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DEPARTMENT OF CIVIL ENGINEERING
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Aalborg University
Department of Civil Engineering
Wave Energy Research Group

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by

Jonas Bjerg Thomsen

June 2017

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# Preface

This report covers a simple investigation of mean drift forces found by use of the boundary element method code NEMOH. The results from NEMOH are compared to analytical results from literature and to numerical values found from the commercial software package WADAM by DNV-GL.

The work was conducted under the project “Mooring Solutions for Large Wave Energy Converters”, during "Work Package 4: Full Dynamic Analysis". The validation compares results from a simple sphere and from a vertical cylinder.

Aalborg University, June 9, 2017

# Contents

# 1 | Introduction

When considering wave loads on offshore structures, the total load is often divided into three separate contributions: a load oscillating at the frequency of the incoming wave and denoted the wave frequency (WF) load, a second order low frequency (LF) load and a mean load, also of second order, cf. Fig 1.1.

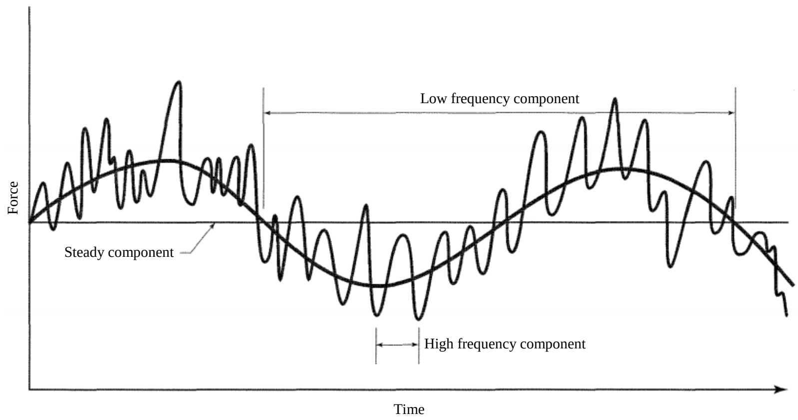


**Fig. 1.1.** Definition of first order wave frequency (WF) load, second order low frequency (LF) load and the mean load contribution. Adapted from API (2005)

In many applications, only the first order WF load is considered, which is a direct output of many commercial software packages such as *WAMIT* (Lee and Newman, 2013) and *WADAM* (DNV, 2013), or of open source codes such as *NEMOH* (Babarit and Delhommeau, 2015). All of these takes advantage of the boundary element method (BEM), with its linear wave potential theory. In design of mooring systems, the second order loads are of considerable influence, and need to be included in the calculations. Different methods are available for estimation of the second order response, including use of full quadratic transfer functions (QTFs) which can be calculated directly by e.g. *WAMIT*, but at present, not by *NEMOH* and *WADAM*. In many cases, however, the Newman approximation is used, implying that only the mean drift forces are required to calculate the second order response. These mean drift forces can be calculated from first order quantities, using different methods such as the far-field or near-field formulations, and, therefore, from the direct output of first order BEM codes.

The present report tends to validate the calculation of drift force coefficients using output from the boundary element method code *NEMOH* (Babarit and Delhommeau, 2015) and the *MATLAB* routine available at ECN (2016). The report is structured with an initiating chapter which shortly describes the method, followed by a chapter which compares numerical (*NEMOH*) results of a floating sphere with analytical results available in literature. The final chapter compares results from *NEMOH* and the commercial software *WADAM* for a vertical cylinder.

# 2 | Calculation of Mean Drift Forces

In calculation of mean drift forces, it is possible to use only the first order quantities, which puts less demands on the analysis tool. Codes such as *NEMOH* and *WADAM*, are fully capable of calculating the first order quantities but are currently not capable of including second order effects. This chapter briefly deals with the method used for calculation of the drift force coefficients. For more detailed description of the theory, cf. e.g. Mauro (1960), Newman (1967), Pinkster (1980), Kim (1999) and Lee and Newman (2005).

Different methods are available for estimation of the horizontal drift forces. Two methods that are often encountered are:

- The momentum conservation formulation (Far-field formulation)
- The pressure integration formulation (Near-field formulation)

The present report deals only with the far-field formulation. A disadvantage of the far-field formulation is that it is restricted to calculate only the horizontal components of the drift force, but in many applications, this is sufficient.

Similar to the first order wave excitation force, the second order drift force is composed by a radiation and diffraction contribution. The drift force can be determined from eq. (2.1).

$$\begin{aligned}\begin{pmatrix} F_{drift,x} \\ F_{drift,y} \end{pmatrix} =& -2\pi\rho a\omega \begin{pmatrix} \cos\beta \\ \sin\beta \end{pmatrix} \mathrm{Im}(\tilde{H}\left(\beta,\omega\right)) \\ &- 8\pi\rho \frac{k\left(k_0 h\right)^2}{h\left((kh)^2-(k_0 h)^2+k_0 h\right)} \int_{\frac{-pi}{2}}^{\frac{\pi}{2}} \mathrm{Re}(\tilde{H}(\theta,\omega))\,\mathrm{Im}(\tilde{H}(\theta,\omega)) \begin{pmatrix} \cos\theta \\ \sin\theta \end{pmatrix} d\theta \end{aligned} \tag{2.1}$$

Where,

| | |
|---|---|
| $F_{drift,x}$ | Drift force in the x-axis |
| $F_{drift,y}$ | Drift force in the y-axis |
| $\rho$ | Fluid density |
| $a$ | Incoming wave amplitude |
| $\omega$ | Wave angular frequency |
| $\beta$ | Incoming wave angle |
| $\tilde{H}\left(\beta,\omega\right)$ | The complex Kochin function |
| $k$ | Wave length at given water depth |
| $k_0$ | Deep water wave length |
| $h$ | Water depth |

The Kochin functions are combined by a contribution from radiation and diffraction and the total Kochin function can be found from equation (2.2) as the complex sum (Folley, 2016; Babarit and Delhommeau, 2015). The output of e.g. *NEMOH* is the separate diffraction and radiation Kochin functions.

$$\tilde{H}(\beta,\omega) = a\tilde{H}_D(\beta,\omega)\, e^{i\frac{\pi}{2}} + \sum_{j=1}^{6} a\tilde{X}_j(\omega)\, \tilde{H}_R(\beta,\omega)\, e^{-i\frac{\pi}{2}} i\omega \tag{2.2}$$

Where,

| | |
|---|---|
| $\tilde{H}_D(\beta,\omega)$ | The Kochin function for the diffraction potential |
| $\tilde{H}_R(\beta,\omega)$ | The Kochin function for the radiation potential |
| $\tilde{X}_j(\omega)$ | The motion Response Amplitude Operators (RAO) |

For use in many types of calculations, the drift force is normalized according the the incoming wave amplitude, $a$.

## Drift Force Coefficient from WADAM

The theory behind the WADAM code will not be treated in this report and must be found in e.g. DNV (2013), but it is worth to notice that the code is capable of using either the far-field or near-field formulation. When using the far-field formulation, however, the code only consider the three horizontal degrees of freedom (DoFs), hence only surge, sway and yaw. The effects of heave, roll and pitch are, therefore, not considered.

# 3 | Investigation of Spherical Shape

The first geometric shape which is considered is a floating sphere as illustrated in Fig. 3.1. The body is located in deep water conditions, and when presenting the results later in this chapter, the drift forces are normalized according to wave amplitude and buoy radius, hence, listing any geometric parameters is without any importance.

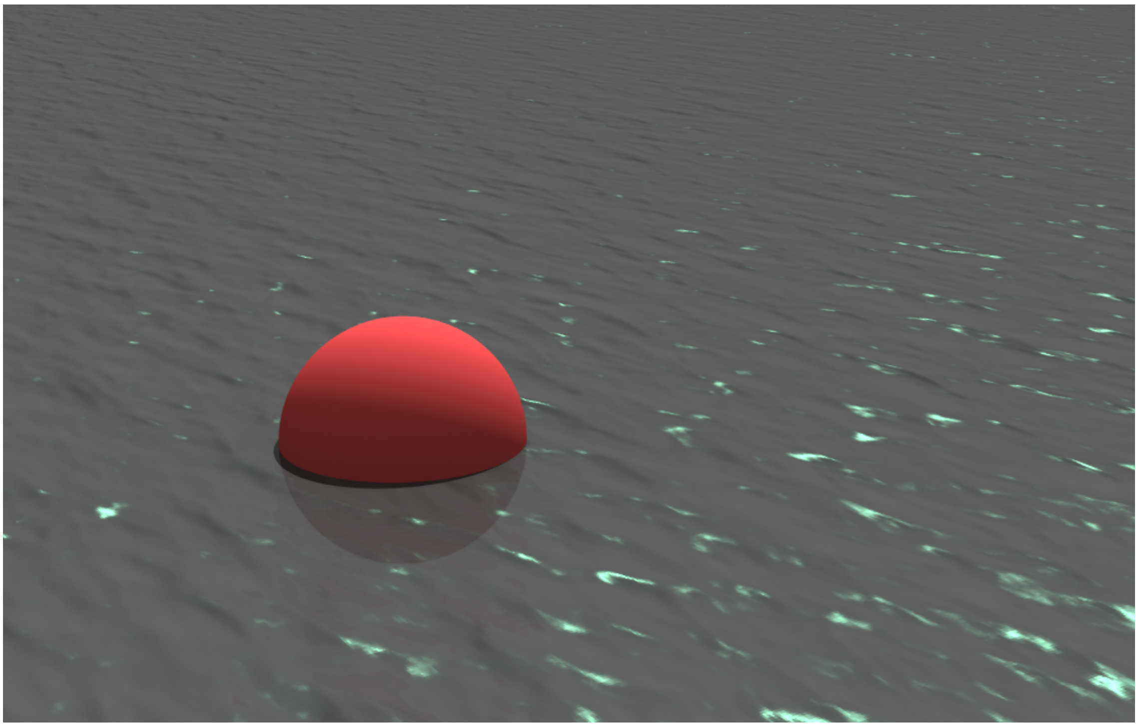

**Fig. 3.1.** Illustration of investigated sphere.

Since the BEM does not consider the geometry above the SWL, the investigated shape is actually a hemisphere, with a panel mesh as illustrated in Fig. 3.2. Several authors such as Pinkster (1980) and Mauro (1960), have described the drift forces on a floating hemisphere, and this chapter will compare the numerical results from *NEMOH*, with the analytical solution from Pinkster (1980).

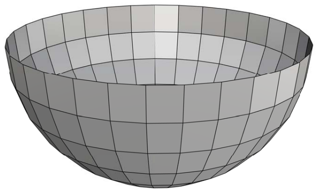

**Fig. 3.2.** Panel mesh used in *NEMOH*.

When plotting the results from *NEMOH* against the analytical solution in Fig. 3.3 a great agreement is observed. The drift force is seen to increase with $ka$ (where $k$ = wave number and $a$ = wave amplitude) until reaching a maximum value, before it starts to decrease until it converges towards a certain value. For a spherical shape like this, the rotational DoFs do not affect the drift forces, while the peak in Fig. 3.3 arises from the vertical heave motions. If e.g. the heave DoF was restrained in the *NEMOH* analysis, the peak would not be present.

In cases with very short and steep waves, there would be almost complete reflection. According to Faltinsen (1993), the drift force on a body with circular waterplane area, can be estimated by equation (3.1), assuming short and fully reflected waves.

$$F_{d,x} = \frac{2}{3}\rho g a^2 r \cos\beta \quad (3.1)$$

This value is plotted in Fig. 3.3 ($\approx 0.67$), which corresponds to the value at which the calculated drift force in *NEMOH* converges towards.

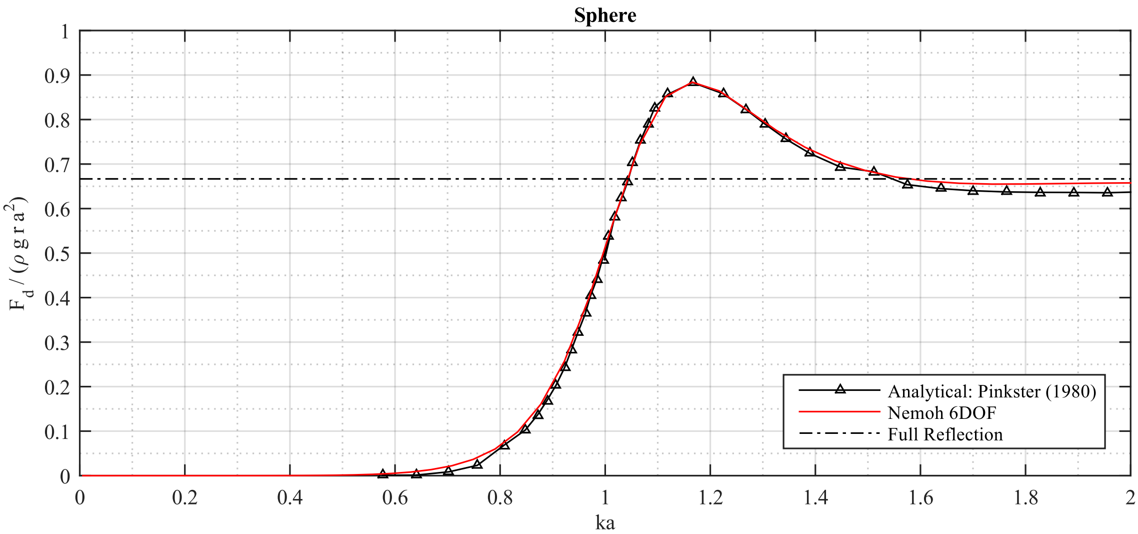


**Fig. 3.3.** Comparison between numerical and analytical drift force on a sphere, and with indication of the drift force on a sphere with full wave reflection.

Considering the agreement between analytical results, the drift force coefficient calculated by *NEMOH* is considered valid for a simple shape like a sphere.

# 4 | Investigation of Vertical Cylinder

The second case that is considered in this report, consist of a vertical cylinder located in deep water depth, cf. Fig. 4.1. In this chapter, the results found from *NEMOH* are compared to results from the *WADAM* package.

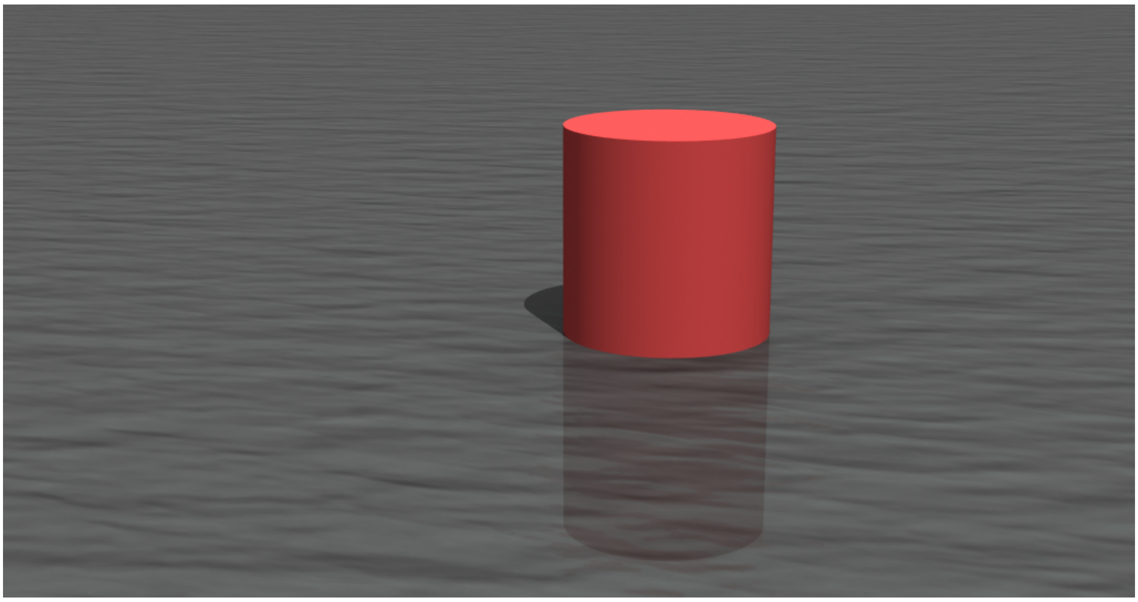

**Fig. 4.1.** Illustration of the investigated cylinder.

The geometrical properties of the cylinder are as listed below.

| **Dimension** | **Notation** | **Value** |
|---|---|---|
| Diameter | $D$ | 10 m |
| Height | $H$ | 20 m |
| Draught | $d$ | 10 m |
| Water depth | $h$ | $\infty$ |

The wetted surface of the model was analysed in both *WADAM* and *NEMOH*, with the mesh illustrated in Fig. 4.2.

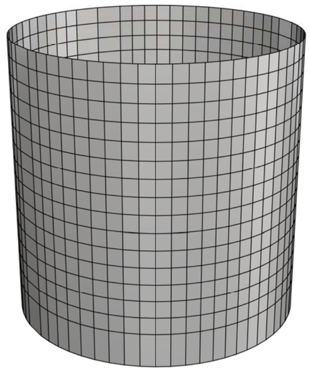

**Fig. 4.2.** Panel mesh used in *NEMOH* and *WADAM*.

In calculation of the drift forces in the *WADAM* model, the far-field formulation was used as this is the method that was used in *NEMOH*. This means that only the horizontal DoFs (surge, sway and yaw) were considered in *WADAM*. Comparing the results from the two models, the effect of this is clearly seen.

In general, Fig. 4.3 present a good agreement between the two models. An analysis was performed in *NEMOH*, considering the same DoFs as in *WADAM* and insignificant difference is seen between the two methods. The effects of using six DoFs in *NEMOH* are obtained from the figure, and present some influence from the inclusion of pitch and heave motions.

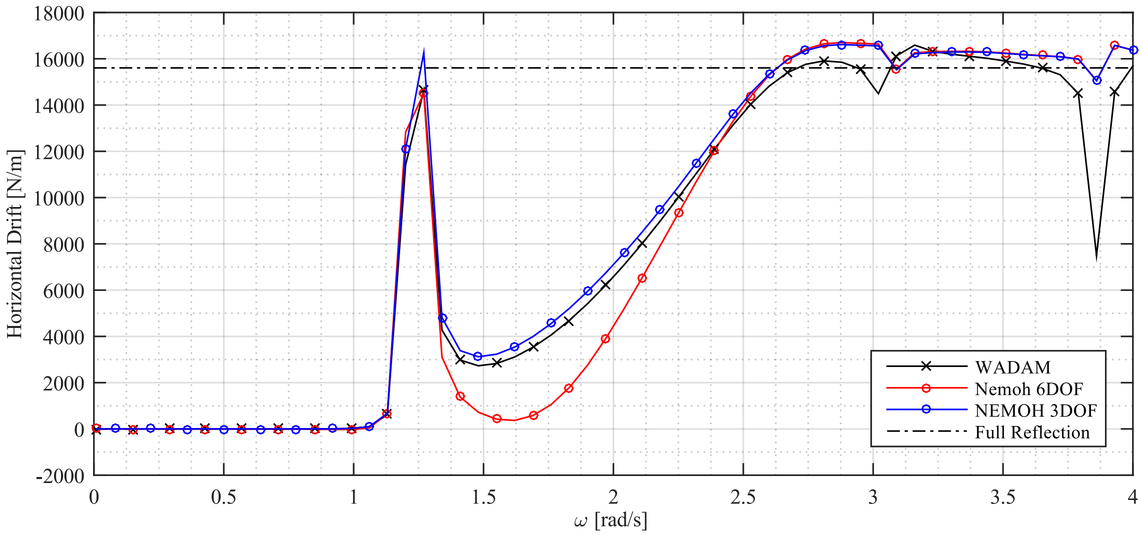


**Fig. 4.3.** Comparison between *WADAM* results and *NEMOH* drift force, where the latter has been analysed with all DoFs and with restrain on the pitch DoF.

For very short waves, full reflection can be assumed and equation (3.1) can be used to find the analytical drift force. As presented in Fig. 4.3, it is seen that both *WADAM* and *NEMOH* converge towards this value for the highest wave frequencies.

In general, the comparison proves good agreement between the commercial *WADAM* software package and *NEMOH*, and helps justify the use of the model and the code available at ECN (2016).

# 5 | Conclusion

This report has investigated the drift forces calculated by the open source BEM code *NEMOH* and the corresponding code available at ECN (2016). The investigation covered a comparison with analytical results and results from the commercial software package *WADAM* by DNV (2013).

The report compared the results for a simple spherical shape and compared it to analytical results. Good agreement was found between the two, and similar was seen for the results from a cylinder, which was compared to *WADAM*. This gives a simple validation of the drift force coefficients from *NEMOH* and help justify the use of the code for more complex structures. The study was limited to simple shapes as these are relatively easy to analyse analytically, while more complex structures need more advanced calculations. Before the use of the coefficients in a detailed analysis of a complex floating structure it is, therefore, recommended to validate the results against e.g. experimental data or more sophisticated models. This is out of scope of this report, but must be considered in later work.

# Bibliography


API (2005). Design and analysis of station keeping systems for floating structures, API-RP-2SK. *American Petroleum Institute.*

Babarit, A. and Delhommeau, G. (2015). Theoretical and numerical aspects of the open source bem solver nemoh. In *11th European Wave and Tidal Energy Conference (EWTEC2015).*

DNV (2013). Sesam user manual. wadam: Wave analysis by diffraction and morison theory. *Høvik, Norway.*

ECN (2016). Nemoh. `http://lheea.ec-nantes.fr/doku.php/emo/nemoh/start`.

Faltinsen, O. (1993). *Sea loads on ships and offshore structures*, volume 1. Cambridge university press.

Folley, M. (2016). *Numerical Modelling of Wave Energy Converters: State-of-the-Art Techniques for Single Devices and Arrays.* Academic Press.

Kim, Y. (1999). *Computation of higher-order hydrodynamic forces on ships and offshore structures in waves.* PhD thesis, Massachusetts Institute of Technology.

Lee, C. and Newman, J. (2013). Wamit user manual, version 7.0. *WAMIT, Inc., Chestnut Hill, MA.*

Lee, C.-H. and Newman, J. (2005). Computation of wave effects using the panel method. *WIT Transactions on State-of-the-art in Science and Engineering*, 18.

Mauro, H. (1960). The drift of a body floating on waves. *Journal of Ship Research*, 4:1–5.

Newman, J. t. (1967). The drift force and moment on ships in waves. *J. Ship Res.*, 11(1):51–60.

Pinkster, J. A. (1980). Low frequency second order wave exciting forces on floating structures.

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