Wave Forces on a Platform Supported on a Large Number of Floating Legs

by

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SUMMARY

A new method is developed for the calculation of the diffraction characteristics of a platform supported on a large number of floating legs.

By exploiting the fact that the number of legs is large, the approximation is introduced that the diffraction characteristics of the legs in the interior differ only by given phases from each other, thus resembling those of an infinite array. The end effects of the finite array are accounted for by considering the full interaction of the peripheral legs with the "infinite array" core. The validity of the present method is confirmed through comparisons with solutions given by the "exact" interaction theory developed by Kagemoto and Yue [1][2]. It is finally applied to an array of 50 rows of many floating legs, to which no other method can give the answer without crude approximations. Comparisons with available experimental data are also made with satisfactory agreements.

The present method makes it possible to estimate the diffraction characteristics of an array of large number of legs accurately with reasonable computational effort. It should likely be a valuable tool in the design of large multile-leg platforms.

INTRODUCTION

With the increasing shortage of usable land and the environmental concern for suitable land use, several proposals now exist, notably in Japan, for the utilization of marine space by floating platforms supported on a large number of legs anchored in intermediate ocean depth. The recent proposals for floating airports and ocean communication cities (Ando et al [3] and Terai [4]) are typical examples.

Among the technical problems to be solved for the realization of such platforms, the estimation of environmental forces, especially those due to waves, is of fundamental importance. Because of the multiple scattering of waves, it is well known that hydrodynamic interactions among the legs cannot be neglected in the determination of diffraction/radiation forces acting on an array. The authors have recently developed an interaction theory which gives the exact solutions for the hydrodynamic interaction among multiple three-dimensional floating bodies (Kagemoto and Yue [1] [2]). However, according to the proposals, the platforms are to be supported by thousands of legs so that even a direct extension of the interaction theory to an array of such large numbers of legs is impractical. When the rows of an array are assumed to consist of an infinite number of regularly spaced legs, a number of theoretical calculation methods exist (Ohkusu [5]; Masumoto, Yamagami and Sakata [6]). These methods, however, assume certain periodic conditions on each leg and thus cannot be applied to diffraction problems of waves of arbitrary incident angles or of arbitrary frequencies. Furthermore, the variations on the legs near the periphery must necessarily be ignored, which is of importance to the structural design and for intermediate-sized platforms may constitute not an insignificant part of the total. The present method removes such restrictions by posing the diffraction/radiation of a large array as a special case of a general hydrodynamic interaction problem. For a large number of legs in the interior (provided they are identical and regularly spaced), a simple phase relationship is assumed for the incident (and hence scattered) waves at each body which corresponds to an "infinite-array" assumption although here the incident wave angle and frequency can remain arbitrary. The total problem is then solved by considering the interaction of the interior core with a relatively small number of legs near the outer boundaries, thus accounting for the "end" effects. The validity of this approach is confirmed by comparison to the full interaction theory results of Kagemoto and Yue [1] [2], and by collaboration with experimental data.

The present method is among the first ones to provide reliable predictions of the diffraction characteristics of an array of a large number of legs and should help pave the way for future large ocean space utilization projects.

RESULTS

We consider several multiple-leg configurations where we compute the primary wave exciting forces and second-order steady drift forces on each leg. The first example is for 19 bottom-seated uniform vertical cylinders of diameter D which are arranged in one line with a center-to-center distance of 2D. Four sets of results are obtained: (a) "exact" solutions as calculated using the full interaction theory for the 19 legs; (b) isolated-leg results where all interactions are ignored; (c) the present approximate interaction results where "infinite-array" relationships are assumed for 13 of the interior legs (interacting with 3 legs on each end); and (d) infinite-array solution where the structure is treated as part of an infinite array. In beam seas, a similar geometry for unlimited number of legs was obtained by Ohkusu [5] whose results are indistinguishable from (d). When interactions are neglected altogether, the sway force is much overpredicted by (b), while the infinite-array result (d) closely approximates and roughly averages the solutions for the interior legs but deviates appreciably from the exact result (a) near the ends. When the interactions of these end legs are included explicitly, our approximate interaction predictions (c) agree very well with exact solutions. The wave drift force is also well approximated by the present theory. Satisfactory results are also obtained in the case of oblique incident waves where there appears to be no existing method which is applicable for arbitrary incident wavelengths.

Finally, the approximate interaction theory is applied to several arrays of respectively 2, 5 and 50 rows of a large number of floating legs in each row. The legs are made up of a vertical cylinder with a cylindrical footing for which some experimental data by Inoue [7] are available for the case of 5 rows of floating legs. Results for the first-order and steady drift forces are obtained for both the horizontal and vertical directions. Comparisons to experiments give fairly reasonable agreement.

CONCLUSION

With the method presented here, the estimation of diffraction characteristics of an array of a very large number of legs is now possible. The present method should be useful in the design of huge multiple-leg platforms as well as other types of large-scale ocean projects such as those related to ocean energy, fishing and mining.

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Discussion

Agnon: I congratulate you on your idea for treating interactions. Have you considered another class of interactions, among the bodies on the "interior" of the edge of the array?

Beck: Are the discrepancies between the theory and experiments in your last slide due to viscous effects?

Yue: Viscous effects might have contributed to the discrepancy.

X.J. Wu: Can you obtain the detailed pressure distribution over a single body in the array?

Yue: Yes, we can calculate the pressure and velocity field on and around the body.

Van Hooff: Can you solve the radiation problem by this method?

Yue: The radiation problem has also been done.

X.J.Wu: This is an important work. Ohkusu's approximation works well in two dimensions, but may not be as effective in three-dimensional cases.

Yeung: It appears to me that your idea may be extended in an even more powerful way if a very large number of bodies of a repetitive pattern should exist. Suppose the hydrodynamic properties of a canonical group of bodies is known, interaction among identical groups can be treated as if it is among single bodies. To construct the hydrodynamic properties of a group, interactions among single bodies are solved using the present procedure. Carrying on to the next level, several groups can be made a consortium, and so on. Finally, interaction among thousands of single bodies involves solving for the interaction of only several "super consortiums".

Yue: Yes, ideas similar to these as well as those Y. Agnon suggested can clearly be adopted for different applications. Our objective here is to show that such an approach is valid and can indeed be quite efficacious.