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WAKE INTERACTION AND SCALE EFFECT ON A LARGE FLOATING WIND TURBINE FOUNDATION

Fengjian Jiang & Babak Ommani

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Introduction



Foundation for large FOWT

Cost-effective, safe mooring
and power cable

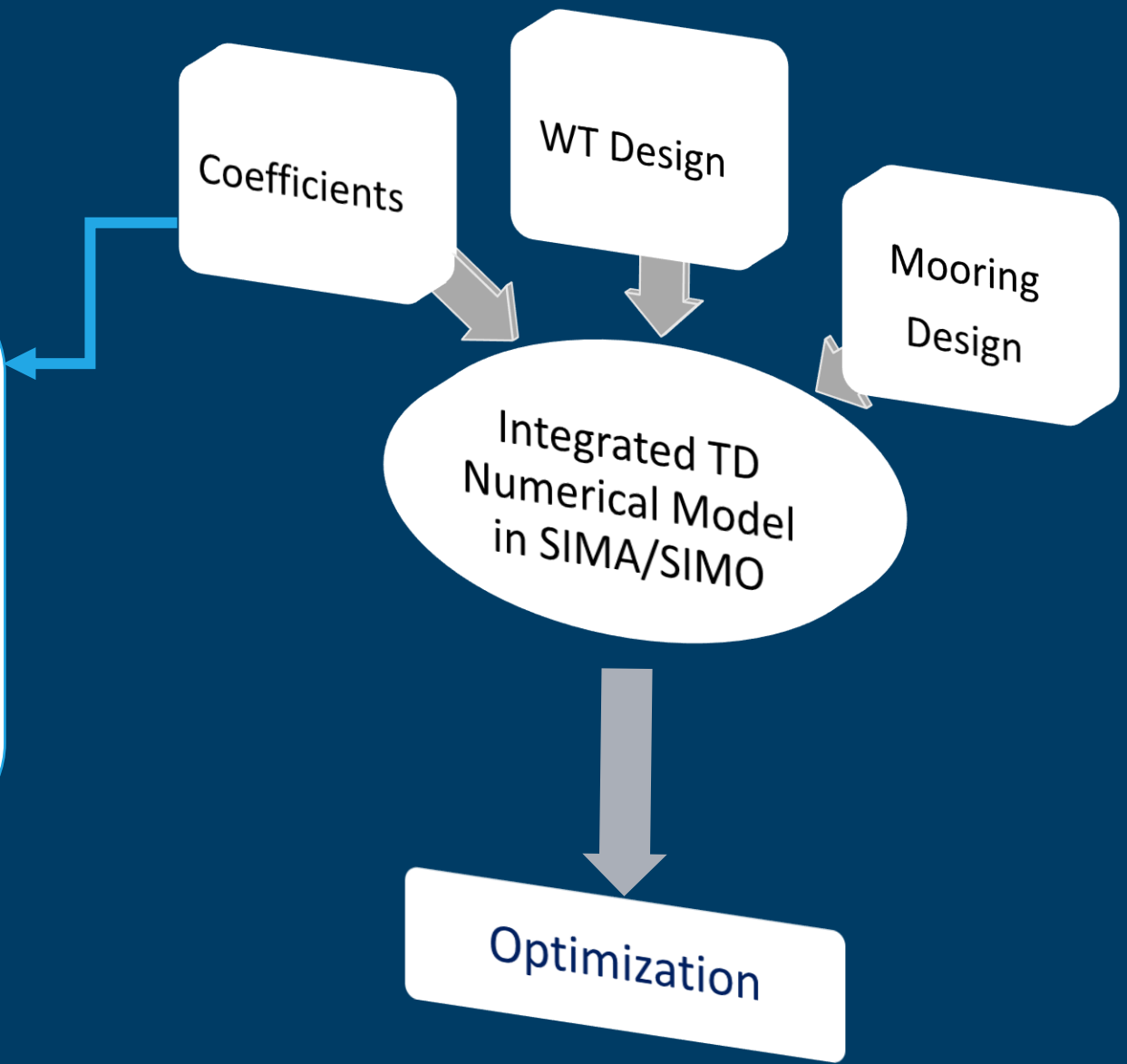
Optimization

Introduction

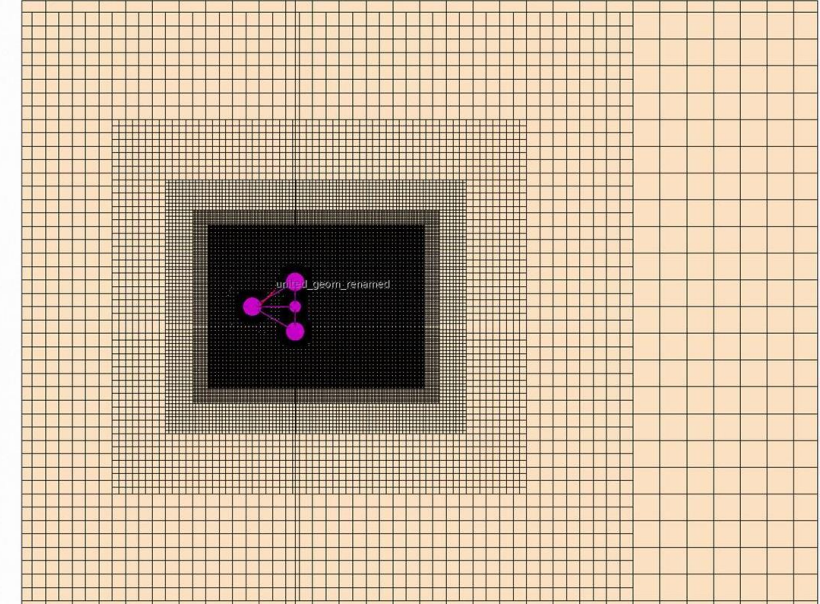
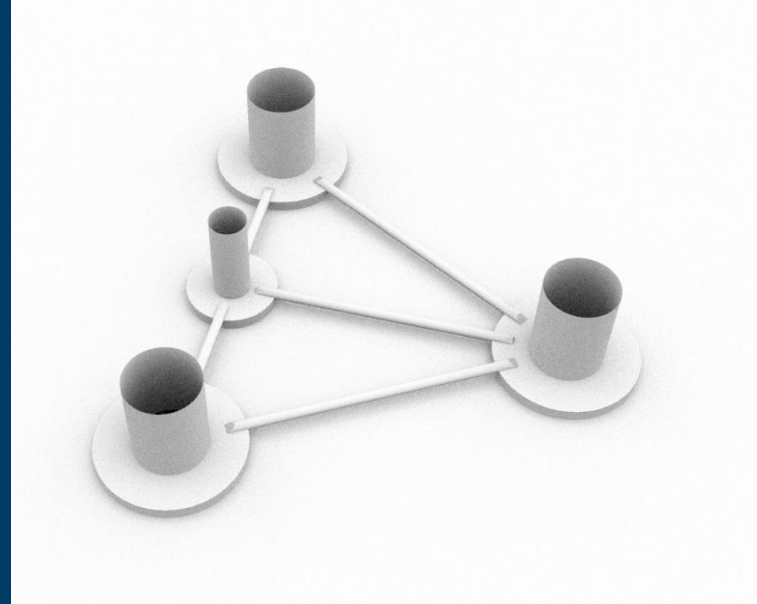
Hydrodynamic force (Current force, viscous forces due to oscillations)

Scale effects

Wake interactions



CFD Setup



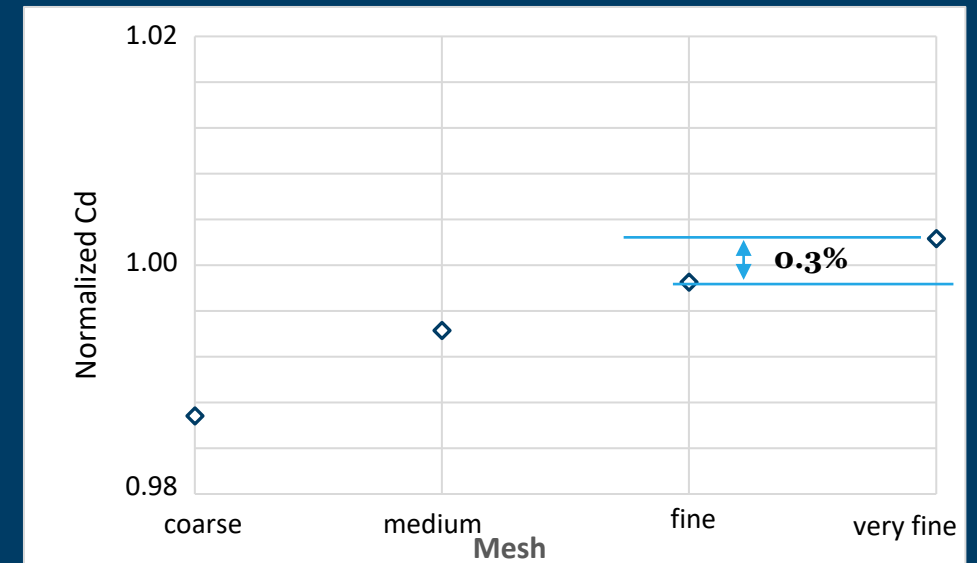
Low Fr, free-surface simplified

Full scale, Re sensitivity

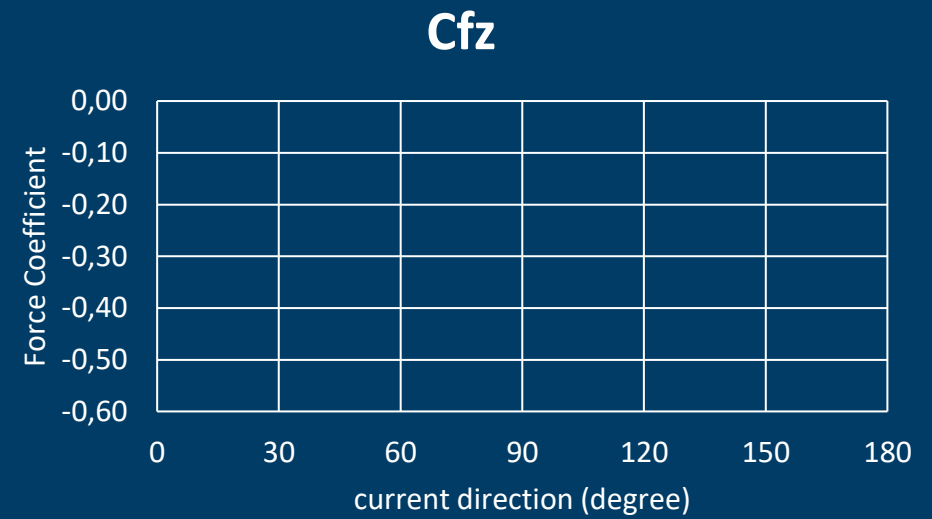
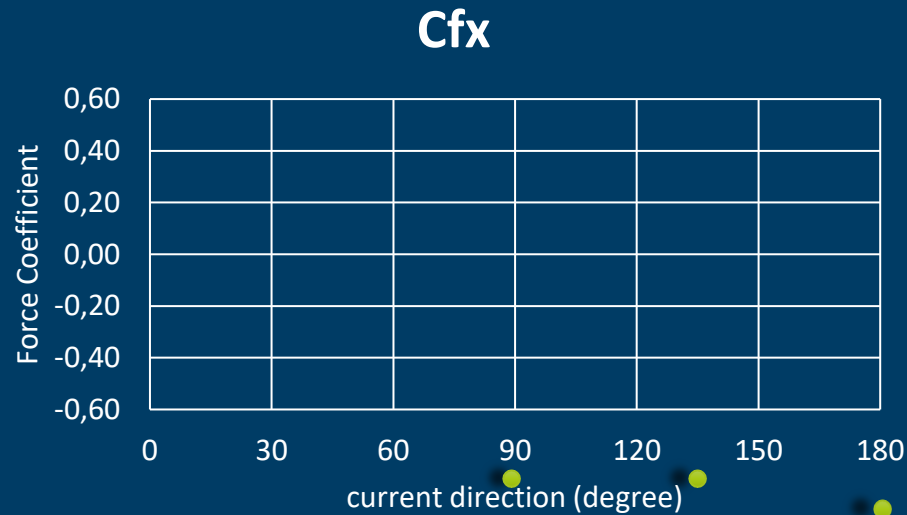
Wake refinement, ~15 million cells.

$$CF_i = \frac{F_i}{0.5 \rho u^2 A} \quad ; \quad CM_{i_Pj} = \frac{M_i}{0.5 \rho u^2 A D}$$

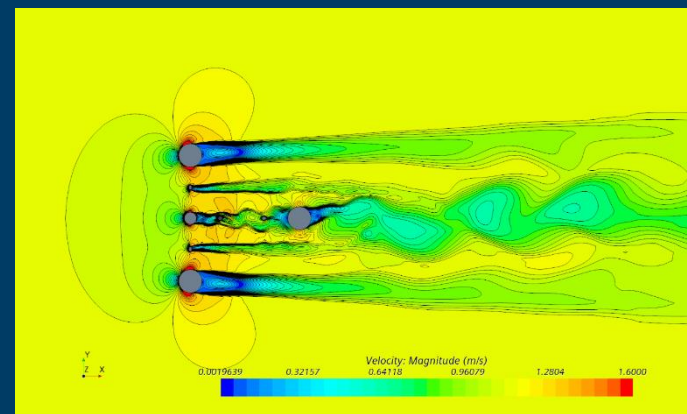
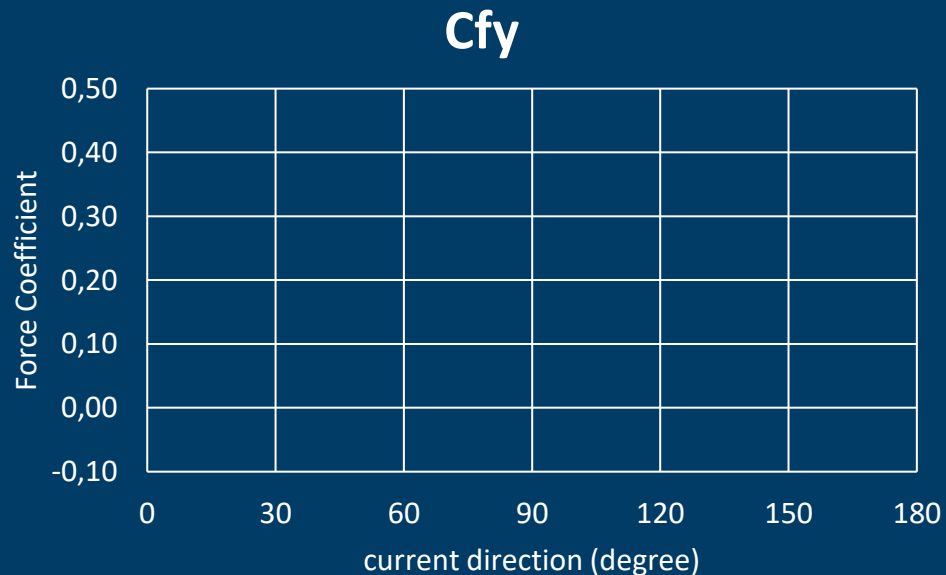
$i = x, y, z, \quad j = 1, 2$



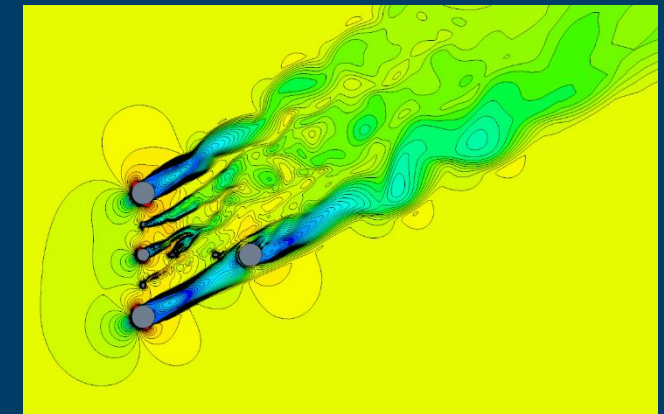
Full scale force coefficient



- Cfx & Cfy symmetric, C fz scattered around 0.4.
- Peak in Cfy is not at 90°, rather 105°. Wake interaction but small
- C fz value small compared to weight, heave expected small.



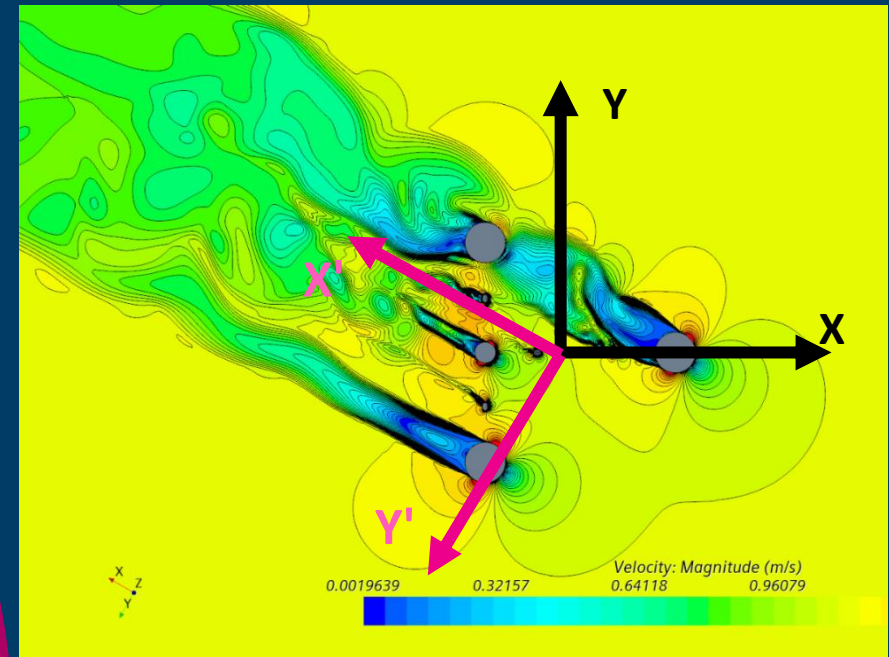
0° heading



30° heading

Drag coefficient

Current direction (degree)	C_{fx}	C_{fy}	C_{fz}	C_f aligned with current
0	0.4470	-0.0053	-0.3410	0.4470
15	0.4467	0.1448	-0.4505	0.4690
30	0.4088	0.2058	-0.4176	0.4569
45	0.3716	0.2580	-0.5074	0.4452
60	0.3107	0.3335	-0.5104	0.4441
75	0.2160	0.3791	-0.4153	0.4221
90	0.0891	0.4514	-0.2450	0.4514
105	-0.0892	0.4648	-0.3516	0.4721
120	-0.1801	0.4303	-0.4660	0.4627
135	-0.2929	0.3459	-0.4654	0.4517
150	-0.3865	0.2519	-0.3545	0.4607
165	-0.4281	0.1150	-0.5321	0.4432
180	-0.4189	0.0035	-0.4623	0.4189

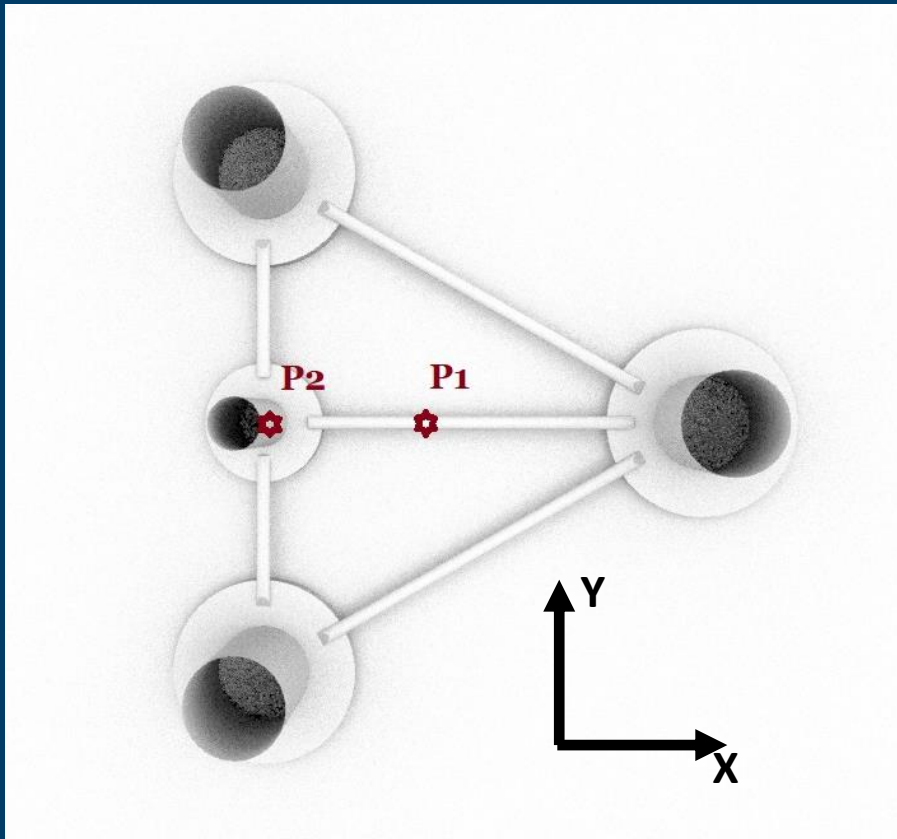


$C_{d_empirical} = 0.43$

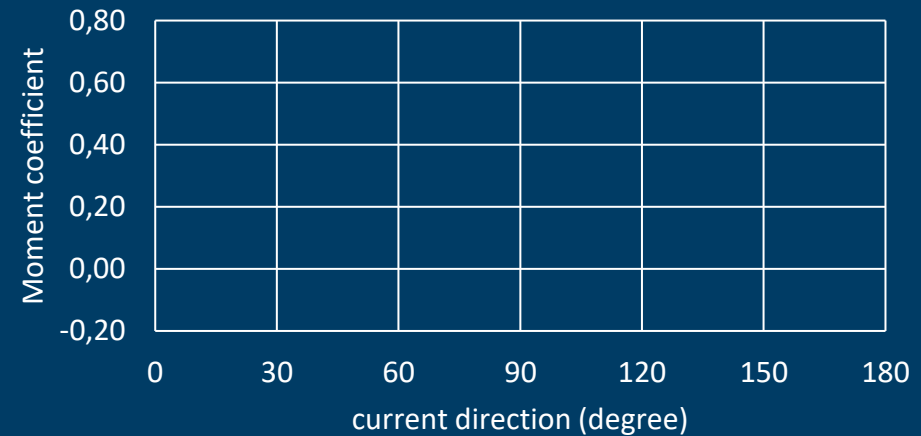
Indicated **relatively insignificant wake interaction effects** for force coefficients.

Empirical calculation is simplified. (take every sub-structure as independent cylinder)

Full scale moment coefficient



Cmx P1 &=P2



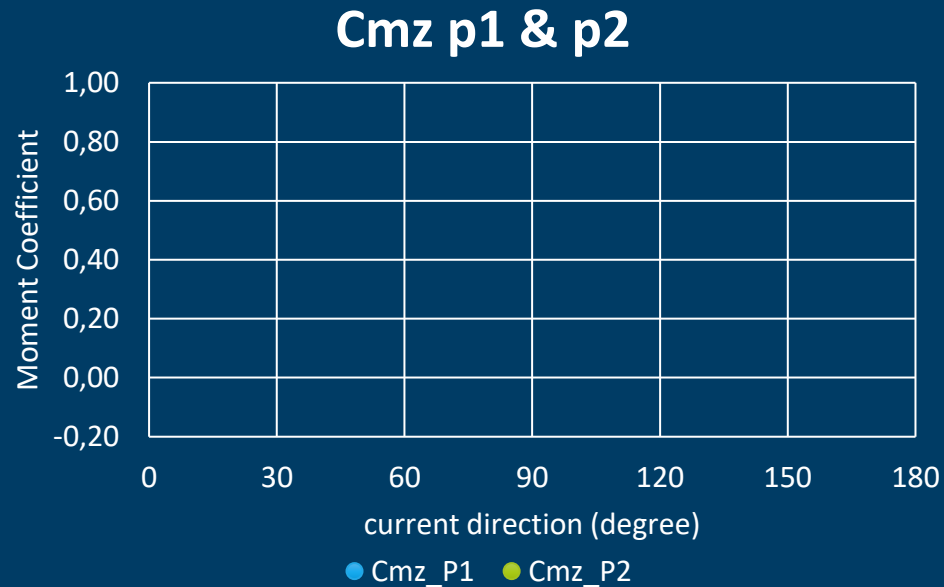
- CMx is identical between P1 and P2.

- "abnormal" point at 150, is a direct result of the scattered Fz.

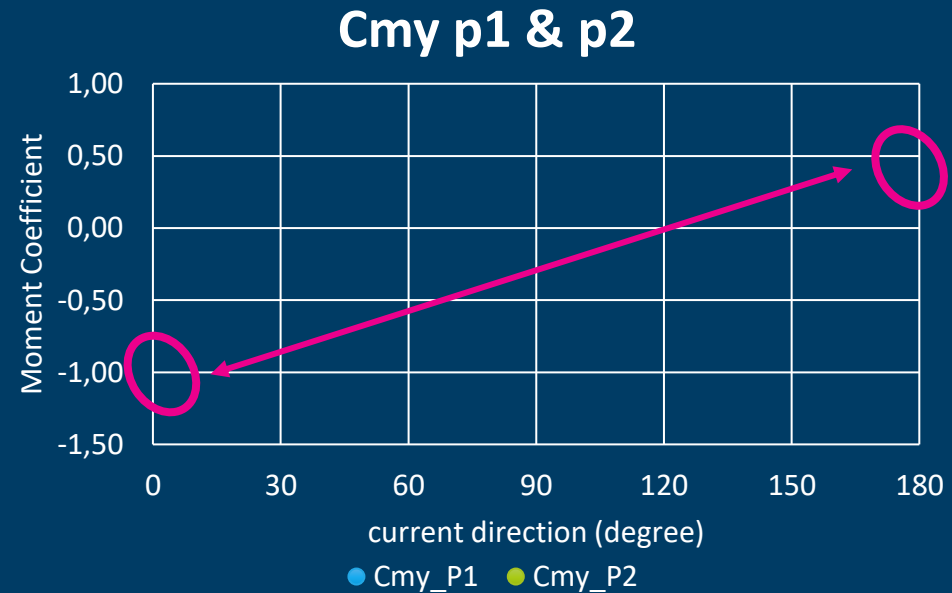
Two reference point:

- Geometric center at Free surface
- Tower center at free surface

Full scale Moment coefficient



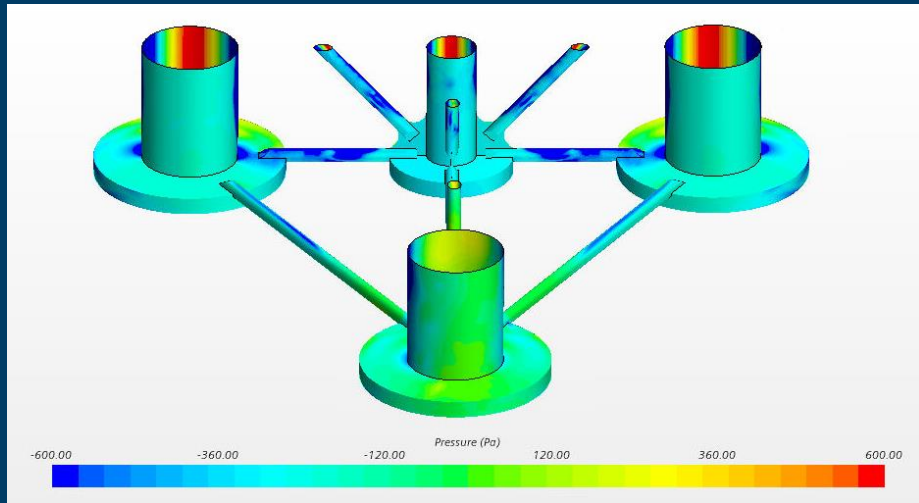
Symmetric Cmz. Peak at 105° as direct result of the same behavior of Cfy.



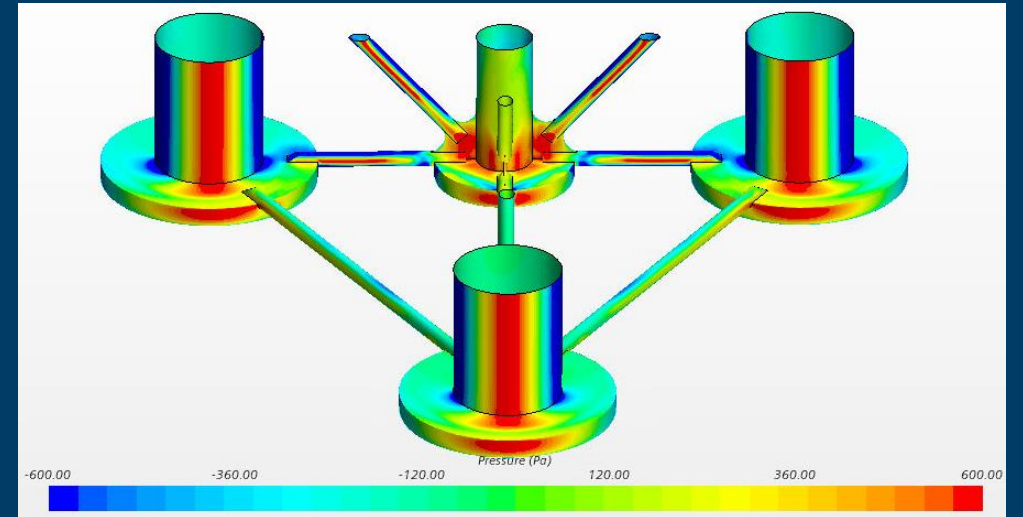
Cmy shows significant asymmetry wrt. heading.

e.g. with P1 as reference, $C_{my} = -1.0$ vs. 0.36 at 0° and 180° headings, respectively. $> 50\%$ difference.

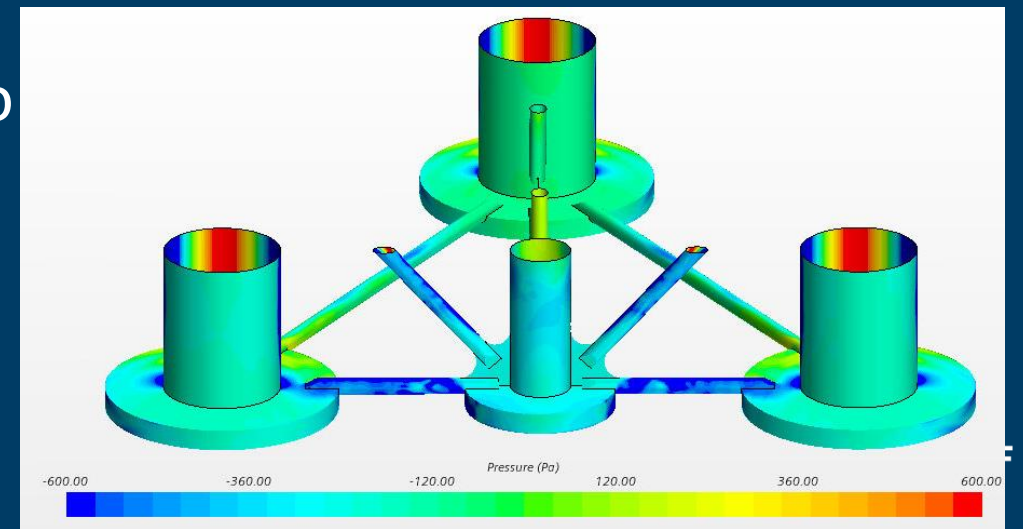
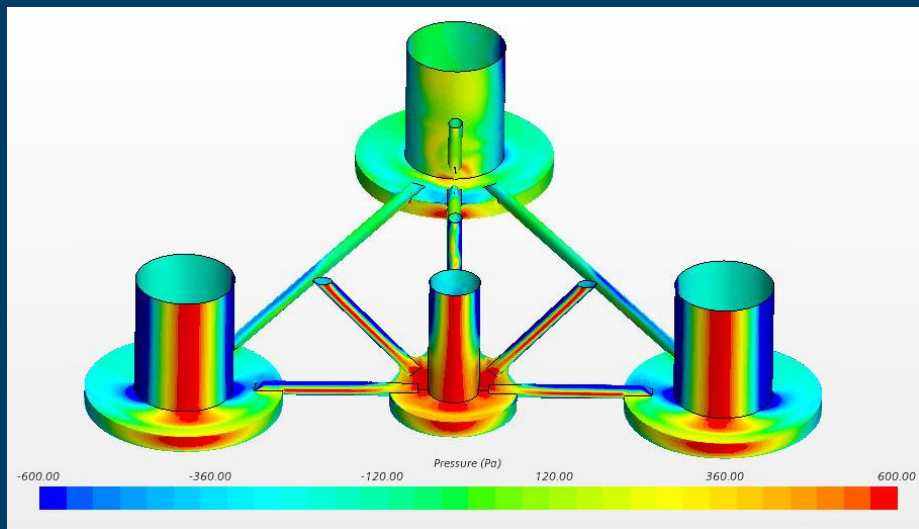
Full scale moment coefficient



0°

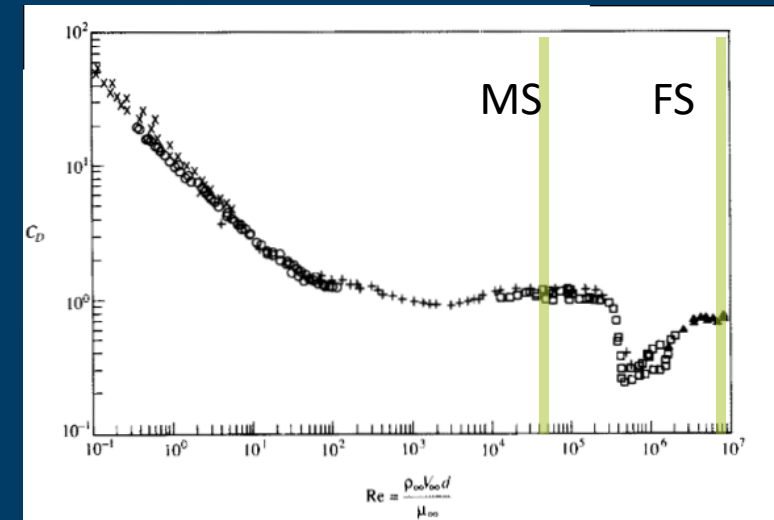
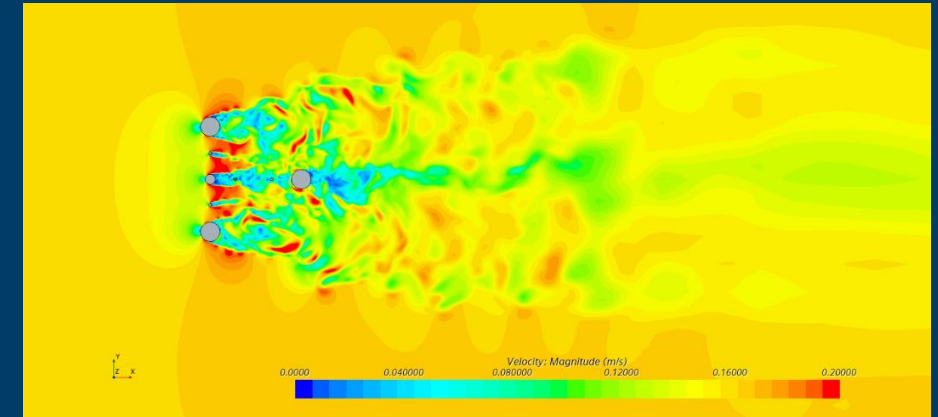


180°



Scale effects

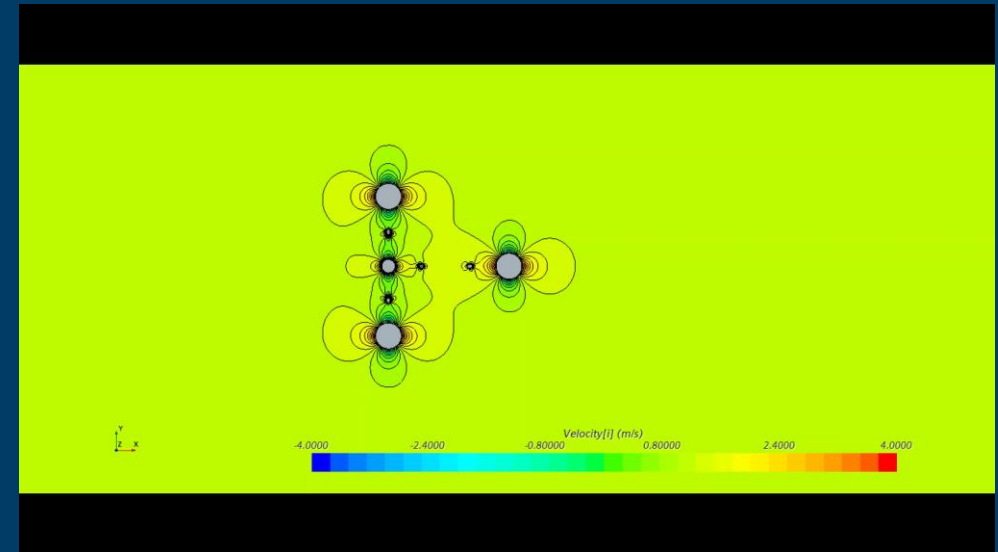
- Model scale simulation
- Froude scaling 1:50
- $Re_{fs} \sim 10^7$; $Re_{ms} \sim 10^4$
- Re crisis around 10^5
- $Re_{fs} / Re_{ms} > 350$



	CFD result	Empirical calculation
Full scale	0.447	0.43
Model scale (1:50)	0.71	1.0

Future work

- Viscous force of the foundation under low KC oscillations
- Current number influence in oscillatory flow
- Implement hydro force from CFD in SIMA/SIMO TD model
- Mooring system optimizations





Teknologi for et bedre samfunn

