EPSRC Marine Wave Energy Programme

New Generation Modelling Suite for the Survivability of Wave Energy Convertors in Marine Environments (WavE-Suite)

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Objectives - What do we plan to achieve

- Develop a new numerical modelling suite (WavE-Suite) equipped with advanced machine leaning algorithms by coupling five individual numerical models that are suitable for physics of different scales and nature
- Realise that WavE-Suite has the ability to deal with irregular waves together with current and wind and to simultaneously capture both large and small-scale physics, crucial for WECs.
- Demonstrate WavE-Suite to be able to identify the survival conditions and quantify extreme loads and motions of WECs

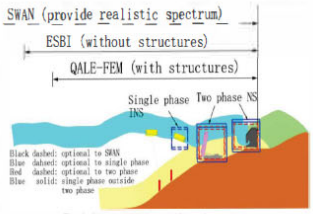

Fig. 2 Sketch of MMS modelling suite

Rational - Why do we do this

- Nonlinearity, wave breaking and turbulence play important roles for WECs survivability
- Long duration and large spatial domain modelling required to provide reliable statistical extreme loading and motion events
- The existing models are either too simple and inaccurate or too computational expensive
- Dealing with turbulence in breaking waves is a huge challenge as the existing turbulent models are not suitable for many breaking-waves cases

Model	The::\ es	Main features	Capability for WECs in survival waves	Comp. costs
Potential	LinearWEC-sim	Linear or second order for waves, hydrodynamics and body motions; artificial viscosity	No strong nonlinearity	+
Potential	and/or weak nonlinear			
Potential	Fully nonlinear potential	QALE-FEM* Waves/current, multibody hydrodynamics and motions; artificial viscosity	fully nonlinear but not breaking waves/viscosity	++
NS (CFD or high fidelity)	Navier-Stokes equation	OpenFOAM, Star-CCM+, Fluidfy*, SPH*, PIC*, Xdolphin3D*	1 or 2-phases, breaking waves, viscosity, restricting to a small region near the structures with prescribed linear/2nd order wave inlets; not widely used for random waves	Resolve physical details, run in small domain; numerical dissemination if run in large domain or long duration; +++++
MMS (Hybrid)	Combined theories	qaleFOAM*, OceanWave3D/ OpenFOAM or SPH	Potential model in large domain, 2-phases/breaking waves/viscosity in small domain near the structures	Deal with wave breaking, turbulence and viscosity; two-phase flow and less numerical damping +++

Fig. 1. Numerical models (+: order of computing costs; * developed by team members)

Workpackages - How do we do this

- ❑WP1: MMS modelling software for analysing survivability of WECs

Unified one-phase model (UnifWSI); Coupling of UnifWSI and 2-phase model; Coupling between UnifWSI and SWAN; Algorithm for automatically selecting right models.

- ❑WP2: ML Algorithms for estimating turbulent effects on WECs

ML-damping; ML-eddyV; ML-Rstress; Model refinement:

- ❑WP3: Databases and repository for WECs in high sea states

Database for eddy viscosity; Database for Reynolds stresses; Database on viscous damping; Data repository on the extreme loads and motions

- ❑WP4: Tailored model tests *testing of OWC; testing of point absorber; testing of hing ed raft WEC;*
- ❑*WP5: Validation of WavE-Suite and* characterisation of survivability validation by testing data; Identify the survival conditions; Quantify extreme loads and motions; Characterise the pressure and velocity fields

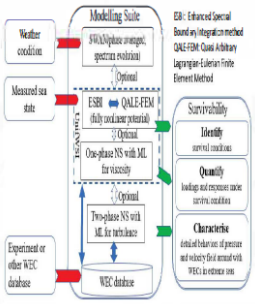

Fig.3 Coupling mechanism of MMS modelling suite

Timeline - when do we do this

WavE-Suite: Working Plan

	Year 1				Year 2				Year 3				Milestones and PDRA allocations (PDRA time is given in months (m))
	1	2	3	4	1	2	3	4	1	2	3	4	
WP1: MMS WavE-Suite for analysing survivability of WECs													**M1**: Couple ESBI with QALE-FEM; **M2**: Couple QALE-FEM with INS and create the UnifWSI; **M3**: Couple UnifWSI with NS2P; **M4**: Couple ESBI with SWAN; **M5**: Develop algorithm for auto-switch models (*PDRA1* 7-33 m; *CUL PhD student*)
1.1	M1				M2								
1.2								M3					
1.3		M4											
1.4												M5	
WP2: ML algorithms for estimating turbulent effects on WECs													**M6**: ML-damping, merged into QALE-FEM in M1; **M7**: ML-eddyV, merged into INS in M2; **M8**: ML-Rstress, merged into NS2P in M3; **M9**: Refined ML algorithms and guideline for extending ML-damping (*PDRA2* 1-36 m 40%)
2.1	M6												
2.2							M7						
2.3								M8					
2.4												M9	
WP3: Database & repository for WECs in high sea states													**M10**: Database (DB) of eddy viscosity for M7; **M11**: DB of Reynolds stress for M8; **M12**: DB on viscos damping for M6; **M13**: Repository for survivability of WECs (*PDRA3* 1-12 m; *PDRA4* 7-18 m)
3.1					M10								
3.2							M11						
3.3							M12						
3.4												M13	
WP4: Tailored model tests on WECs in survival conditions (Dashed: to be done by IIT Madras)													**M14**: Model test for OWC; **M15**: Model test for point absorbers; **M16**: Model test for attenuator WEC; **M17**: Scaling effects on point absorber (*PDRA5* 13-24 m, *In-kind contribution by IIT Madras*)
4.1		M14											
4.2					M15	M17							
4.3							M16						
WP5: Validation of the numerical suite and characterisation of survivability of typical WECs													**M17**: Validated WavE-Suite; **M18**: Survival condition of single WEC; **M19**: Survival condition for a WEC array; **M20**: Quantified extreme loading/responses of WECs; **M21**: Characterised flow field for WECs(*PDRA1* 7-33 m, *CUL PhD student*)
5.1								M17					
5.2		M18							M19				
5.3												M20	
5.4												M21	
	+		+*		+		+		+		+	*	Project meeting +; Workshops *

Deliverables - What will be expected from us

- ❖Open accessible WEC modelling suite -- WavE-Suite
- ❖Numerical databases (open access)
- ❖Test data of WEC models (open access)
- ❖Guideline for identifying survival conditions
- ❖Characteristics of survival conditions, loads and motions and pressure and velocity fields associated with typical WECs