Datawave Marine Science

OFreq Dynamics

Hydrodynamic Inputs

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April 14, 2013

Rev: 1.0

DMS1303-001-110-06

Revision History

Revision	Date	Changes	Approval
1.00	Apr 14, 2013	Initial Issue	Nicholas Barczak

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1 Introduction

2 Input Types

There are six major forces retrieved from a hydrodynamic database.

Table 2.1: Hydrodynamic Forces

Force Name	**Variable Type**	**Object Type**	**Associated Derivative**
Added mass	Double	Hydrodynamic Reaction Force	2^{nd} order derivative
Added damping	Double	Hydrodynamic Reaction Force	1^{st} order derivative
Hydrostatic spring	Double	Hydrodynamic Reaction Force	0^{th} order derivative
Cross-body mass	Double	Hydrodynamic Cross-Body Force	2^{nd} order derivative
Cross-body damping	Double	Hydrodynamic Cross-Body Force	1^{st} order derivative
Excitation force	Complex	Hydrodynamic Active Force	No derivative. Constant value.

Each one of these forces is actually a 6x6 matrix of coefficients relating force to motion variables. Be aware that each coefficient will vary with wave direction and wave frequency. And some of the coefficients also vary with wave amplitude. The coefficients retrieved from the databases are generic. They must be processed to produce a set of coefficients specific to the given run of oFreq.

3 Wave Force Processing

There are several major steps to process wave forces correctly for input into a dynamic solver.

1. Interpolate for wave direction
2. Interpolate for wave frequency

3. Scale wave amplitude

The first two steps require use of a generic interpolation function, which is defined in the next section.

3.1 Interpolation Function

An interpolation function finds data points within a given data and interpolates to return some value between the data points. The following function is a linear interpolation; it assumes a straight line between the two data points.

$$out = interp(x, data) \quad \text{Equation 3.1}$$

Where:
out = Output from interpolation function.
x = Input variable that you want to interpolate into your data set.
data = Data set that you want to interpolate for. Should be a two column array (independent and dependent variable).

Start by searching through the data set and find the two entries for the independent variable which are closest to the input value of x. It is safe to assume that the data is in sequential order. After those two entries are found, apply Equation 3.2 through Equation 3.4.

$$m = \frac{Y_2 - Y_1}{x_2 - x_1} \quad \text{Equation 3.2}$$

Where:
m = Slope of interpolation.
Y_2, Y_1 = Data point for dependent variable of interpolation.
x_2, x_1 = Corresponding data points for independent variable of interpolation.

$$b = Y_1 - m x_1 \quad \text{Equation 3.3}$$

Where:
b = Zero intercept for interpolation.

$$interp = m x + b \quad \text{Equation 3.4}$$

Where:

x = Input variable for interpolation

The output is a single value interpolated to match the provided input value of x.

3.1.1 Error Checking

If the input value of x falls outside the range of values supplied, do not interpolate.

Just return out the entry in the data set which is closest to the supplied input variable. There may also be a need to write a warning to a log file. This is not necessarily a critical error, depending on how the user setup the problem. But it can produce misleading results.

3.2 Interpolate Wave Direction

The first step is to interpolate wave direction. Each wave force must be interpolated for wave direction (added mass, added damping, hydrostatic spring, cross-body mass, cross-body damping, and excitation force). The input is a selected wave angle, α, measured in radians. Each hydrodynamic databases will contain one of more hydrodynamic directions.

$$out = interp(\alpha, data_{WaveDirection}) \quad \text{Equation 3.5}$$

Where:
out = Output from interpolation function.
α = Input variable wave direction [radians], measured with 0 = True North.
$data_{WaveDirection}$ = Data set for wave forces, varying with wave direction.

This interpolation is repeated for every required wave frequency and every given wave amplitude available within the supplied hydrodynamic databases. However, there is an opportunity to reduce the amount of data processing and reduce program efficiency. The program can pre-condition the data by first selecting only the necessary data points. For each wave direction, the program will need the two wave frequencies that are closest to the supplied input frequency. The program will also only need the two wave amplitudes that are closest to the supplied wave amplitude. This reduces the data set drastically down to just 2 frequencies for each direction, and 2 wave amplitudes (8 data points total).

3.2.1 Error Checking

If only one wave direction is available within the hydrodynamic database, it is acceptable to just use that direction for the output data. But a warning should be written to a log file.

3.3 Interpolate Wave Frequency

The next step is to interpolate wave frequency. Use the set of data just generated by interpolating wave direction. That should give one data point for each wave frequency (or only two data points if the data was pre-conditioned to only include the two closest frequencies.) This data is supplied for each considered wave amplitude. Perform this interpolation for each type of force. For each force type, you will obtain a single value of force for the specified wave direction and wave frequency.

This completes the processing of all forces from the hydrodynamic database, except the wave excitation force. The wave excitation force must be scaled for wave amplitude.

3.4 Scale Wave Amplitude

Only the wave excitation force is scaled with wave amplitude. All other force types bypass this step of wave scaling. Each hydrodynamic database will have full values for each wave force type, but the wave excitation force is the only one which will vary with wave amplitude. All other force types will be identical for each hydrodynamic database. The wave excitation force is scaled in the following manner.

If only one hydrodynamic database is provided, follow method A. If more than one database is provided, follow method B. The difference between the two methods is that method A assumes linear wave scaling. Without any further data, this is a reasonable assumption. Wave forces scale approximately linear to wave amplitude. But not perfectly linearly. Method B compares the data sets to determine the level of non-linearity and account for it in the wave scaling.

3.4.1 Method A – Linear Wave Scaling

The first method is simple linear wave scaling. The wave force is scaled up by the ratio of wave amplitudes.

$$F_{out}=F_0\left(\frac{\zeta}{\zeta_0}\right) \qquad \text{Equation 3.6}$$

Where:
ζ = Wave amplitude for this run of oFreq.
ζ_0 = Reference wave amplitude used to generate the hydrodynamic database.
F_0 = Reference wave force obtained from interpolation of the hydrodynamic database.

3.4.2 Method B – Non-linear Wave Scaling

Some hydrodynamic runs consider non-linear effects of wave amplitude. oFreq should be able to recognize these non-linear effects and take advantage of the additional accuracy that they represent. To do this, oFreq must use non-linear wave scaling.

Start by finding the two wave amplitudes closest to the input wave amplitude. Then interpolate with Equation 3.7 through Equation 3.9.

$$\gamma=\frac{\ln\left|\frac{F_2}{F_1}\right|}{\ln\left|\frac{\zeta_2}{\zeta_1}\right|}$$ Equation 3.7

Where:
F_1, F_2 = Force data points from hydrodynamic database.
ζ_1, ζ_2 = Wave amplitude data points from hydrodynamic database.
γ = Exponent of non-linearity. (If $\gamma = 1$, then it is a linear scaling.)

$$A=\frac{F_1}{\zeta_0^{\gamma}}$$ Equation 3.8

Where:
A = Slope of non-linear scaling

$$out=A\zeta^{\gamma}$$ Equation 3.9

Where:
ζ = Input value for wave amplitude.

4 Outputs

The final outputs are a set of seven forces, each specific to the given wave frequency, wave direction, and wave amplitude.

Added mass
Added damping
Hydrostatic spring
Cross-body mass
Cross-body damping
Excitation force

In reality, each one of these forces is a 6x6 matrix of values. Each value went through the conditioning process presented in this document.

5 Conclusion

This document presented the process to take a generalized database of hydrodynamic forces and convert them into a set of forces specific to the given user inputs. This process repeats for every single wave frequency and direction because inputs for wave environments can vary the wave amplitude with each frequency and direction.

6 References