REGULAR AND IRREGULAR WAVE GENERATION IN OPENFOAM USING HIGH ORDER SPECTRAL METHOD

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Introduction

On a number of engineering applications involving wave-structure interactions [1], the use of CFD is essential in order to account for viscous effects and non-linear deformations and breaking of the free surface. Solving Navier-Stokes equations in a viscous numerical wave tank is of low efficiency, in particular is the target is a fully developed sea state. The High Order Spectral (HOS) method [2], [3] solving the nonlinear inviscid problem is therefore applied for outer field wave generation. This reduces the computational cost, by reducing the size of the viscous domain. HOS method has been validated and developed [4], [5], [6] into two open source solvers available on github, nonlinear wave propagation in open sea (HOS-Ocean) [6] and in numerical wave tank (HOS-NWT) [7].

The spatial discretization needed for the solution of the Euler equations with HOS and the Navier-Stokes equations with OpenFOAM is very different. Grid2Grid [8] is a wrapper program of HOS (also available on github) developed to exchange the information between the two solvers. The plug-in toolbox of OpenFOAM waves2Foam [9] can generate fully developed wave fields in arbitrary time and space. In this paper we aim to combine these two methods and this new method is implemented to do the simulations.

Major Work

Inlet and outlet can be imposed in waves2Foam through the relaxation zones which can be seen as coupling zones. At each time step the flow velocity (u,v,w) and the volume fraction of the fluid (α) in coupling zone is computed with equation 1. The value of Φ_{target} is obtained from HOS results. Through the relaxation zone, the values of wave fields such as wave elevation and velocity from HOS can be transfered into inner CFD zone and the scattered wave in CFD zone can be mapped in target (incident) wave components when spreading outside. The sketch of the coupling method is shown in Figure 1.

$$\Phi = \alpha_R \Phi_{computed} + [1 - \alpha_R] \Phi_{target} \tag{1}$$

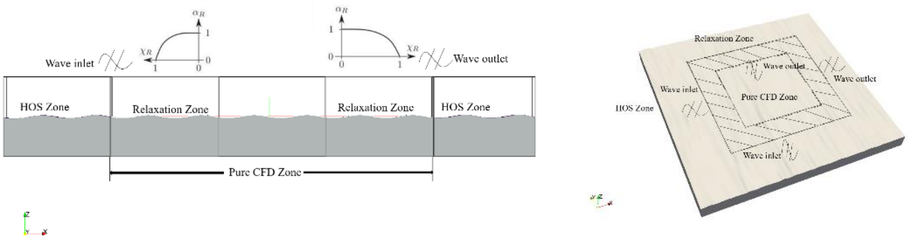


Figure 1 Sketch of the coupling method to compute the propagation wave in 2D and 3D

Results and Conclusions

To validate the effectiveness and accuracy of the coupling method, 6 cases are considered to compare the HOS solution to the CFD solution, shown in table 1. These tests have been computed [8], [10] in coupled method with HOS and foamStar, which is developed by Bureau Veritas and based on OpenFOAM. Therefore, we include the results from foamStar to compare.

Table 1 HOS wave conditions

Wave type	**Value**	**HOS-Ocean**		**HOS-NWT**	
		2D	3D	2D	3D
Regular wave	T (s)	-	-	0.702	0.702
	H (m)	-	-	0.0431	0.0288
Irregular wave	Tp (s)	0.702	1.0	1.0	0.702
	Hs (m)	0.0288	0.10	0.05	0.0384
	γ	3.3	3.3	3.3	3.3

The mesh generation is shown in Figure 2. The 2D cases are 1.14M grid numbers ($\lambda / \Delta x = 95$, $H / \Delta z = 17$ $T / \Delta t = 400$) and 3D cases are 3.2M grid numbers ($\lambda / \Delta x = 32$, $H / \Delta z = 20$ $T / \Delta t = 400$). [10] The wave elevation is analyzed based on the wave probe. The wave probe is put in the middle of the computational domain, see in figure 3. The wave probe is set in the same place both in HOS zone and in CFD zone. Figure 4 shows the comparison of wave elevation results from three methods.

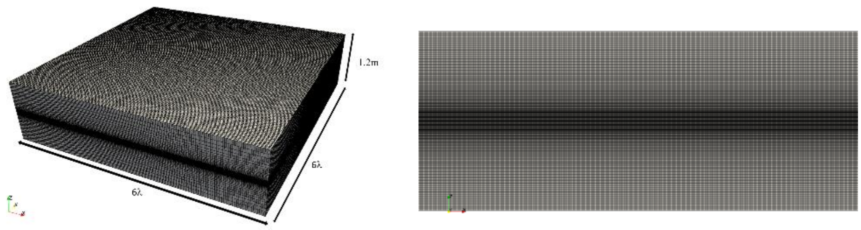
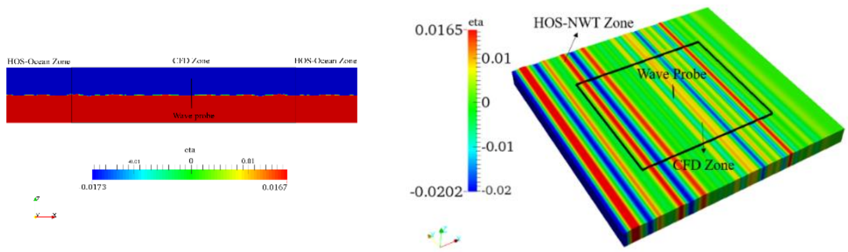


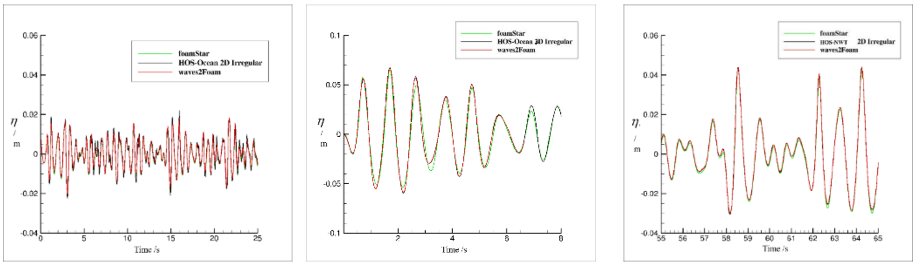
Figure 2 Mesh generation

The time history of wave elevation from CFD zone fairly agree with that from HOS zone, which shows the coupling method has the ability to simulate identical wave elevation which is generated by HOS. The contour of wave elevation indicates that the CFD zone can simulate in arbitrary space. The coupling method can do the simulation in naval and offshore wave-structure interaction effectively in the future.

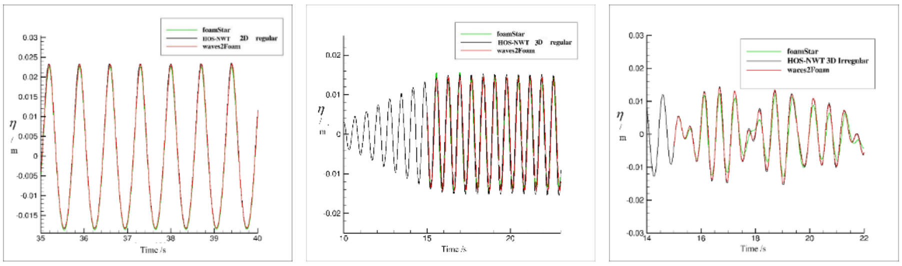


(a) HOS-Ocean 2D irregular wave (b) HOS-NWT 3D irregular wave

Figure 3 Wave elevation of coupled methods with HOS and waves2Foam.



(a) HOS-Ocean 2D irregular wave (b) HOS-Ocean 3D irregular wave (c) HOS-NWT 2D irregular wave



(d) HOS-NWT 2D regular wave (e) HOS-NWT 3D regular wave (f) HOS-NWT 3D irregular wave

Figure 4 Validation and comparison of coupled methods with HOS and waves2Foam.

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