Manual for the open source potential solver: NEMOH

Derivation of potentials and drift forces for a semi-submersed heaving sphere

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February 2017

General Information

The purpose of this manual is to assist the students of the course: *Loads and Motions in Waves*, in the implementation of their assignment. NEMOH (Babarit and Delhommeau, 2015) is a *Boundary Element Method* (BEM) code dedicated to the computation of first order wave loads on offshore structures (added mass, radiation damping, diffraction forces, etc). NEMOH is based on *3D-Diffraction Theory* (Journée et al., 2015, Chapter 7). Based on first order order potentials, calculated by NEMOH, it is possible to derive estimation for the second order mean drift forces acting on offshore structures steady or floating. The mean drift forces will be computed for the semi-submersed sphere created with the aid of the previously provided SALOME manual. It is recommended for students, before start working with NEMOH, to read the *General Notations and Conventions* used by the code, by following the link:
`http://lheea.ec-nantes.fr/lib/exe/fetch.php/emo/nemoh/general_notations_and_conventions.pdf`

Install NEMOH

In this section, the installation of NEMOH for Windows is discussed. There is no need for the use of other operating system throughout this manual. NEMOH can run in terms of executable *.exe* files. So as to download these files, click on the link below:
`http://lheea.ec-nantes.fr/lib/exe/fetch.php/emo/nemoh/nemoh_v2.03.zip`
The downloaded *.zip* file contains all the executable files needed for NEMOH to run. For every different NEMOH case a folder containing these files should be created. For the assignment purpose create a working folder under the name: *NEMOH_assignment*, which will be our working folder. The folder does not need to be placed somewhere specifically. Then, copy the downloaded *.zip* file in the folder and extract the files, it contains. Four different solvers should have been extracted, namely: *preProcessor, Solver, postProcessor* and *Mesh*, allong with a *LICENSE* and *NOTICE* documents. These solvers can be run, one by one, by opening a *Command Prompt* window. Alternatively, we will create a *batch* file for automating the process and save time. To do so, open a new text document with *Notepad* or any other text editor you use within the working folder. Inside the text document, write the following commands:
@echo off
START/W preProcessor.exe
START/W Solver.exe
START/W postProcessor.exe
Next, from the *File* menu on top, choose *Save As…*. The *Save As* dialog box should be open. In the *File Name* field write a name for the *batch* file followed by the *.bat* extension. For our case, write *run.bat* and click on *Save*. The *batch* file should have been created. Every time you want to run NEMOH just copy this file in the working folder and double-click on it. The solvers will be run and executed in sequence. Finally, it is needed to create two folders within the working folder, namely: *Results* and *Mesh* for output storage. Once everything is done, the working folder should appear as in Figure 1. We are ready to start

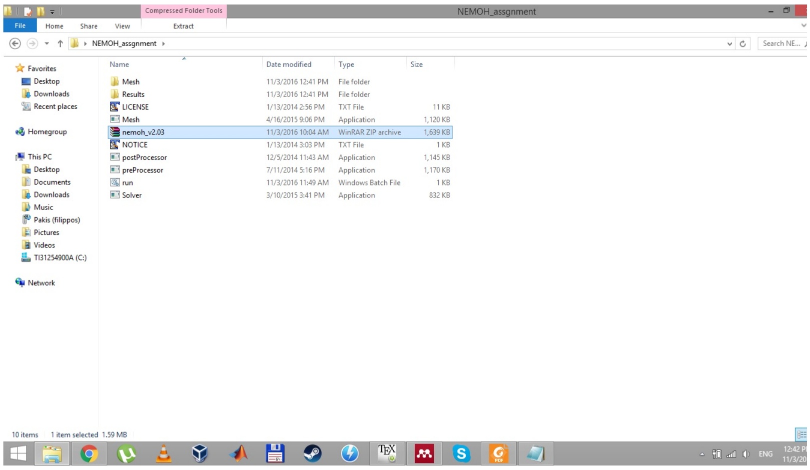


Figure 1: Working folder of NEMOH without input files

providing input.

Providing Input

So as to download the input files for NEMOH, click on the following link:
`http://lheea.ec-nantes.fr/lib/exe/fetch.php/emo/nemoh/cylinder.zip`
Then, copy the downloaded *.zip* file in the working folder and extract the input files it contains, namely: *ID.dat*, *input.txt*, *Nemoh.cal* and *Cylinder.dat*. Then delete *cylinder.zip*, *Cylinder.dat* and *Nemoh.cal* as they refer to another example case and not to the semi-submersed sphere of the assignment. Now, we are going to use the files we converted during the implementation of the previous manual for SALOME, namely the converted *Mesh_1_new.dat* file and the subsequent updated *Nemoh.cal* file. Copy these two files in the working folder. Once done, all the input files needed are located within the working folder. *ID.dat* and *input.txt* do not need any change and they will remain as they are. The *Nemoh.cal* file, on the other hand, is the most basic file for the communication of the user with the code and it is analyzed in the following section.

Nemoh.cal

Double-click on *Nemoh.cal* file. Figure 2 should appear on your screen. On the top, in the environment section, change the value for *Fluid specific volume* (water density) to $1025kg/m^3$. The next line of *Gravity* acceleration stays the same. Next, change the *Depth* to $25m$. For zero, deep water conditions are implied for all frequencies.

The next lines refer to the *Description of floating bodies*. Keep the value of 1 as the *Number of bodies*. Then, we describe the properties of *Body 1*. At first, the *Name of mesh file* has to be changed to *Mesh_1_new.dat* so as to match the file name we gave to our mesh file. If the name is not given precisely, the simulation crashes. The *Number of points and number of panels* has already

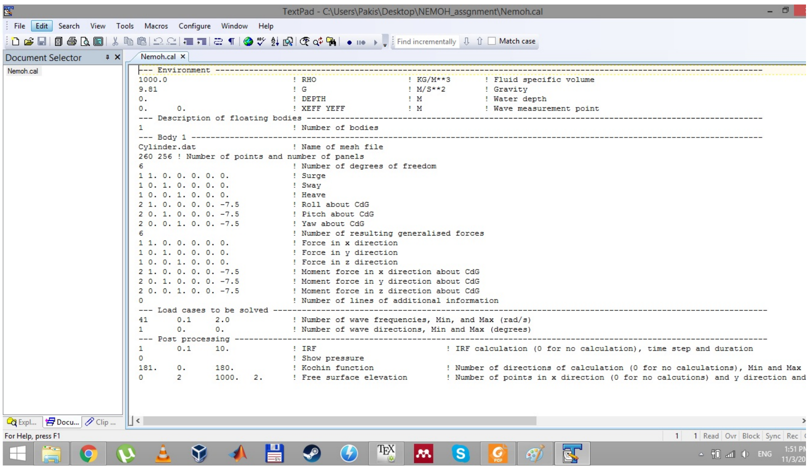


Figure 2: Nemoh.cal file overview

been updated during file conversion in Linux. Then we need to decide for the *Number of degrees of freedom*. As the assignment refers to a heaving sphere, use a value of 1. Below, information is given for every possible degree of freedom. The first number to the left, for every degree of freedom, is 1 for translation and 2 for rotation. You can notice that it is 1 for *Surge*, *Sway* and *Heave* and 2 for *Roll*, *Pitch* and *Yaw*. The next three numbers denote the axis of translation or rotation, using an xyz convention. Heave, as an example, refers to a translation in the direction of the unit vector $(0, 0, 1)$. The last three numbers denote the position of *Center of Gravity* (CoG). The position of CoG is irrelevant for translation motions but very important for rotation ones. As it is already noted, the semi-submersed sphere of the assignment is restrained to only *Heave* motion. For that reason, we need to delete all the lines referring to the other five *Degrees of motion*. Do it without leaving any empty lines in between. Next, we need to define for which forces and moments acting on the sphere we are going to ask for output. As we are interested in wave drift forces, we are going to ask for first order hydrodynamic forces in $x-$ and $y-$direction for comparison purposes. For deriving the RAO in heave, we will also ask for the hydrodynamic force in $z-$direction. Define then, the *Number of resulting generalized forces* as 3. The principle for defining each resulting force/moment is the same as before. The first number is 1 for forces and 2 for moments. The next numbers for direction and CoG are the same as before. Force in $z-$direction implies a force acting in the direction of the unit vector $(0, 0, 1)$. Finally, delete all the lines referring to *Moments* without leaving any empty lines and leave the *Number of lines of additional information* as 0.

Next, we will define the *Load cases to be solved*. Different load cases are created by alternating the range and resolution of discrete wave frequencies and by solving for various wave directions with respect to the $x-$axis. First, we will define the *Number of wave frequencies, Min, and Max (rad/s)*. The first number to the left denotes the total number of discrete frequencies to be solved by NEMOH. Set the number to 51. The next two numbers denote the minimum and the maximum wave frequency of the range. Set the minimum to $0.5 rad/s$ and the maximum to $3 rad/s$. This way a frequency resolution of $0.05 rad/s$ has been created. Students are encouraged to verify it. Next, we will define the *Number of wave directions, Min and Max (degrees).* The first number at the left denotes the total number of wave directions to be solved by NEMOH. For the assignment purposes set this value to 1. Then set both the maximum and the minimum of the wave direction range to 0. This means that the only wave direction to be solved will travel along the $x-$axis.

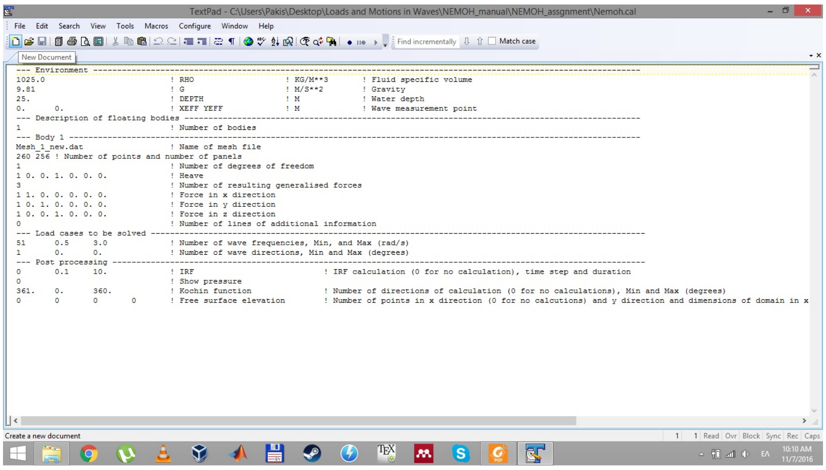
Finally, *Post processing* options will be set. *IRF* corresponds to the *Impulse Response Function* which is needed for calculating the radiation convolution term in the Cummins equation of motion in the time domain (Journée et al., 2015, Chapter 6). Set the first number to 0 as IRF is not needed for the current assignment. The other two numbers correspond to the time step and the duration for which IRF is estimated. Next, set *Show pressure* value to 0 as deriving hydrodynamic pressure for each panel of the sphere in terms of amplitude and phase difference is not needed for the assignment. *Kochin function* refers to the so-called **far-field coefficients** to be used for estimating the mean drift forces. You can read the NEMOH conventions for Kochin functions by following the link:
`http://lheea.ec-nantes.fr/lib/exe/fetch.php/emo/nemoh/kochin_function.pdf`
Set the first number to the left to a value of 361 for the number of directions of calculation. Set the range of calculation directions to $0-360$ degrees by applying these values to minimum and maximum. This configuration implies a circular directional resolution of 1 degree. Finally, we need to define the points for which we ask for *Free surface elevation.* The first two numbers at the left correspond to the number of points in $x-$ and $y-$direction. The last two correspond to the size of the domain. As an example, if we set the numbers to $[11, 11, 50, 50]$ we will derive a domain of size $50 \times 50m^2$ with a space step resolution of $5m$ and the body symmetrically placed in the middle of the domain. Set all the numbers to zero as free surface elevation is not relevant for the assignment. The resulting *Nemoh.cal* file should appear as in Figure 3.

NEMOH Run

If the previous steps were followed properly, NEMOH is ready to run. To do so, double-click on the *run.bat* file we created. After a while and a couple of popping windows, you should be able to see Figure 4 on your screen. You can notice that NEMOH solves for 102 problems while the number of discrete frequencies we chose is 51. The reason for this, is that NEMOH for every frequency solves one *diffraction* problem with the body restrained in incoming waves and one *radiation* problem for every degree of freedom. As we restrained our sphere only in heave, then NEMOH solves for two problems in total for every frequency. Keep this in mind because it is important for recognizing output files.

NEMOH Output

In this section, the output files which are relevant to the assignment are discussed. Output files are located within the *Results* folder. Enter the *Results* folder and you should be able to see the files shown in Figure 5.



```
--- Environment -------------------------------------------------------------
1025.0                  ! RHO                   ! KG/M**3      ! Fluid specific volume
9.81                    ! G                     ! M/S**2       ! Gravity
25.                     ! DEPTH                 ! M            ! Water depth
0.      0.              ! XEFF YEFF             ! M            ! Wave measurement point
--- Description of floating bodies ------------------------------------------
1                       ! Number of bodies
--- Body 1 ------------------------------------------------------------------
Mesh_1_new.dat          ! Name of mesh file
260 256 ! Number of points and number of panels
1                       ! Number of degrees of freedom
1 0. 0. 1. 0. 0. 0.     ! Heave
3                       ! Number of resulting generalised forces
1 1. 0. 0. 0. 0. 0.     ! Force in x direction
1 0. 1. 0. 0. 0. 0.     ! Force in y direction
1 0. 0. 1. 0. 0. 0.     ! Force in z direction
0                       ! Number of lines of additional information
--- Load cases to be solved -------------------------------------------------
51      0.5     3.0     ! Number of wave frequencies, Min, and Max (rad/s)
1       0.      0.      ! Number of wave directions, Min and Max (degrees)
--- Post processing ---------------------------------------------------------
0       0.1     10.     ! IRF                       ! IRF calculation (0 for no calculation), time step and duration
0                       ! Show pressure
361.    0.      360.    ! Kochin function           ! Number of directions of calculation (0 for no calculations), Min and Max (degrees)
0       0       0       0       ! Free surface elevation    ! Number of points in x direction (0 for no calcutions) and y direction and dimensions of domain in x
```

Figure 3: Nemoh.cal file overview for the case of the semi-submersed sphere

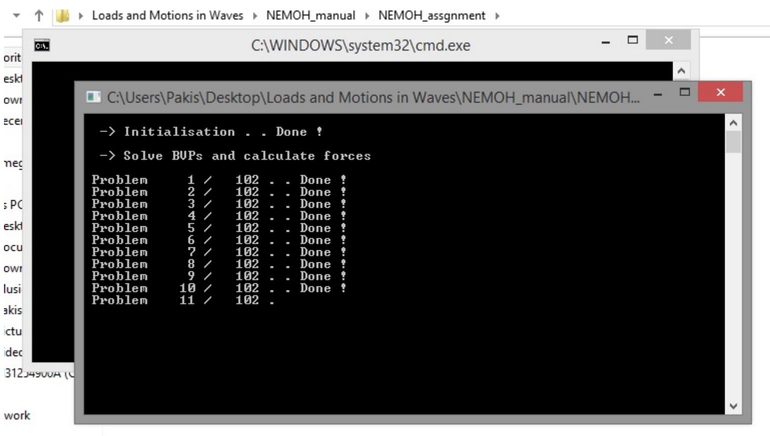


Figure 4: NEMOH running screen

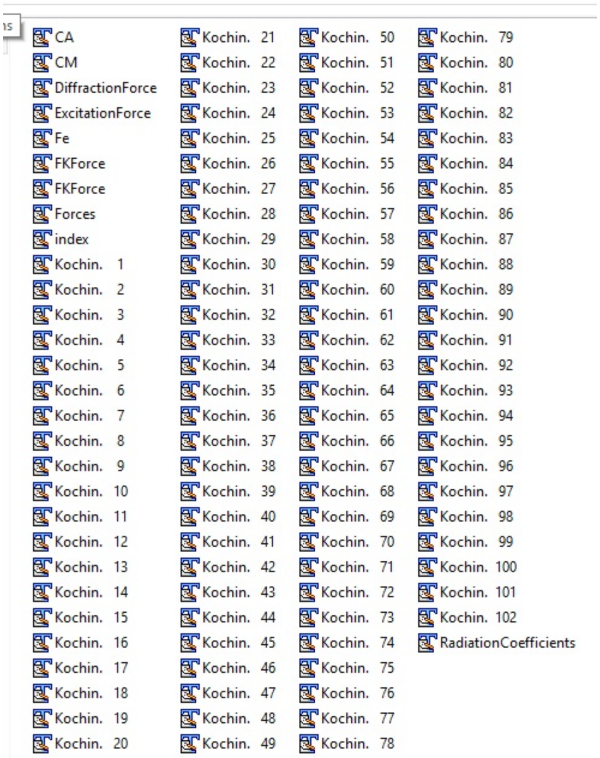
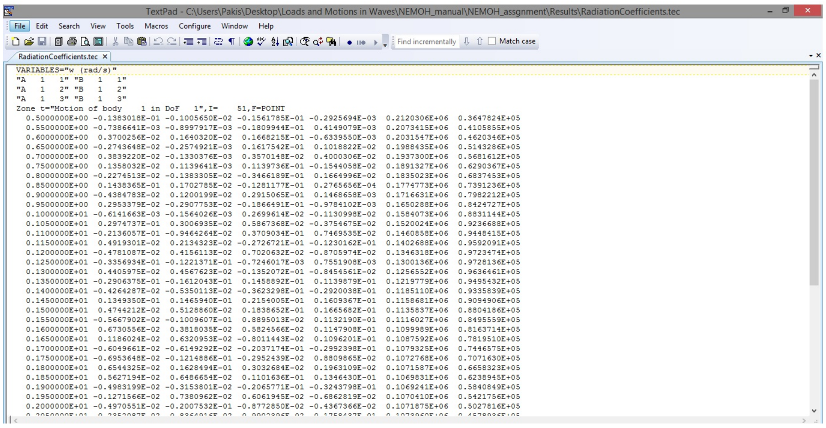


Figure 5: NEMOH output files



```
VARIABLES="w (rad/s)"
"A   1   1" "B   1   1"
"A   1   2" "B   1   2"
"A   1   3" "B   1   3"
Zone t="Motion of body    1 in DoF   1",I=    51,F=POINT
  0.5000000E+00 -0.1383018E-01 -0.1005650E-02 -0.1561785E-01 -0.2925694E-03  0.2120306E+06  0.3647824E+05
  0.5500000E+00 -0.7386641E-03 -0.8997917E-03 -0.1809944E-01  0.4149079E-03  0.2073415E+06  0.4105855E+05
  0.6000000E+00  0.3700256E-02  0.1640320E-02  0.1668215E-01 -0.6339550E-03  0.2031547E+06  0.4620346E+05
  0.6500000E+00 -0.2743648E-02 -0.2574921E-03  0.1617542E-01  0.1018822E-02  0.1988435E+06  0.5143286E+05
  0.7000000E+00  0.3839220E-02 -0.1330376E-03  0.3570148E-02  0.4000306E-02  0.1937300E+06  0.5681612E+05
  0.7500000E+00  0.1358032E-02  0.1139641E-03  0.1139736E-01 -0.1544058E-02  0.1891327E+06  0.6290367E+05
  0.8000000E+00 -0.2274513E-02 -0.1383305E-02 -0.3466189E-01  0.1664996E-02  0.1835023E+06  0.6837453E+05
  0.8500000E+00  0.1438365E-01  0.1702785E-02 -0.1281177E-01  0.2765656E-04  0.1774773E+06  0.7391236E+05
  0.9000000E+00 -0.4384783E-02  0.1200199E-02  0.2915065E-01  0.1468658E-03  0.1716631E+06  0.7982212E+05
  0.9500000E+00  0.2953379E-02 -0.2907753E-02 -0.1866491E-01 -0.9784102E-03  0.1650288E+06  0.8424727E+05
  0.1000000E+01 -0.6141663E-03 -0.1564026E-03  0.2699614E-02 -0.1130998E-02  0.1584073E+06  0.8831144E+05
  0.1050000E+01  0.2974737E-01  0.3006935E-02  0.5867368E-02 -0.3754675E-02  0.1520024E+06  0.9236688E+05
  0.1100000E+01 -0.2136057E-01 -0.9464264E-02  0.3709034E-01  0.7469535E-02  0.1460858E+06  0.9448415E+05
  0.1150000E+01  0.4919301E-02  0.2134323E-02 -0.2726721E-01 -0.1230162E-01  0.1402688E+06  0.9592091E+05
  0.1200000E+01 -0.4781087E-02  0.4156113E-02  0.7020632E-02 -0.8705974E-02  0.1346318E+06  0.9723474E+05
  0.1250000E+01 -0.3356934E-01 -0.1221371E-01 -0.7246017E-03  0.7551908E-03  0.1300136E+06  0.9728136E+05
  0.1300000E+01  0.4405975E-02  0.4567623E-02 -0.1352072E-01 -0.8454561E-02  0.1256552E+06  0.9636461E+05
  0.1350000E+01 -0.2906375E-01 -0.1612043E-01  0.1458892E-01  0.1139879E-01  0.1219779E+06  0.9495432E+05
  0.1400000E+01 -0.4264287E-02 -0.5350113E-02 -0.3623298E-01 -0.2920038E-01  0.1185110E+06  0.9335839E+05
  0.1450000E+01  0.1349350E-01  0.1465940E-01  0.2154005E-01  0.1609367E-01  0.1158681E+06  0.9094906E+05
  0.1500000E+01  0.4744212E-02  0.5128860E-02  0.1838652E-01  0.1665682E-01  0.1135837E+06  0.8804186E+05
  0.1550000E+01 -0.5667902E-02 -0.1009607E-01  0.8895013E-02  0.1132190E-01  0.1116027E+06  0.8495559E+05
  0.1600000E+01  0.6730556E-02  0.3818035E-02  0.5824566E-02  0.1147908E-01  0.1099989E+06  0.8163714E+05
  0.1650000E+01  0.1186024E-02  0.6320953E-02 -0.8011443E-02  0.1096201E-01  0.1087592E+06  0.7819510E+05
  0.1700000E+01 -0.6049661E-02 -0.6149292E-02 -0.2037174E-01 -0.2992398E-01  0.1079325E+06  0.7446575E+05
  0.1750000E+01 -0.6953648E-02 -0.1214886E-01 -0.2952439E-02  0.8809865E-02  0.1072768E+06  0.7071630E+05
  0.1800000E+01  0.6544325E-02  0.1628494E-01  0.3032684E-02  0.1963109E-02  0.1071587E+06  0.6658323E+05
  0.1850000E+01  0.5627194E-02  0.6486654E-02  0.1101636E-01  0.1346430E-01  0.1069831E+06  0.6238945E+05
  0.1900000E+01 -0.4983199E-02 -0.3153801E-02 -0.2065771E-01 -0.3243798E-01  0.1069241E+06  0.5840849E+05
  0.1950000E+01 -0.1271566E-02  0.7380962E-02  0.6061945E-02 -0.6862819E-02  0.1070410E+06  0.5421756E+05
  0.2000000E+01 -0.4970551E-02 -0.2007532E-01 -0.8772850E-02 -0.4367366E-02  0.1071875E+06  0.5027816E+05
```

Figure 6: NEMOH derived added mass and radiation coefficients

Response Amplitude Operator (RAO)

First, we are going to extract the information needed so as to derive the RAO of the sphere in heave. Double-click and open the *RadiationCoefficients.tec* file. You should be able to see Figure 6 on your screen. The first column corresponds to the discrete frequencies we input in NEMOH. The sixth and seventh columns denote the added mass and radiation damping coefficients in heave respectively. The results for every degree of freedom are separately written. The coefficients are given with the sequence the generalized forces were asked in *Nemoh.cal*. It is reminded that as a result of *coupling* of motions and forces/moments (Journée et al., 2015, Chapter 7), every separate motion returns radiation forces and moments in every of the total six directions. This is why we derived three sets of coefficients as we declared that we are interested in resulting forces in $x-$, $y-$ and $z-$direction. The order at which the degrees of freedom and the requested resulting forces are declared in *Nemoh.cal* file is determinant for the structure of the output files. It is recommended to keep the x, y, z convention sequence for both. The next step is to extract the excitation force for every discrete frequency as it is needed for the RAO calculation. It is reminded that the excitation force on the body is the superposition of the undisturbed force (Froude-Krylov force) and the diffraction force. Double-click on the *ExcitationForce.tec* file. Again here, the first column corresponds to the discrete frequencies we input in NEMOH. The sixth column denotes the excitation force amplitude in heave and the seventh column the corresponding phase angle with respect to the incoming wave elevation (see Notation and Conventions).

Drift Forces

NEMOH allows for calculating the mean drift forces acting on any geometry floating or steady. This is implemented via the so-called *far-field coefficients* or equivalently the *Kochin functions*. For formulas and mathematical description of the calculation download the file: *Drift force computation with nemoh_v2.pdf* from Blackboard. The document also contains validation cases for the drift forces calculated by NEMOH output. It has been created and shared with the NEMOH community by Vincent Arnal. Download also the provided MATLAB function, named *Drift_function.m*, for the final calculation of the drift forces. By providing the appropriate input, it is now possible to calculate drift forces for any object simulated in NEMOH. The MATLAB function comes with a function for calculating the wave numbers, named *wvs_wvnr.m*. Success!

References

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