Numerical Investigations of a Hydrodynamic Interaction between two Floating Structures in Waves

J.A. Pinkster and I.N. Dmitrieva

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Dear participants of the Conference, ladies and gentlemen!

On behalf of the organisers I am glad to welcome you to the Third final International Conference "300 Years of Russian Fleet".

We are assembled here in the city founded by the distinguished reformer of Russia, creator of the Russian Fleet Peter the Great in the year of the glorious jubilee.

Peter's time witnessed remarkable achievements, brilliant military victories, promoted the national self-consciousness enforcement and Russia entering the European community.

History of the Russian Fleet is versatile and instructive. It is filled with examples of courage and heroism of the seamen, talent and high skill of shipbuilders, scientists and inventors.

The present stage of development of Russia and its fleet in particular has much in common with the Peter's epoch. Following the traditions of the great reformer, we arrived to this forum to underline again our aim at co-operation, good will and consolidation of efforts in development of science and practice of shipbuilding and operation.

I wish all the participants fruitful discussions and contacts, good impressions of staying in St. Petersburg.

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STATUTE OF THE MEMORIAL JUBILEE MEDAL "PETER THE GREAT"

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NUMERICAL INVESTIGATIONS OF A HYDRODYNAMIC INTERACTION BETWEEN TWO FLOATING STRUCTURES IN WAVES

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Abstract

For several years numerical methods have been available for evaluating the wave diffraction loads on large volume fixed or floating offshore structures such as storage tanks, gravity and semisubmersible platforms, etc. These techniques have been further extended in order that mean and slowly varying wave drift responses might be assessed. In the case when the geometry of the body is complex, interaction effects between bodies become important.

In this paper one of the versions of the program DELFRAC for multibodies which is based on the three-dimensional potential theory is investigated. In order to solve the problem use is made of discretisation of a boundary integral equation on the submerged surface of the body by means of using of a source distribution. The boundary integral procedure is based on an assumed constant distribution of the source strength over each panel into which the surface is divided.

For such solution a great number of panels are required, especially because of several bodies' interactions. As an example of such an interaction effect two structures which are floating in waves in each other's vicinity have been selected.

* Professor, Prof., Dr. ir.
** Associate Prof., Ph.D.

The hydrodynamic coefficients of each body and hydrodynamic interaction coefficients are calculated for several configurations of bodies. Results are obtained for two closely spaced floating bodies free to move independently. The dimensions of bodies are similar. Comparisons with experimental and theoretical results of other authors are discussed. Some conclusions about the use of a 3D diffraction method and especially the version of DELFRAC program for multibodies are given.

Computation times strongly depend on the number of bodies. For the case of a single body (cylinder or box with approximately the same total number of panels) the calculation of forces and motions including drift forces takes 10 minutes per frequency and per body. For the case of calculations of two bodies' interaction the time increase to one hour. If it is not necessary to calculate the drift forces using the pressure integration method the time of calculation can be decreased to 20 minutes per frequency.

1 Introduction

In offshore industry the use of several structures, floating in each other's vicinity, is a rather common practice. In such case the behaviour of each of these structures is influenced, besides possible restraints due to mooring connections, by hydrodynamic interaction effects due to the neighbouring structure.

The above problem has been discussed by a number of authors. First of them is G. van Oortmerssen [1], whom the method of calculation of first order quantities was developed on a base of 3D technique. R.E. Taylor and J. Zietsman [2] have proposed the method of interaction analysis which is based on combining a finite element idealisation of the fluid region close to a body with a boundary integral representation of the far field behaviour. They have highlighted that such a method can be selected as an economical numerical technique. Further development of this problem has been made by D.M. Ferreira and C.-H.Lee [4]. They have represented the effective method of the calculation of drift forces on two independent close bodies. Lastly a method to obtain the solution of the equations in the unknown source strengths has been worked out by J.A. Pinkster [6]. This method is based on successive approximation of source strengths.

Nowadays the first problem is to improve the existing methods and to do its faster and more effective. The second problem is to obtain more data for a verification of results of computations and to analyse data obtained.

In order to solve the last problem the present investigation has been carried out. Next aim of our investigations is to show that 3-D diffraction methods generally can be applied to such cases and, for instance, the computer code DELMULTI is suitable for such investigations.

In the present study, attention is paid to interaction effects in the hydrodynamic reaction forces of first order as well as the drift forces, acting on oscillating floating bodies.

2 Theoretical Aspects

Following to G. van Oortmerssen [1] and to J.A. Pinkster [6], consider two rigid floating bodies of arbitrary shape in response to excitation by a long crested regular wave. The fluid is assumed to be ideal and irrotational.

Use is made of a rectangular Cartesian coordinate system. The origin of the coordinate system is located on the free surface of the fluid. The z - axis is vertical and positive upward. The oscillating body motions are described in local coordinate systems of each body. Each local system is connected with the centre of gravity.

The free surface is defined in the same way as in all potential cases.

The flow field is characterized by a velocity potential

$$\Phi(x_1, x_2, x_3, t) = \varphi\,(x_1, x_2, x_3)e^{-i\omega t}\,. \qquad (1)$$

The potential function φ as a function of coordinates can be separated into contributions from all modes of motion of both bodies and from the incident and diffracted wave potentials :

$$\varphi = -i\omega\left[(\varphi_0 + \varphi_d)\bar{\zeta} + \sum_{j=1}^{6}\varphi_j^{(1)}\,\bar{y}_j + \sum_{j=1}^{6}\varphi_j^{(2)}\,\bar{z}_j\right], \qquad (2)$$

where

- $\bar{\zeta}$ - wave amplitude;
- $\varphi_j^{(1)}$ - the scattering wave potential due to motion of first body in the j-th mode;
- $\bar{y}_j$ - the complex amplitude of j-th mode of motion for the first body;
- $\varphi_j^{(2)}$ - the scattering wave potential due to motion of second body in the j-th mode;
- $\bar{z}_j$ - the complex amplitude of j-th mode of motion for the second body.

According to potential theory, the described potentials satisfy the Laplace equation in combination with several known boundary conditions. The pressure in any point of fluid can be calculated with both potentials of each body :

$$p=-\rho\frac{\partial\varphi}{\partial t}=\rho\omega^2\left\{\left(\varphi_0+\varphi_d\right)\bar{\zeta}+\sum_{j=1}^{6}\varphi_j^{(1)}\bar{y}_j+\sum_{j=1}^{6}\varphi_j^{(2)}\bar{z}_j\right\}e^{-i\omega t}. \qquad (3)$$

The hydrodynamic reaction force in the k-th mode on the first body is follows:

$$F_k^{(1)}=-\rho\omega^2 e^{-i\omega t}\sum_{j=1}^{6}\iint_{S^{(1)}}\left(\bar{y}_j\varphi_j^{(1)}+\bar{z}_j\varphi_j^{(2)}\right)n_k dS \qquad (4)$$

and on the second body :

$$F_k^{(2)}=-\rho\omega^2 e^{-i\omega t}\sum_{j=1}^{6}\iint_{S^{(2)}}\left(\bar{y}_j\varphi_j^{(1)}+\bar{z}_j\varphi_j^{(2)}\right)n_k dS. \qquad (5)$$

As it can be seen from the equations (4) - (5) and according to G. van Oortmerssen the following coefficients may be defined :

$$\begin{aligned}
P_{kj}^{(1)} &= -\rho\omega^2 \iint_{S^{(1)}} n_k\varphi_j^{(1)}\,dS;\\
Q_{kj}^{(1)} &= -\rho\omega^2 \iint_{S^{(1)}} n_k\varphi_j^{(2)}\,dS;\\
P_{kj}^{(2)} &= -\rho\omega^2 \iint_{S^{(2)}} n_k\varphi_j^{(2)}\,dS;\\
Q_{kj}^{(2)} &= -\rho\omega^2 \iint_{S^{(2)}} n_k\varphi_j^{(1)}\,dS.
\end{aligned} \qquad (6)$$

These coefficients define the force components due to appropriate motion according to the following rule :

$P_{kj}^{(1)}$ - the force of k-mode on $S^{(1)}$ due to motion in the j-mode of $S^{(1)}$;
$Q_{kj}^{(1)}$ - the force of k-mode on $S^{(1)}$ due to motion in the j-mode of $S^{(2)}$, etc.

Therefore, the coefficients $Q_{kj}^{(1)}$ and $Q_{kj}^{(2)}$ are connected with body's interaction, when the coefficients $P_{kj}^{(1)}$ and $P_{kj}^{(2)}$ describe the forces due to own body motions.

Using a well-known way all coefficients can be separated into real and imaginary parts as follow:

$$\begin{aligned}
P_{kj}^{(1)} &= \omega^2 a_{kj}^{(1)} + i\omega b_{kj}^{(1)};\\
P_{kj}^{(2)} &= \omega^2 a_{kj}^{(2)} + i\omega b_{kj}^{(2)};\\
Q_{kj}^{(1)} &= \omega^2 d_{kj}^{(1)} + i\omega e_{kj}^{(1)};\\
Q_{kj}^{(2)} &= \omega^2 d_{kj}^{(2)} + i\omega e_{kj}^{(2)}.
\end{aligned} \qquad (7)$$

where a_{kj} and b_{kj} are well-known added mass and damping coefficients;
d_{kj} and e_{kj} are in-phase and out-of-phase interaction coefficients.

As it is shown by Oortmerssen, for the case of multibody's motions the interaction coefficients satisfy the symmetry relationships, i.e.

$$d_{kj}^{(1)} = d_{jk}^{(2)};$$
$$e_{kj}^{(1)} = e_{jk}^{(2)}. \quad (8)$$

It is obvious that in the case of single body's motions the coefficients d_{kj} and e_{kj} are equal to zero.

The relationships (8) can be an effective basis for checking calculations of the interaction effects of two bodies.

3 Equations of Motion of Two Unconnected Bodies

We describe here the equations of motions for the several bodies to illustrate clearly the mechanism of the interaction between the bodies as well as hydrodynamic interaction coefficients.

According to potential theory the equations of motions can be written as follow:

- first body

$$\sum_{j=1}^{6}\left[-\omega^2\left(M_{ij}^{(1)} + a_{ij}^{(1)}\right) - i\omega b_{ij}^{(1)} + c_{ij}^{(1)}\right]\bar{y}_j + \\ + \left[-\omega^2 d_{ij}^{(1)} - i\omega e_{ij}^{(1)}\right]\bar{z}_j = X_i^{(1)}; \quad (9)$$

- second body

$$\sum_{j=1}^{6}\left[-\omega^2\left(M_{ij}^{(2)} + a_{ij}^{(2)}\right) - i\omega b_{ij}^{(2)} + c_{ij}^{(2)}\right]\bar{z}_j + \\ + \left[-\omega^2 d_{ij}^{(2)} - i\omega e_{ij}^{(2)}\right]\bar{y}_j = X_i^{(2)}; \quad (10)$$

where M_{ij} - the inertia matrix of body ;
a_{ij} - the dimensional added mass ,
b_{ij} - the dimensional damping coefficient ;
d_{ij} - in-phase hydrodynamic interaction coefficients , yielding a force in i-mode due to motion in the j-mode of a neighbour

structure ;

c_{ij} - out-of-phase hydrodynamic interaction coefficients, yielding a force in i-mode due to motion in the j-mode of a neighbour structure ;

X_i - wave exciting force ;

$\bar{y}_j$, $\bar{z}_j$ - complex amplitude of motion in the j-mode of first and second bodies respectively.

The affix (1) or (2) serves to identify the bodies, while the subscripts i and j denote the modes of motion.

In order to calculate mean drift forces, acting on both bodies, the pressure integration method is applied. See Pinkster [7]. The pressure field (3) is known after solving a first order problem.

4 The Computer Code

In order to solve the potential problem of multibody interaction the computer code DELMULTI was developed at the Delft University of Technology. This code is one of the versions of the program DELFRAC which is based on the application of 3D linear diffraction theory. Basically the problems are defined as boundary value problems where the solution is found by using a panel method. Using this code a calculation can be made for two or several bodies which may oscillate in waves with zero forward speed or be fixed. Relative locations of each body can be arbitrary.

For evaluation of the Green function and its derivatives the MIT routine is used [8]. The input data which include a description of each body are the same as in the case of the program DELFRAC for one body [3].

5 Calculations and Conclusions

5.1 Description of Bodies

In order to analyse the results of computations and especially the hydrodynamic interaction between two structures, floating in waves, two bodies have been selected (according to the results of computations and experiments of G. van Oortmerssen [1]) :

- cylinder ;
- box .

These bodies are shown in figures 1 - 2, including the panels. In figure 1 the meshes of two bodies from the bottom side are shown. One of configurations of these bodies is shown in figure 2.

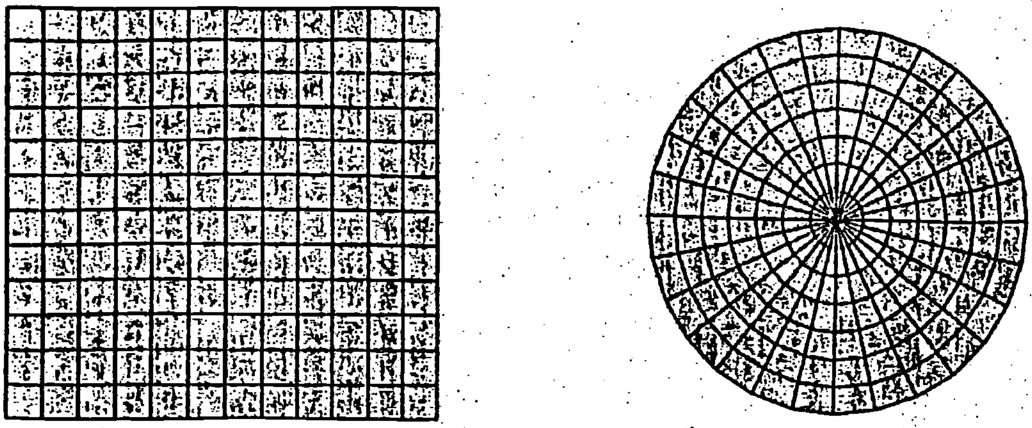

Fig. 1

The bottom view of two bodies,
total numbers of panels of a cylinder and a box are 392 and 432 respectively.

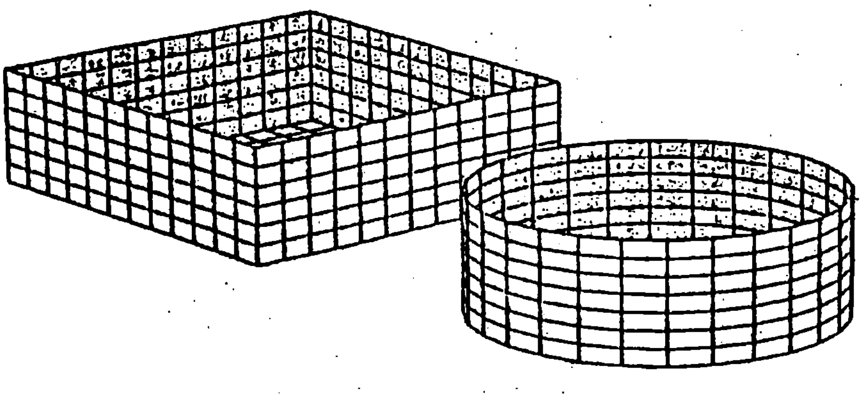

Fig. 2

The distance between the centres of two bodies is 152.75 meters,
the ratio distance / draft is 5.092 .

The first body is a floating cylinder of radius R = 47.9 m. The draft of the cylinder is 30 m. The centre of gravity is located at the waterline of the cylinder. The wetted surface of the body is discretized by 98 panels per quadrant or 392 for the whole body. Use is made of quadrilateral panels but in the bottom triangular panels are applied close to the centre of cylinder as can be seen in figure 1. For the calculation of drift forces 7 waterline elements have been applied per quadrant.

The second body is a rectangular barge of 109.7 m length, 101.4 m breadth with a draft of 30 m. The calculation point is at gravity centre located at the waterline. The wetted surface of box is discretized by 108 numbers quadrilateral panels per quadrant or 432 for the whole body. For calculation of the drift forces 11 waterline elements per quadrant are applied.

The table below shows the number of panels per wave length at different periods for the two investigated bodies.

Tab. 1

Number of panels per wave length for two bodies

Frequency, rad/sec	0.05	0.3	0.5	0.7	0.75
Period, sec	125.6	20.93	12.56	8.971	8.373
Wave length, m	24609.6	683.4	246.1	125.55	109.37
Cyl. 98*4 [l=10.66 m]	2308.6	64.11	23.09	11.78	10.26
Box 108*4 [l=9.14 m]	2692.5	74.77	26.93	13.74	11.97

From this table it can be seen that the mesh refinements for the two bodies are satisfactory. Even for the highest frequency the number of panels per wave length is sufficient in order to calculate the first order loads and motions in accordance with existing practice. However, for accurate calculation of second order loads these numbers of panels for the highest frequency are not enough. For this case smaller panels are preferable.

In figure 2 one configuration of the two bodies is shown . Calculations were carried out for three distances between bodies. See table 2.

Tab. 2

Distances between bodies

Separation distance, m	50	100	150
Distance between the centres of bodies, m	152.75	202.75	252.75
Ratio distance/draft, -	5.092	6.758	8.425
Ratio separ. distance/length of box, -	0.456	0.912	1.367

5.2 Calculation Conditions

In our numerical investigation we obtained results for regular waves. In this case, the amplitude of wave is 1 m. The circular frequencies of oscillation of the incident waves ω are varied from 0.05 to 0.75 rad/sec corresponding to wave periods of 125.6 to 8.373 seconds. This range corresponds to the range of frequencies applied by van Oortmerssen [1].

The calculations were carried out for one wave direction - 180 degree.

All of results were obtained for a water depth of 220 meters and for one draft of 30 meters.

The program of investigation of bodies' interaction consisted of comparisons of the following data :

- hydrodynamic coefficients (surge and heave added mass and damping coefficients) calculated for single bodies by using the main DELFRAC program ;
- the same hydrodynamic coefficients obtained by taking into account the interaction effects and using the version of DELFRAC for multibodies ;
- hydrodynamic interaction coefficients which are equal to zero for the case of a single body;
- drift forces on each body calculated by a pressure integration method.

5.3 Descriptions of Dimensions of Output Data

Output files of all versions of DELFRAC contain dimensional values. In order to compare the results they were made non-dimensional according to the data of van Oortmerssen [1] in the following way :

Non-dimensional wave frequency - $\omega' = \sqrt{l^{(2)}/g}$,

where ω is dimensional circular wave frequency ;

$l^{(2)}$ is the length of second body (in our case it is a box) ;

g - gravity acceleration .

Non-dimensional hydrodynamic coefficients are given in the table 3.

Tab. 3

Non-dimensional hydrodynamic coefficients

Definition	Body I (cylinder)	Body II (box)
Non-dimensional added mass	$A_{ik}^{(1)} / (\rho V^{(1)})$	$A_{ik}^{(2)} / (\rho V^{(2)})$
Non-dimensional damping	$B_{ik}^{(1)} / \left(\rho V^{(1)} \sqrt{g/l^{(1)}}\right)$	$B_{ik}^{(2)} / \left(\rho V^{(2)} \sqrt{g/l^{(2)}}\right)$
Non-dimensional interaction coefficients :		
coupled added mass	$d_{ik}^{(1)} / (\rho V^{(1)})$	$d_{ik}^{(2)} / (\rho V^{(2)})$
coupled damping coefficients	$e_{ik}^{(1)} / \left(\rho V^{(2)} \sqrt{g/l^{(2)}}\right)$	$e_{ik}^{(2)} / \left(\rho V^{(2)} \sqrt{g/l^{(2)}}\right)$

in which :

ρ is the mass density of water ,
g is gravity acceleration ;
$l^{(1)}$ or $l^{(2)}$ are the diameter of a cylinder or the length of a box respectively;
$V^{(1)}$ or $V^{(2)}$ are the volumes of displacement of a first or second bodies respectively

and other values are described earlier in the equations of motions .

5.4 Discussions of the Results

We obtained the results of calculations using the multibody version of DELFRAC which was created at the Delft University of Technology. This program DELMULTI is based on the solution of a 3D diffraction problem and takes into account interaction effects. This can be made by using the velocity potential which consists the contributions from all modes of motion of both bodies and from the incident and diffracted wave fields.

As the first step of the investigations we obtained the hydrodynamic forces on two bodies separately using the main 3D diffraction program (see description of this program ref. [3]). These results were compared with the results of van Oortmerssen obtained by using the 3D diffraction code developed in MARIN. The good correlation between the results for single and rather simple bodies has been obtained with the using of the different 3D codes even for the cases in which different number of panels have been used. The last can be seen from the table 4.

Tab. 4

Comparison of the total number of panels

Type of a body	DELFRAC	van Oortmerssen [1]
Cylinder	392	92
Box	432	104

In fig. 3 through fig. 10 the results are given of calculations of hydrodynamic coefficients of two bodies - cylinder and box separately for the smallest separation distance between them, where the effects of interaction are more significant. Agreement between the results of DELFRAC and of van Oortmerssen is found to be generally very good for all coefficients.

On the same graphs the results for the single bodies are also shown. By comparing the graphs, it can be seen that the interaction effects are more important for the horizontal mode than for the vertical mode and also for the rather high frequencies. In our calculated case the coefficients diverge above the non-dimensional wave frequency $\omega' > 1$. No effects due to the presence of the neighbouring structure are observed at the lower range of frequencies.

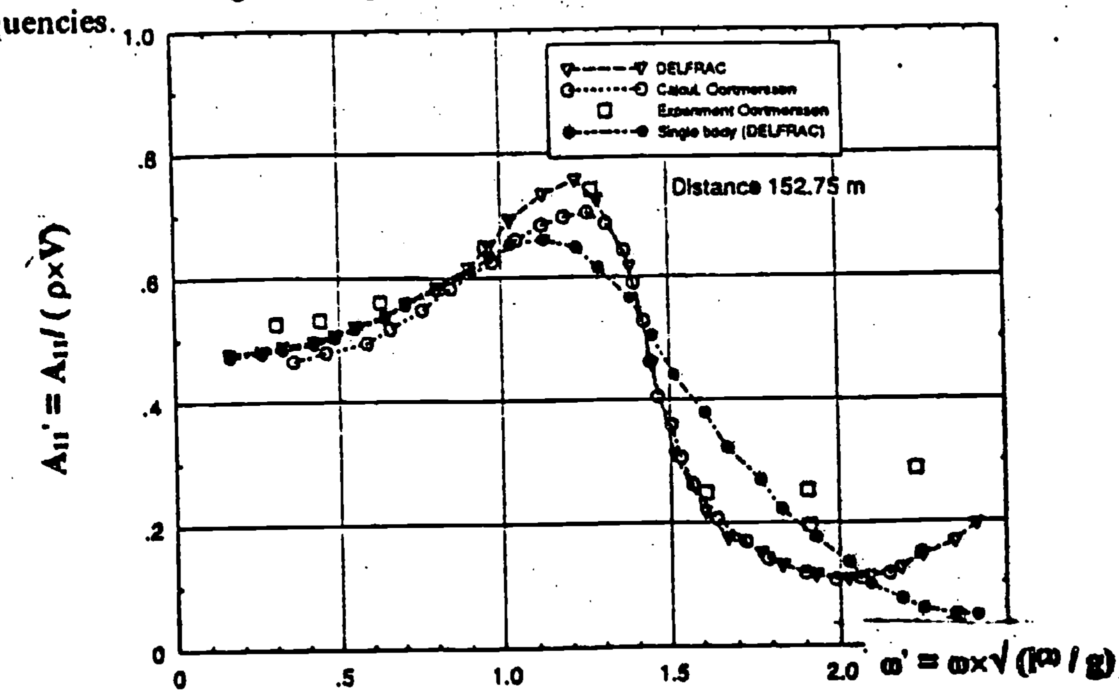

Fig. 3. Surge added mass coefficient $A'_{11}{}^{(2)}$ of the box as a function of a non-dimensional wave frequency ω'.

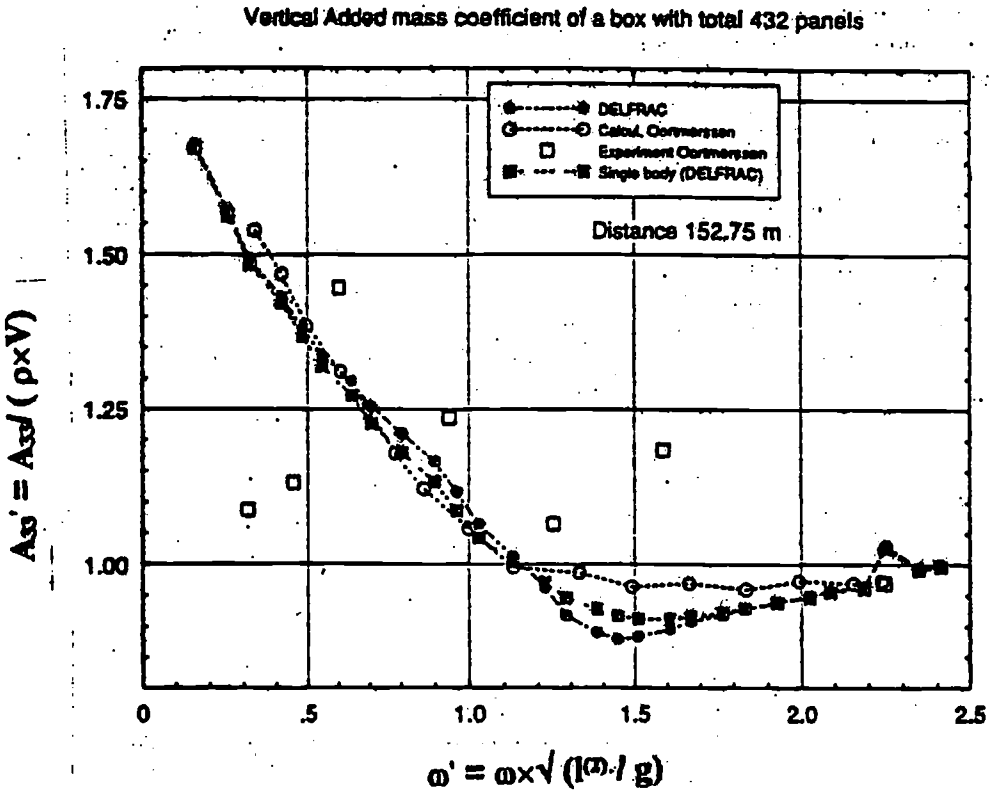

Fig. 4. Heave added mass coefficient $A'_{33}{}^{(1)}$ of the box as a function of a non-dimensional wave frequency ω'.

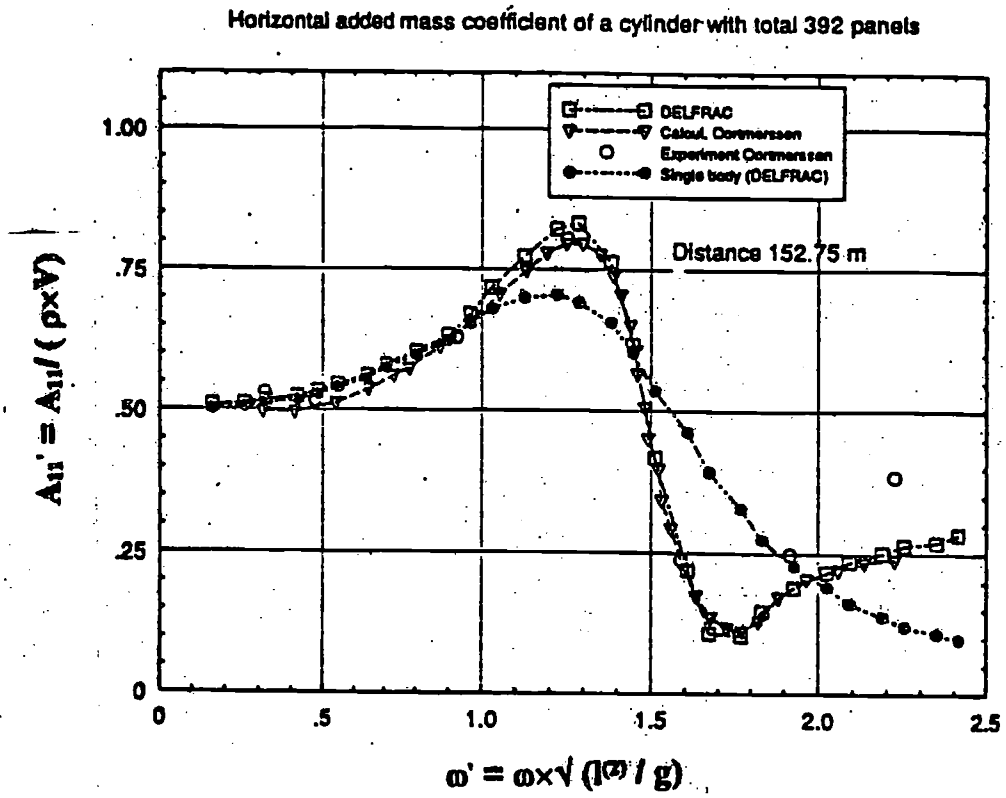

Fig. 5. Surge added mass coefficient $A'_{11}{}^{(2)}$ of the cylinder as a function of non-dimensional wave frequency ω'.

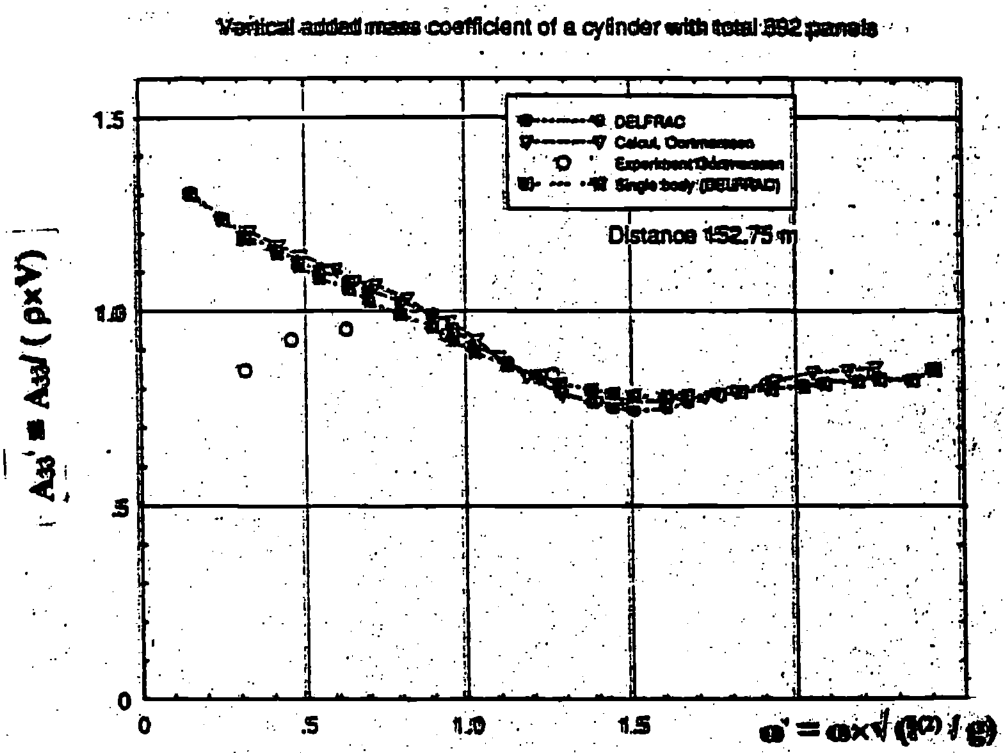

Fig. 6. Heave added mass coefficient $A'^{(2)}_{33}$ of the cylinder as a function of a non-dimensional wave frequency ω'.

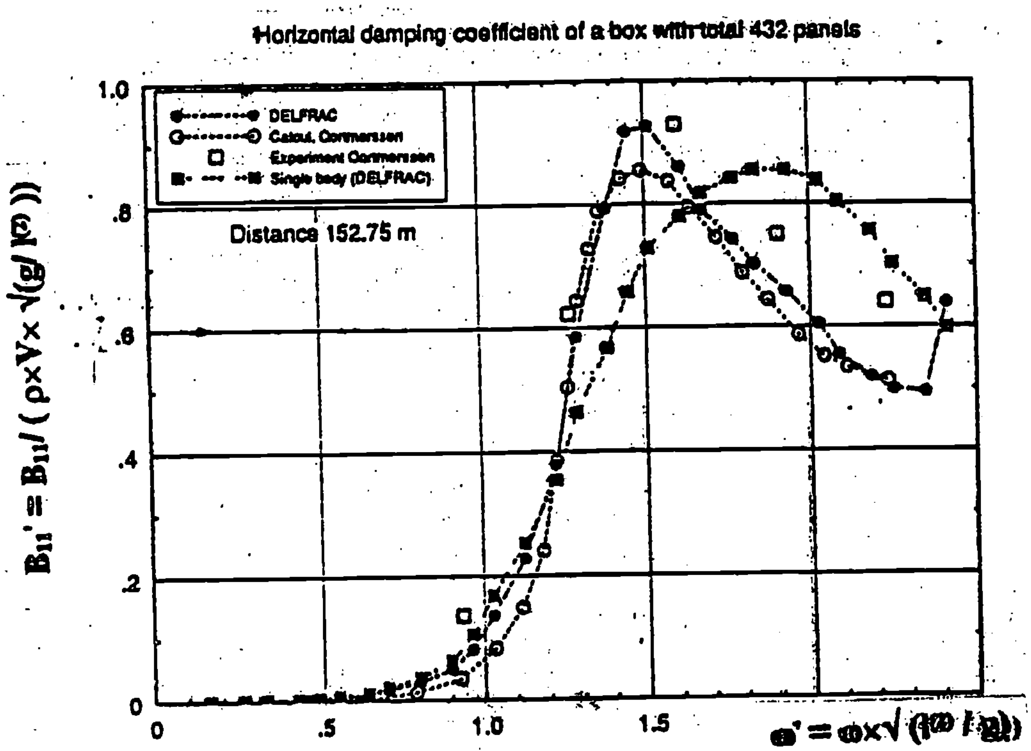

Fig. 7. Surge damping coefficient $B'^{(1)}_{11}$ of the box as a function of a non-dimensional wave frequency ω'.

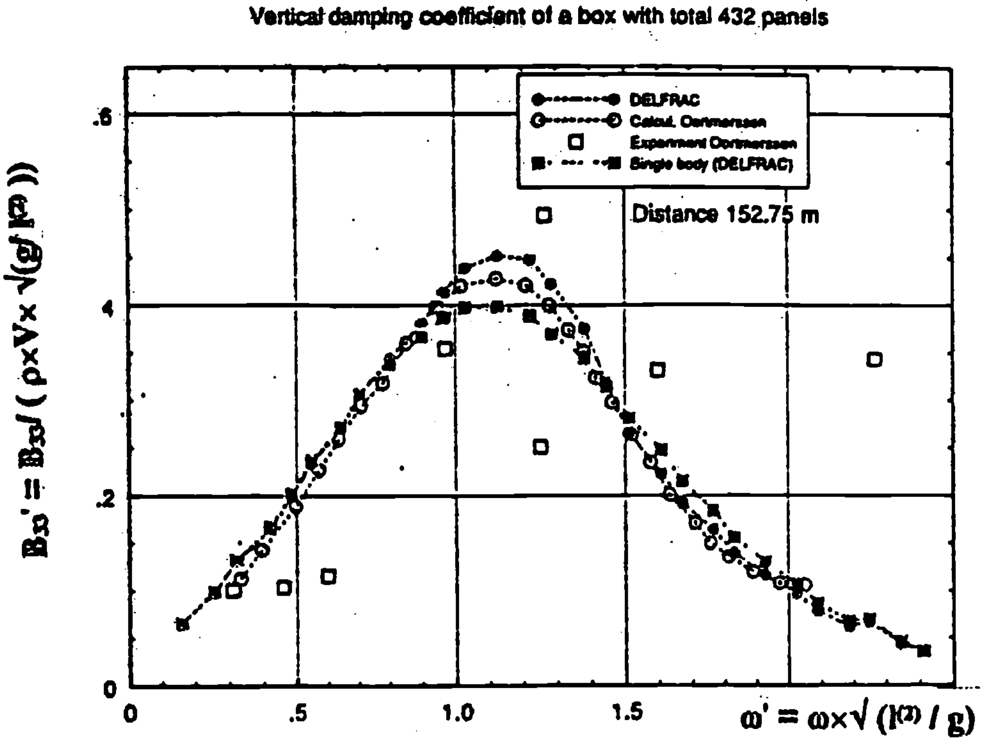

Fig. 8. Heave damping coefficient $B'_{33}{}^{(1)}$ of the box as a function of a non-dimensional wave frequency ω'.

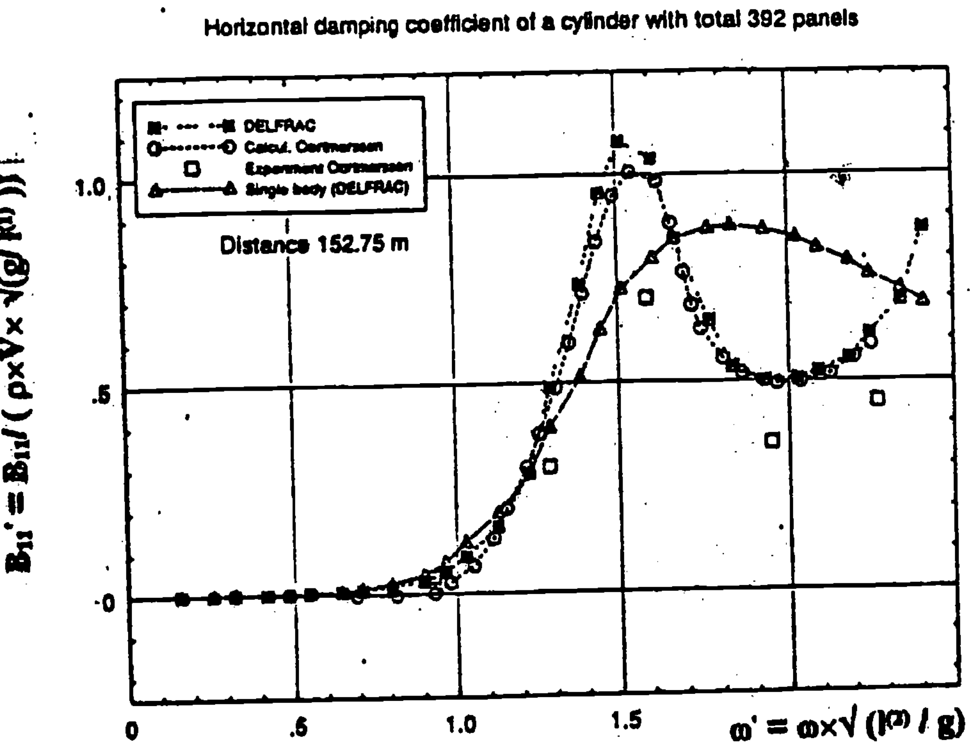

Fig. 9. Surge damping coefficient $B'_{11}{}^{(2)}$ of the cylinder as a function of a non-dimensional wave frequency ω'.

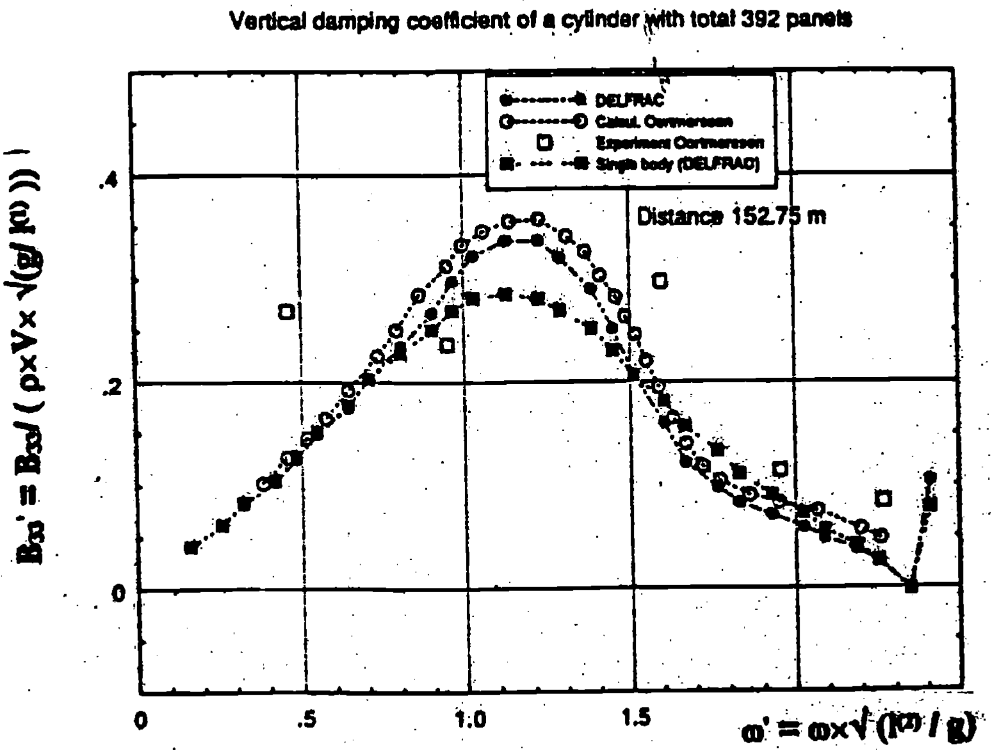

Fig. 10. Heave damping coefficient $B'_{33}{}^{(1)}$ of the cylinder as a function of a non-dimensional wave frequency ω'.

Figures 11 - 14 give an impression of the interaction effects which exist for the multibody case. The hydrodynamic interaction coefficients d_{ij} and e_{ij} are given in non-dimensional forms.

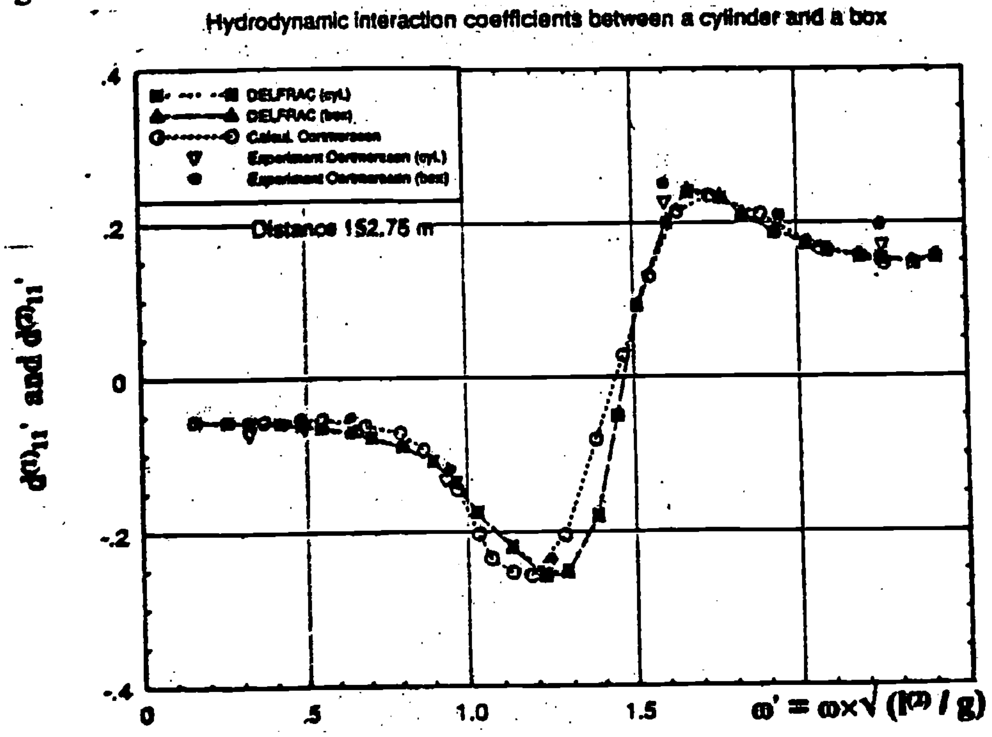

Fig. 11. Hydrodynamic interaction coefficients $d_{11}{}^{(2)}$ and $d_{11}{}^{(1)}$ between the box and the cylinder as a function of a non-dimensional wave frequency ω'.

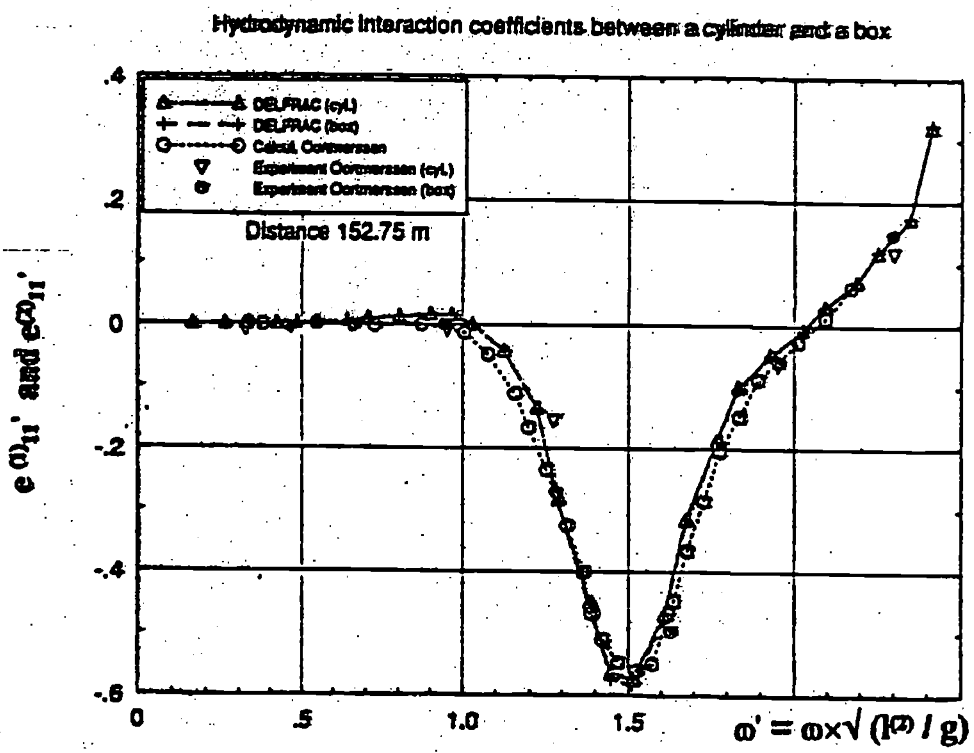

Fig. 12. Hydrodynamic interaction coefficients $e'^{(1)}_{11}$ and $e'^{(2)}_{11}$ between the box and the cylinder as a function of a non-dimensional wave frequency ω'.

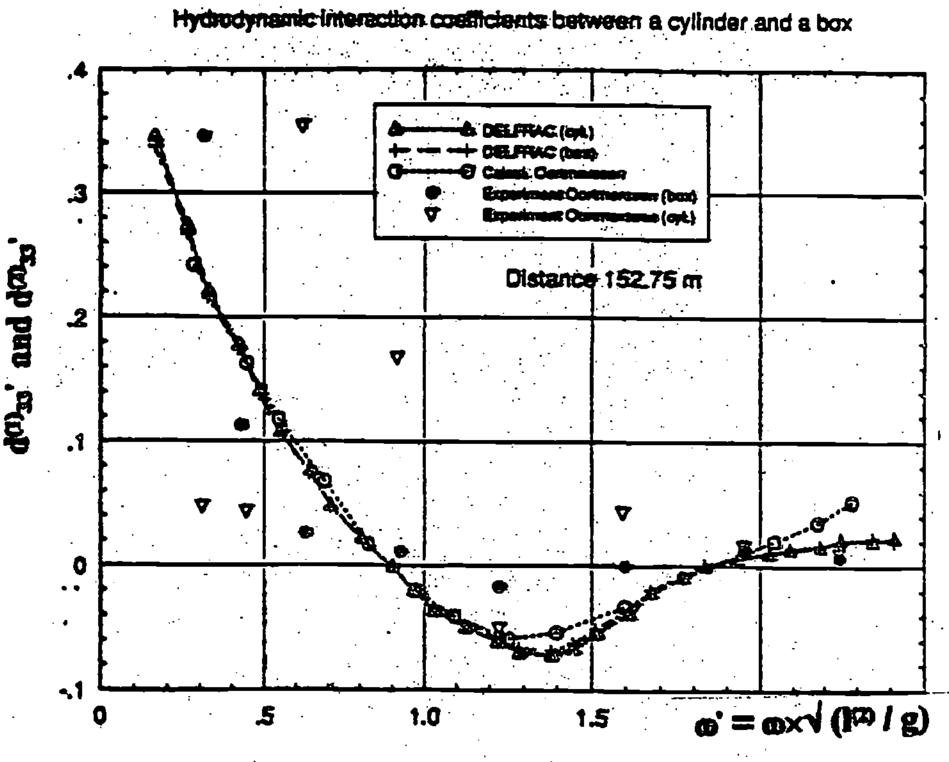

Fig. 13. Hydrodynamic interaction coefficients $d'^{(1)}_{33}$ and $d'^{(2)}_{33}$ between the box and the cylinder as a function of a non-dimensional wave frequency ω'.

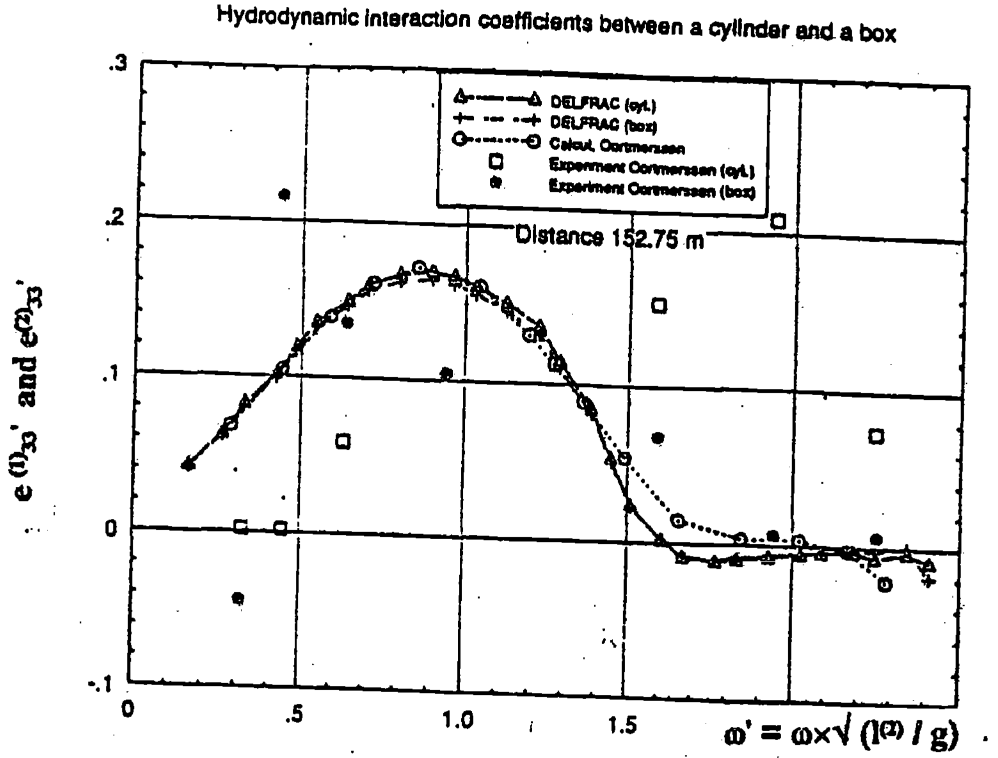

Fig. 14. Hydrodynamic interaction coefficients $e_{33}^{(2)}$ and $e_{33}^{(1)}$ between the box and the cylinder as a function of a non-dimensional wave frequency ω'.

From the calculations presented in figures 11 through 14 it can be seen that the hydrodynamic interaction coefficients really have the symmetry relationships. These coefficients depend strongly on the presence of the moving neighbouring structure over a wide range of frequencies, especially the coefficients d_{ij} which are not equal to zero at all frequencies calculated. Following van Oortmerssen [1], it can be concluded that, where the effect of the neighbouring structure on the added mass and damping disappears at very low frequencies, this is not the case for the interaction forces. Even at low frequencies, a structure will experience hydrodynamic forces as a result of the motions of a nearby floating structure. These forces appear to be in phase with the motion of the neighbour, since for frequencies approaching zero the coefficients e_{ij} tend to zero. For the case of hydrodynamic interaction forces the correlation between calculated and measured values are reasonable.

For the second and third configurations of the bodies the same conclusions can be drawn as in the previous case. A significant influence of interaction effects is observed for the horizontal hydrodynamic coefficients and no influence on the vertical hydrodynamic coefficients .

The influence of the distance between two interacted bodies can be seen from figures 15 - 16. As expected, the interaction forces decrease with increasing distance between the two bodies. For this distance which is 8.425 times to compare the draft of bodies, the interaction still exists however. Of course, it is interesting to continue the calculations in order to obtain the results for other bodies' configuration. However, the computing cost increases significantly.

The last part of our investigations is related to the calculation of drift forces which were obtained for several cases of wave heading - 180, 225 and 270 degrees. In order to illustrate the influence of the wave heading on the horizontal drift forces the graph 17 is shown.

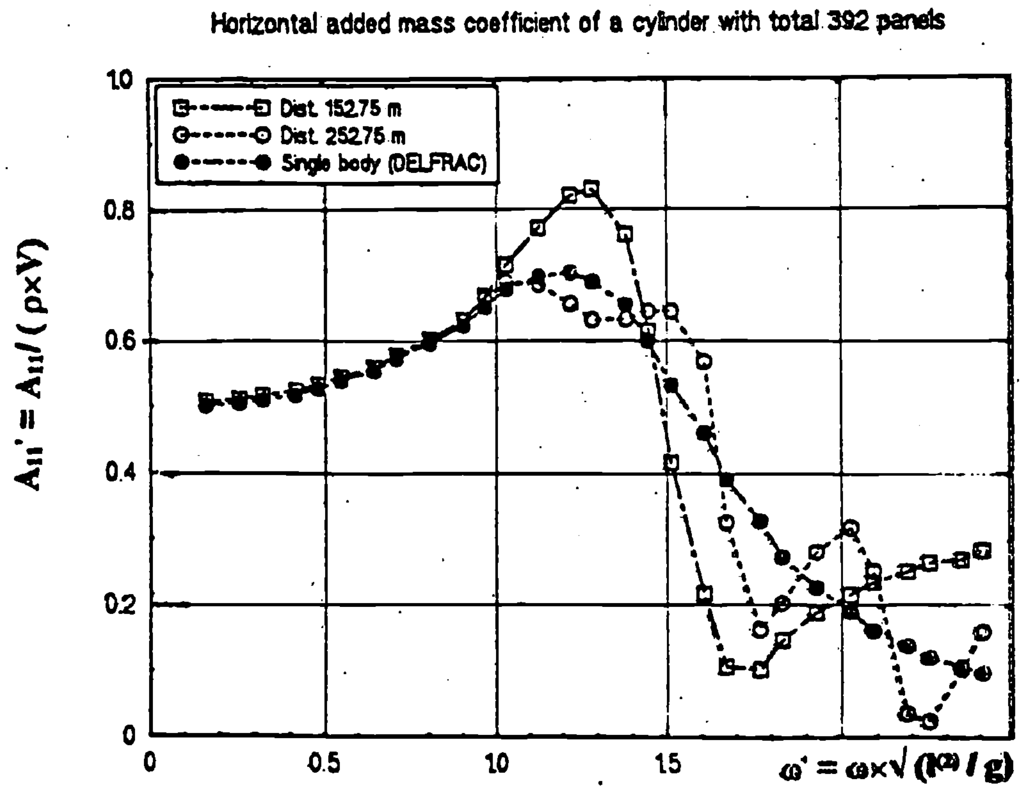

Fig. 15. Influence of the separated distance between two bodies on the surge added mass coefficient of the cylinder versus a non-dimensional wave frequency.

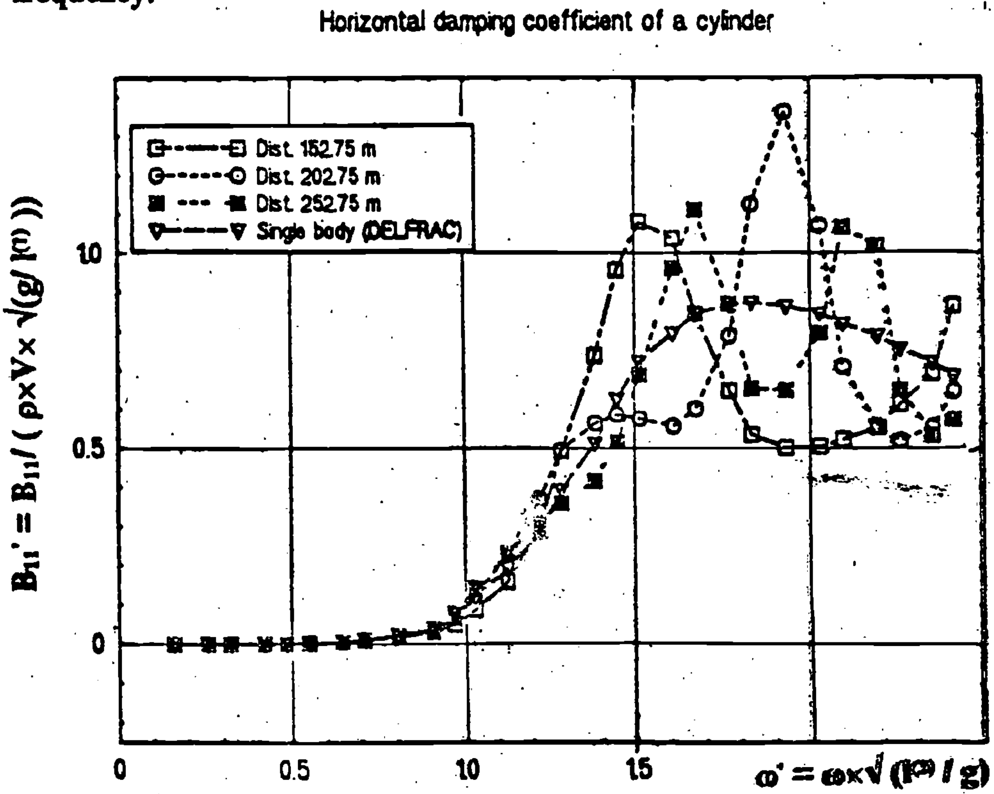

Fig. 16. Influence of the separated distance between two bodies on the surge damping coefficient of the cylinder versus a non-dimensional wave frequency.

This influence can be seen at practical frequencies when the drift forces can even change direction. This fact is explained by complex interaction between two bodies and by significant influence of wave elevation which dominate in drift forces.

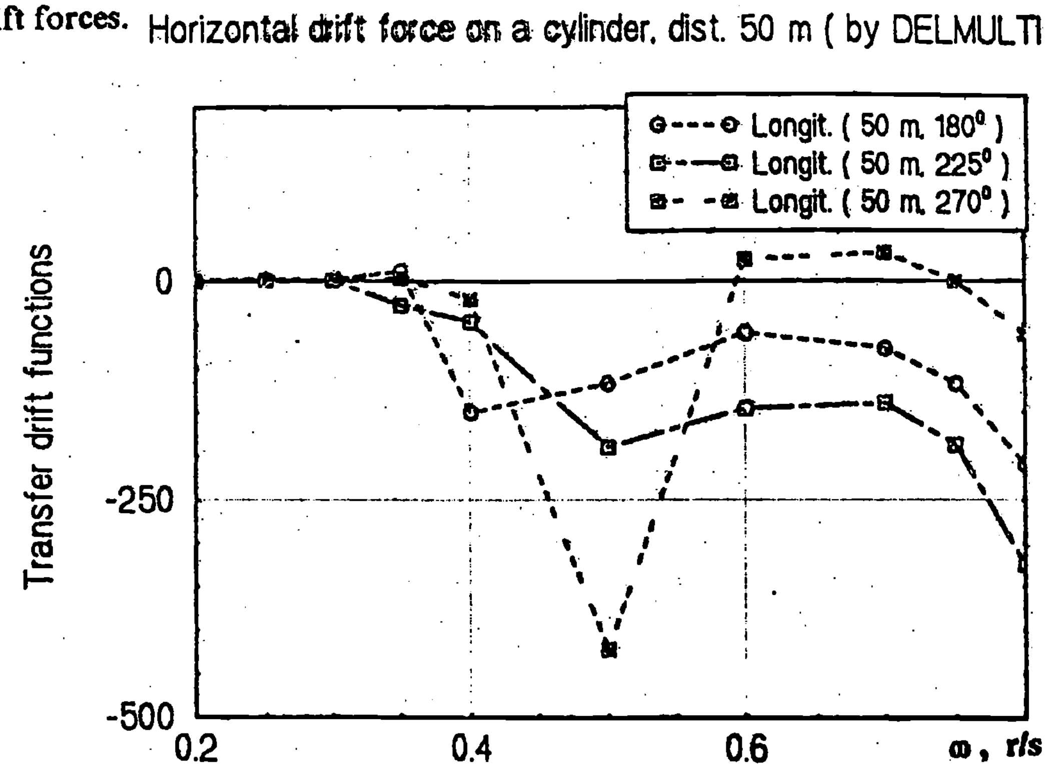

Fig. 17. **Influence of wave heading on the longitudinal drift force transfer function of the cylinder vs a wave frequency.**

In figures 18 - 19 the results of comparisons of drift forces are presented. The results of the calculations by Ferreira and Lee (see ref. [4]) are shown in the same figures as well as experimental points of van Oortmerssen. On comparing the curves good agreement was found between the theoretical results of Ferreira and Lee and those obtained using the program DELMULTI.

In summary, it can be concluded that the using of 3D methods for the calculation of first order and mean second order forces in the interaction case can give quite satisfied results.

Computation times strongly depend on the number of bodies. For the case of a single body (cylinder or box with approximately the same total number of panels) the calculation of forces and motions including drift forces takes 10 minutes per frequency and per body. For the case of calculations of two bodies' interaction the time increase to one hour. If it is not necessary to calculate the drift forces using the pressure integration method the time of calculation can be decreased to 20 minutes per frequency. It is necessary to underline that for the multibody case a computer IBM - 486 DX with frequency 66 MHz and 32 Mb RAM is used. For calculation of a single body a computer IBM - 386 DX with frequency 40 MHz and 16 Mb RAM is used.

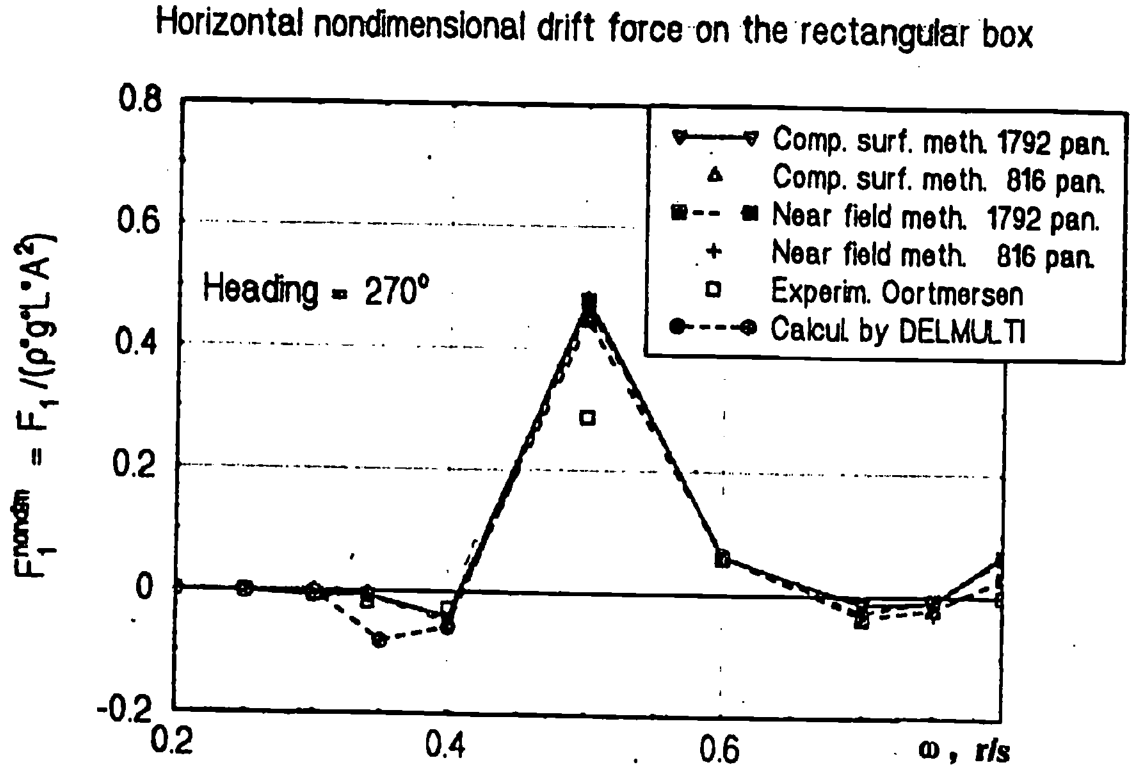

Fig. 18. The longitudinal drift force transfer function of the rectangular box versus a wave frequency for the several calculation conditions.

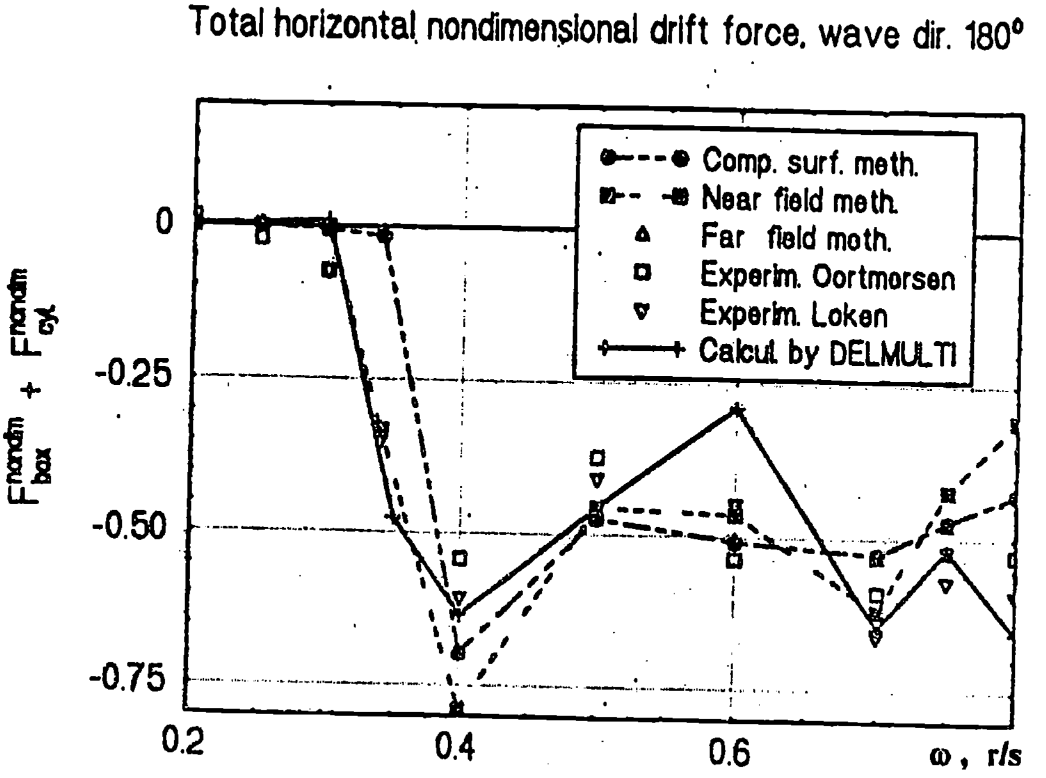

Fig. 19. Total longitudinal drift force transfer function obtained by several methods as a function of a wave frequency.

6 Conclusions

The main conclusions from our numerical investigations are as follows :

- linear 3D diffraction theory is suitable to predict hydrodynamic interaction effects between floating bodies ;
- the comparisons of computed and measured values of hydrodynamic coefficients of the bodies and hydrodynamic interaction coefficients are quite good ;
- the computed results obtained using the multibody version of DELFRAC correlate well with the results of other authors ;
- the biggest interaction effects are observed at rather high frequencies and can be significant. When two structures have the same size and similar motions amplitudes, it appears that the hydrodynamic forces due to the motions of the neighbour, can be of the same order of magnitude as the forces, induced by the body's own motions ;
- in literature only few results it can be found of 3D calculation of drift forces acting on two or more bodies, especially when bodies have an arbitrary or ship shape. In order to have more experimental data for a testing of existing computer codes the investigations have to be continued. However, some conclusions about drift forces can be made from our analysis.

Acknowledgment

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