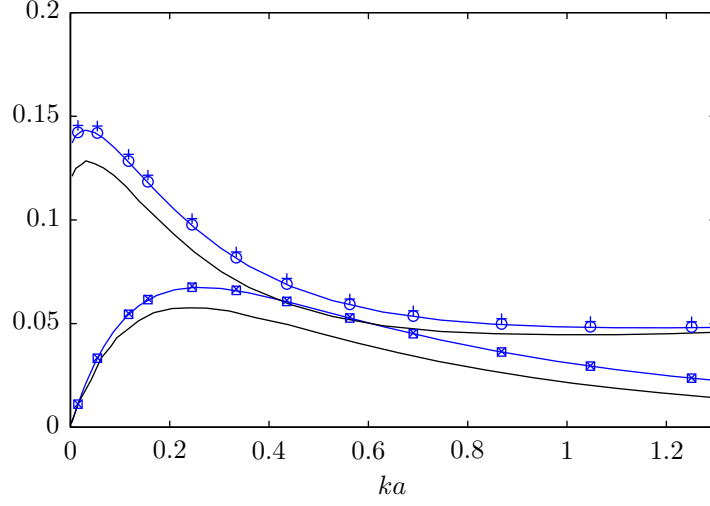


Figure 18: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with wall gradient of 6. Black lines are Hulme's results, blue lines are WAMIT results. Also shown are WAMIT results for a cone truncated 1/10 from the base (circles and squares) and 1/5 from the base (pluses and crosses).

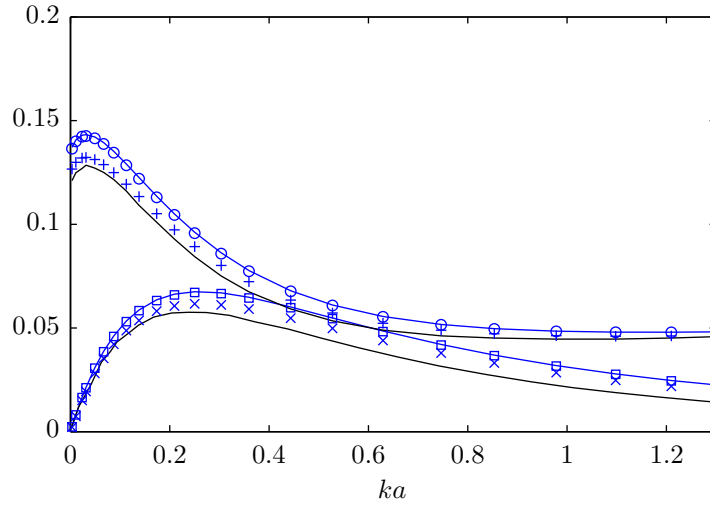


Figure 19: Comparison of non-dimensional added mass and radiation damping coefficients for a cone with wall gradient of 6. Black lines are Hulme's results, blue lines are WAMIT results. Also shown are WAMIT results obtained by low-order panel method with 1728 panels (circles and squares) and 108 panels (pluses and crosses).