MEMO

To	:	**To who it might concern**
From	:	**Jorrit-Jan Serraris (MARIN): j.w.serraris@marin.nl**
CC	:	
Date	:	**2020-05-27**
Subject	:	**Description of the MARIN hydrodynamic databases**

1 INTRODUCTION

The vessel motions due to sea waves and swell are calculated by MARIN. The calculations are performed with in-house developed hydrodynamic softwares (PANSHIP and PyMARIN). These calculation result in vessel motions (6 DOF), accelerations (6 DOF) and comfort rating (MSI, SPOWTT seasickness). The results of the calculations are stored in hydrodynamic databases. These databases give the vessel response (output) as function of the environmental conditions (input). The body motions of the technicians are the same as the vessel motions. Therefore the seasickness follows directly from these vessel motion calculations. The calculation approach is sketched schematically in Figure 1.

The sign conventions and contents of these databases are described in the present memo.

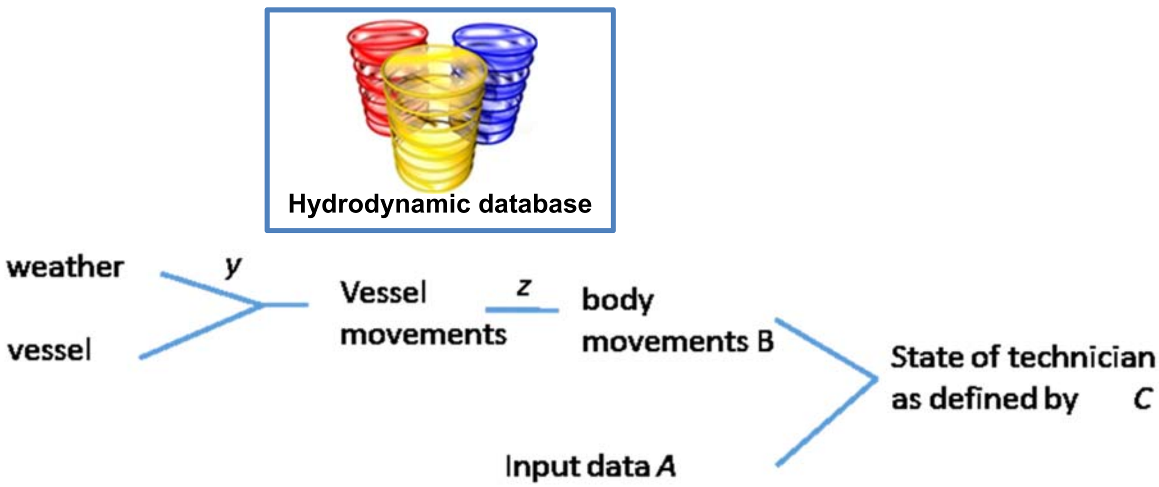

Figure 1: Vessel and body motion calculations

2 SIGN CONVENTION

2.1 Units

The following metric (SI) units are used throughout this report unless otherwise stated:
- Motions and dimensions are given in metres [m]
- Angles are given in degrees [deg]
- Forces are given in 1,000 Newtons [kN]
- Moments are given in 1,000 Newton metres [kNm]

2.2 Ship Fixed (SF) Local Coordinate System (LCS)

The applied sign convention and coordinate system are in accordance with the OCIMF standard. An overview of this standard is given in Figure 2. The origin of the Local Coordinate System (LCS) is located at the intersection of the keel, centreline and halfway L_{pp}. A right handed coordinate system is applicable. The order of rotations is Yaw-Pitch-Roll.

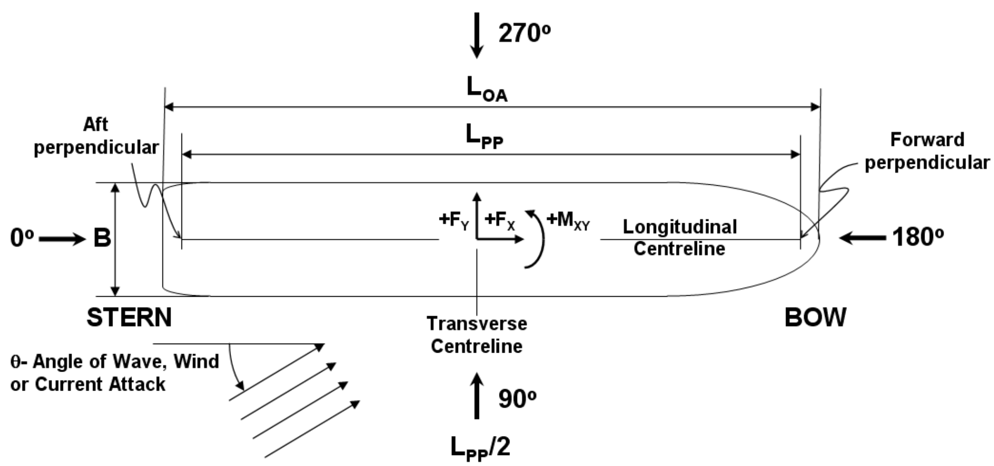

Figure 2: General OCIMF convention

The motions are positive in the following directions:

positive surge	(x) :	:	towards the bow
positive sway	(y) :	:	towards port side
positive heave	(z) :	:	upwards
positive roll	(ϕ) :	:	starboard side down
positive pitch	(θ) :	:	bow down
positive yaw	(ψ)	:	bow towards port side

The forces and moments are positive in the following directions:

positive longitudinal force	(F_x)	:	towards the bow
positive lateral force	(F_y)	:	towards port side
positive vertical force	(F_z)	:	upwards
positive roll moment	(M_x)	:	starboard side down
positive pitch moment	(M_y)	:	bow down
positive yaw moment	(M_z)	:	bow towards port side

The relative environmental headings are defined as follows:

0 degree heading	:	stern on
90 degrees heading	:	starboard side on
180 degrees heading	:	bow on
270 degrees heading	:	port side on

2.3 Earth Fixed (EF) Global Coordinate System (GCS)

In the Earth Fixed coordinate system environmental conditions are defined as follows:

- Wind and wave: “coming from”, positive clockwise with respect to North
- Current: “going”, positive clockwise with respect to North

This definition results in the following environmental directions for wind and waves:

DIR EF: Earth-Fixed environmental directions, where:

- 0° : Environmental from North to South
- 90° : Environmental from East to West
- 180° : Environmental from South to North
- 270° : Environmental from West to East

The orientation of the vessel in the Earth Fixed coordinate system is defined positive for clockwise with respect to North:

ΨEF: ClockWise wrt North

- 0° : Bow pointing to North
- 90° : Bow pointing to East
- 180° : Bow pointing to South
- 270° : Bow pointing to West

2.4 Conversion of the Ship Fixed to Earth Fixed Coordinate System

Environmental directions presented in the databases are Ship-Fixed, see Section 2.2. This means all environmental conditions are given relative to the vessels (180° environmental direction refers to head on conditions). The Ship-Fixed environmental conditions, in combination with the heading of the vessel, are related to the actual Earth-Fixed environmental conditions by:

$$\begin{aligned}
DirCur_CF &= \mathrm{mod}(DirCur_GT + 180, 360)\\
DirCur_EF &= DirCur_CF\\
DirCur_SF &= \mathrm{mod}(180 - DirCur_EF + \Psi EF, 360)\\
DirWind_SF &= \mathrm{mod}(180 - DirWind_EF + \Psi EF, 360)\\
DirWave_SF &= \mathrm{mod}(180 - DirWave_EF + \Psi EF, 360)\\
DirSwell_SF &= \mathrm{mod}(180 - DirSwell_EF + \Psi EF, 360)
\end{aligned}$$

In which:

CF: Coming from
GT: Going to
SF: Ship-Fixed environmental direction
EF: Earth-Fixed environmental directions, where:

- 0° : Environmental from North to South
- 90° : Environmental from East to West
- 180° : Environmental from South to North
- 270° : Environmental from West to East

ΨEF: ClockWise wrt North
- 0° : Bow pointing to North
- 90° : Bow pointing to East
- 180° : Bow pointing to South
- 270° : Bow pointing to West

3 DATABASE INPUT (IN)

3.1 Vessel data

Hydrodynamic database are available for a generic CTVs ranging in length between 13m and 25m Lpp. The main particulars of the CTVs are listed in Table T-1. The hull geometry is shown in Figure F-1.

3.2 Environmental conditions

The environmental conditions consist of 10 parameters:

- Waves
  - Direction [deg]
  - Significant wave height, Hs_sea [m]
  - Peak period, Tp_sea [s]
- Swell
  - Direction [deg]
  - Significant wave height, Hs_swell [m]
  - Peak period, Tp_swell [s]
- Current
  - Velocity [m/s]
  - Direction [deg]
- Wind
  - Velocity [m/s]
  - Direction [deg]

The wind and wave direction is chosen to be the same, since wind generates waves.

In addition to the environmental parameters the calculations are performed for three CTV speeds: 15, 20 and 25 kts, representing 50%, 75% and 100% MCR.

4 DATABASE OUTPUT SIGNALS (OUT)

4.1 Calculated signals

The signals calculated for the CTV in transit phase are listed in Table T-2 and consist of:

- 6 DOF motions at COG
- 3 DOF and accelerations at the bow (Bow) and resting (Rest) area (surge, sway and heave)
- Motion Induced Interruption (MII), Motion Sickness Incidence (MSI), Motion Illness Rating (MIR). These signals are explained in Reference [1] and [2].
- SPOWTT seasickness (SS) the bow (Bow) and resting (Rest) area

4.2 Presentation of the results

The simulations for the transit phase are performed in the frequency domain using the results of linearized diffraction analysis. Diffraction analysis is based on potential theory and assumes a linear response of the body. Diffraction analysis was carried out using MARINs software PANSHIP.

The results of the diffraction analysis are what are called Response Amplitude Operators (RAOs). These give the motion response of the center of gravity (CoG) of the vessel for a 1m amplitude regular wave of different frequencies and from different directions.

However, waves are rarely regular (single frequency) and are instead described by a spectral formulation which describes how the wave energy is distributed over different frequencies. The applied spectral formulation is the JONSWAP wave spectrum. Here the significant wave height (Hs), peak wave period (Tp) and spectral peak parameter (gamma) are used to describe the shape of the spectrum.

Once the RAO of the vessel for a particular mode is known, it is be combined with the wave spectra to get the motion response spectrum. This is defined as follows:

$$S_x(\omega, \Theta) = S_\zeta(\omega, \Theta). RAO^2(\omega). d\omega$$

Where $S_x(\omega, \Theta)$ is the motion response spectra (function of frequency) and $S_\zeta(\omega, \Theta)$ is the wave response spectra including directional spreading. Various moments of the motion spectra can now be defined, the zeroth moment is given below:

$$m0 = \int_0^\infty S_{mot}(\omega) * d\omega$$

The Root Mean Square (RMS) is defined as the square root of the zeroth spectral moment:

RMS=sqrt(m0)

The RMS is presented as STD (standard deviation) in the hydrodynamic databases.

5 REFERENCES

[1] Bos, J.E. and Dallinga, R.P., *“Fundamental issues on human discomfort aboard small craft, and how to apply this to yacht design”*. Conference on the Design of Small Craft, 2006, Bodrum, Turkey.

[2] Dallinga, R.P. and Bos, J.E., *“Cruise Ship Seakeeping and Passenger Comfort”, HPAS 2010*, Jun 2010.

TABLE T-1 CALCULATED SIGNALS: CTV TRANSIT

description	symbol	CTV-13m	CTV-14m	CTV-15m	CTV-19m	CTV-20m	CTV-25m
Length between perpendiculars	L_{pp} [m]	12.67	14.11	14.62	19.00	19.25	25.00
Length overall	L_{oa} [m]	13.86	15	17	22	22.8	N/A
Mean draft	T_{mean} [m]	1.07	1.00	1.21	1.25	1.28	1.30
Longitudinal centre of gravity	LCG [m]	6.18	5.45	6.48	7.78	7.25	10.19
Vertical centre of gravity	KG [m]	1.86	2.17	2.17	2.59	2.50	4.28

Table: main particulars of CTVs

TABLE T-2 HYDRODYNAMIC DATABASE SIGNALS

Signal	I/O	Unit	Range	Description
Thrust	IN	%	50, 75, 100	Maximum Continuous Rating (MCR)
Wave Direction	IN	deg	0......330	Ship-Fixed wave direction
Wave Height	IN	m	0.25......2.00	Significant wave height
Wave Period	IN	s	2, 3, 4, 5	Peak wave period
Swell Wave Direction	IN	deg	0......330	Ship-Fixed swell direction
Swell Wave Height	IN	m	0.25......1.50	Significant swell wave height
Swell Wave Period	IN	s	4, 5, 6, 7, 9	Peak swell period
Current Direction	IN	deg	0	Ship-Fixed current direction
Current Speed	IN	m/s	0	Current speed
Wind Direction	IN	deg	0	Ship-Fixed wind direction
Wind Speed	IN	m/s	0	1-hour mean wind speed at z=10m
RMS_surge [m]	OUT	m	0<	RMS Surge Motion @ Centre of Gravity
RMS_sway [m]	OUT	m	0<	RMS Sway Motion @ Centre of Gravity
RMS_heave [m]	OUT	m	0<	RMS Heave Motion @ Centre of Gravity
RMS_roll [deg]	OUT	deg	0<	RMS Roll
RMS_pitch [deg]	OUT	deg	0<	RMS Pitch
RMS_yaw [deg]	OUT	deg	0<	RMS Yaw
RMS_ax_Bow [m/s^2]	OUT	m/s^2	0<	RMS Surge Acceleration @ Bow
RMS_ay_Bow [m/s^2]	OUT	m/s^2	0<	RMS Sway Acceleration @ Bow
RMS_az_Bow [m/s^2]	OUT	m/s^2	0<	RMS Heave Acceleration @ Bow
RMS_ax_Rest [m/s^2]	OUT	m/s^2	0<	RMS Surge Velocity @ Resting area
RMS_ay_Rest [m/s^2]	OUT	m/s^2	0<	RMS Sway Velocity @ Resting area
RMS_az_Rest [m/s^2]	OUT	m/s^2	0<	RMS Heave Velocity @ Resting area
Vessel Speed [kn]	OUT	kn	15, 20, 25	Vessel speed
MII_Bow [1/hr]	OUT	1/hr	0<	Motion Induced Interruption @ Bow
MSI_Bow [%]	OUT	%	0-100	Motion Sickness Incidece @ Bow
MIR_Bow [-]	OUT	-	0-100	Motion Illness Rating @ Bow
SS_Bow [-]	OUT	-	0-1	SPOWTT Seasickness @ Bow
MII_Rest [1/hr]	OUT	1/hr	0<	Motion Induced Interruption @ Resting a
MSI_Rest [%]	OUT	%	0-100	Motion Sickness Incidece @ Resting area
MIR_Rest [-]	OUT	-	0-100	Motion Illness Rating @ Resting area
SS_Rest [-]	OUT	-	0-1	SPOWTT Seasickness @ Resting area

FIGURE F-1 CTV HULL LINES