SHIP COLLISION ON MONOPILE OFFSHORE WIND TURBINES

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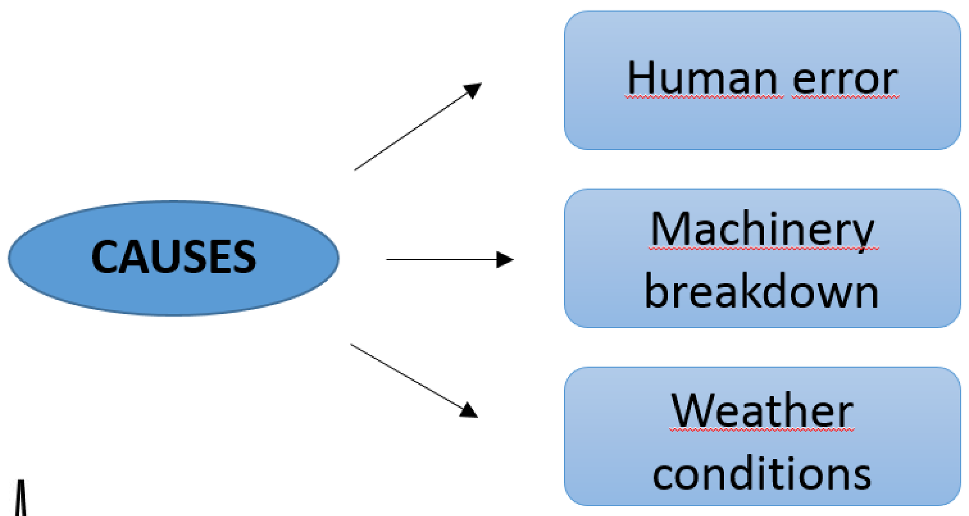
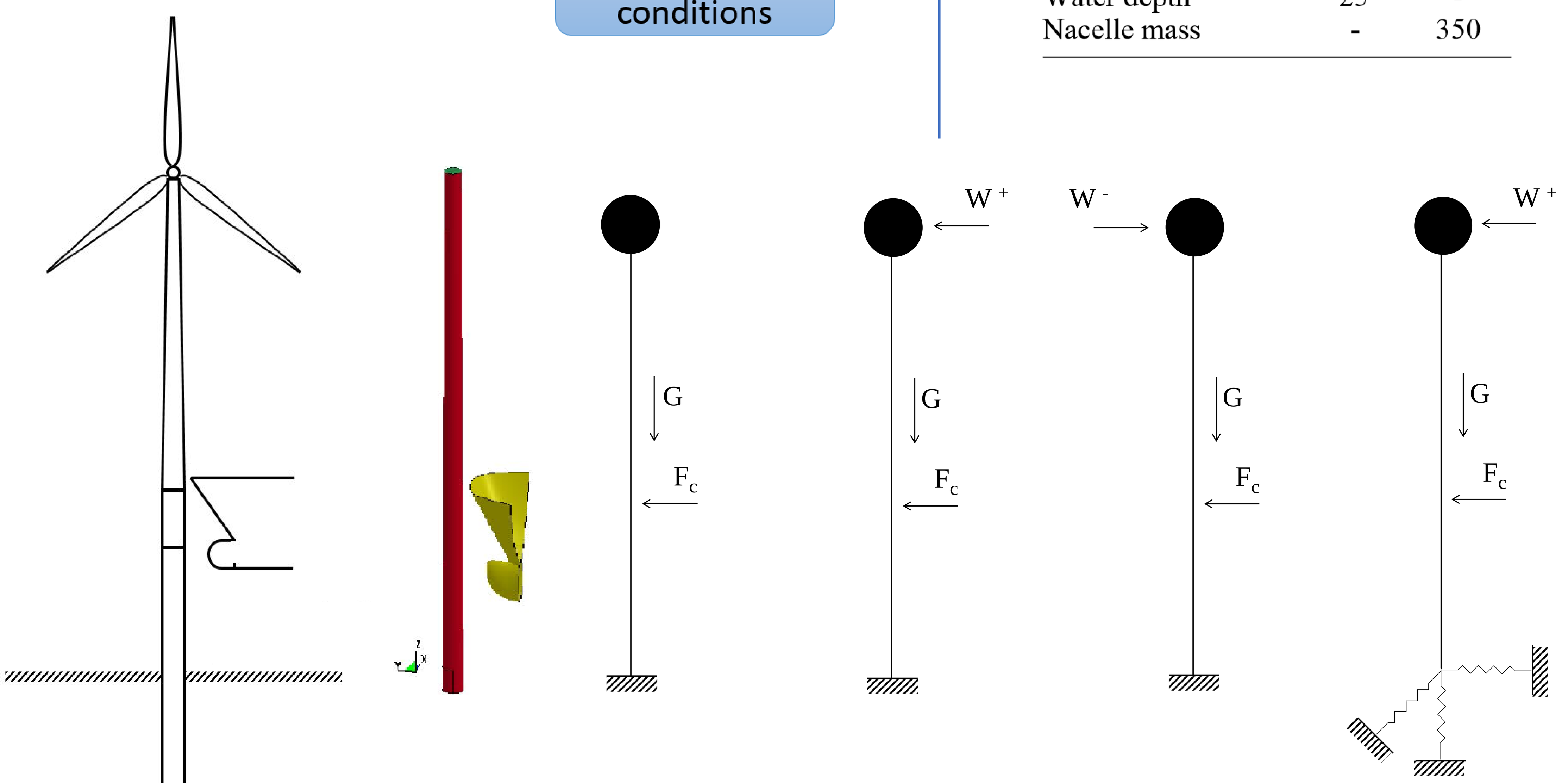
Every year, the offshore wind industry is expanding and the location of the future wind farms tends to move to deeper waters and closer to the traffic lanes. The consequence of this growth is that the probability of ship collisions will increase. For any new offshore wind farm projects, a collision risk analysis must be performed in order to identify the collision scenarios having the greatest probabilities of occurrence and to evaluate the consequences on the supporting structure and also on the mechanical parts of the wind turbines. The goal of this paper is to outline the behaviour of the monopile foundations during ship collision by performing non-linear finite elements simulations. Many collision scenarios are analysed in order to study the sensitivity of the monopile to a series of parameters like impact velocity of the striking ship, wind loads and soil stiffness.

Ship collision





Added mass Wind force 0° Wind force 180° SSI

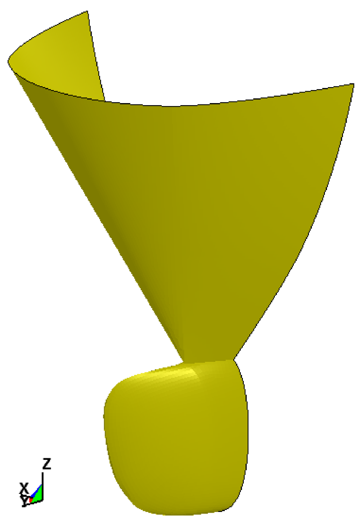
Finite elements model particularities

Offshore Wind Turbine (OWT)

Characteristic	Unit	
	m	tones
Top diameter	4	-
Bottom diameter	5	-
Height	115	-
Wall thickness	0.06	-
Water depth	25	-
Nacelle mass	-	350

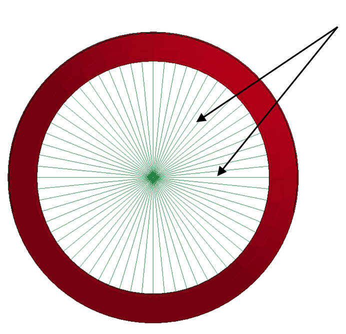
Offshore Supply Vessel (OSV)

Characteristic	Unit	
	m	tones
Type	bulbous bow	
Length	102.4	-
Breadth	23.23	-
Depth	25.89	-
Draft	4.12	-
Displacement	-	5000
Water (added mass)	-	250



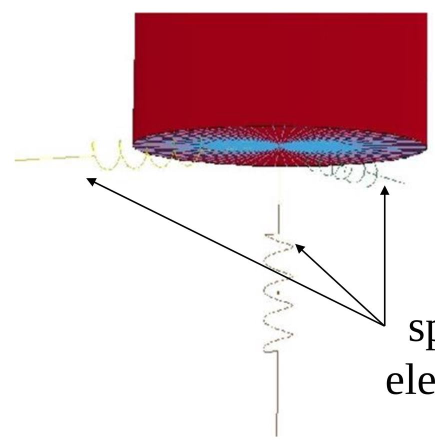
Wind loads

Characteristic	Unit	
	kN	kN·m
F_x	-39	-
F_y	586	-
F_z	-3512	-
M_x	-	3922
M_y	-	2967
M_z	-	-3144



Soil properties

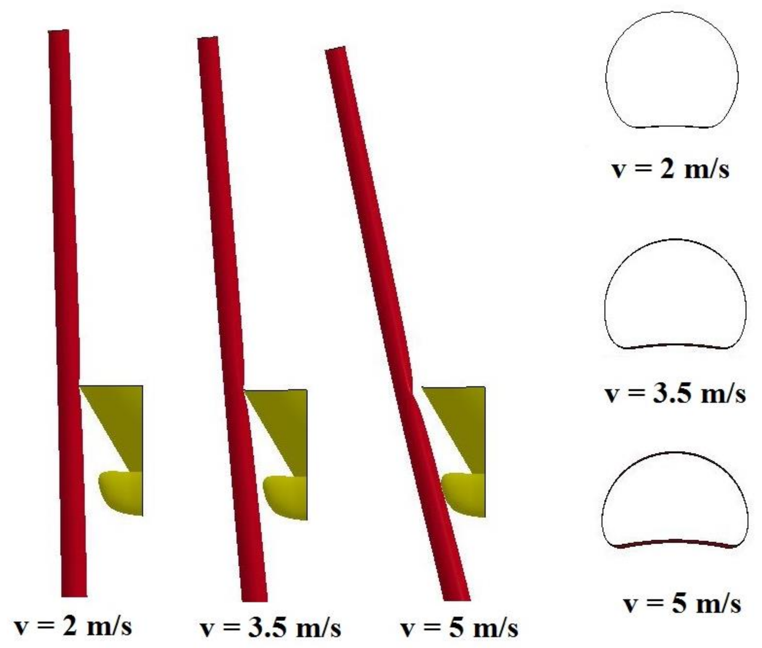
Characteristic	Unit	
	kN/m	kN·m/rad
k_{xx}	$7.4\cdot10^6$	-
k_{yy}	$7.4\cdot10^6$	-
k_{zz}	$1.5\cdot10^6$	-
θ_{xx}	-	$1.3\cdot10^7$
θ_{yy}	-	$1.3\cdot10^7$
θ_{zz}	-	$3.2\cdot10^5$



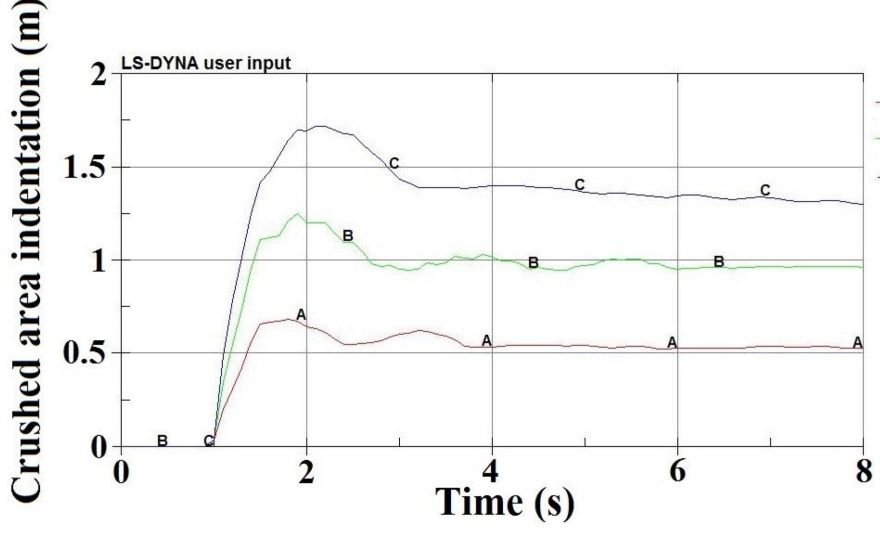
Numerical simulations

Impact velocity

A series of head-on collision were analysed for three different values of the impact velocities. At the beginning of the collision event, local crushing occurs in the impacted area. Once a certain value of the local indentation is reached, an overall bending of the structure also develops.

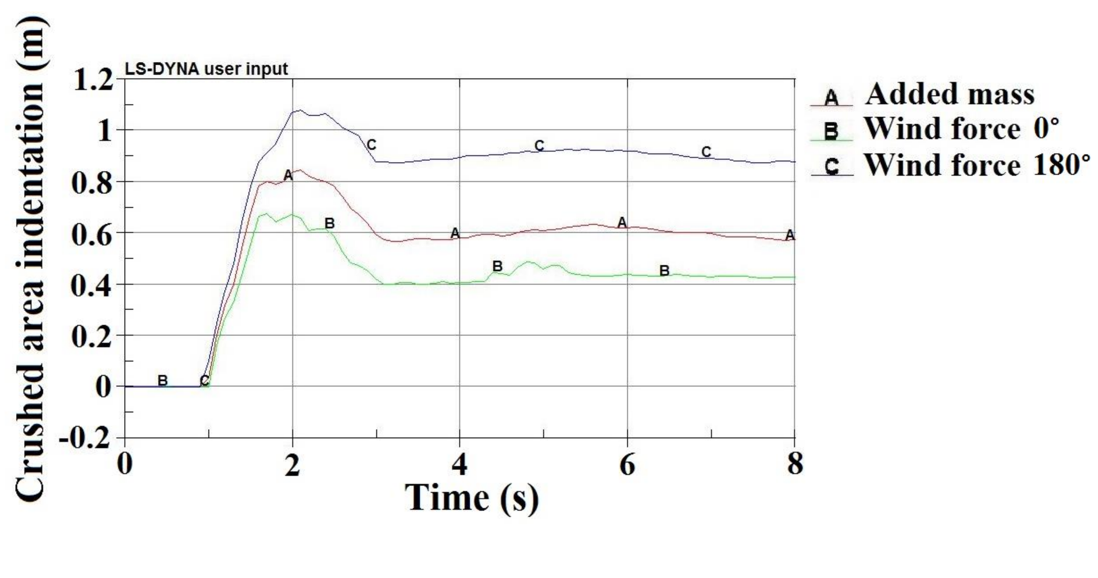


The impact velocity is the most influential parameter, whose slight variation leads to significant changes in the behaviour of the structure ranging from minor damage to collapse.

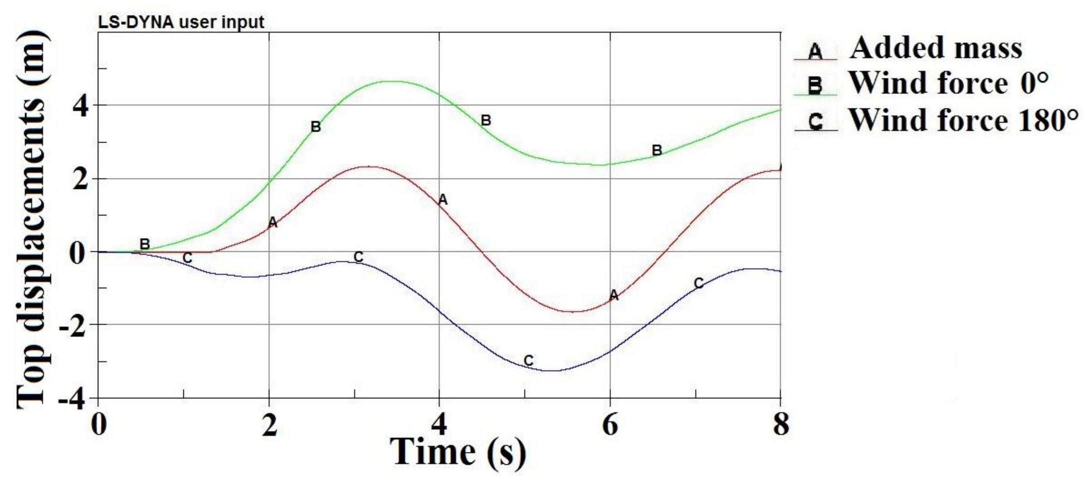


Wind loads

In order to evaluate the influence of the wind on the behaviour of the structure during collision, three cases are analysed: added mass, wind force 0° and wind force 180° (detailed above).

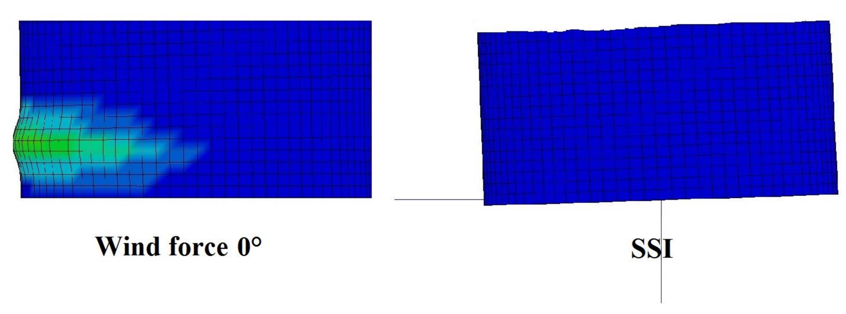


When the wind has the same direction as the impact force, the top displacements of the tower are amplified. However, the local indentation the crushed area is smaller compared to the case in which the wind is opposite to the impact force.

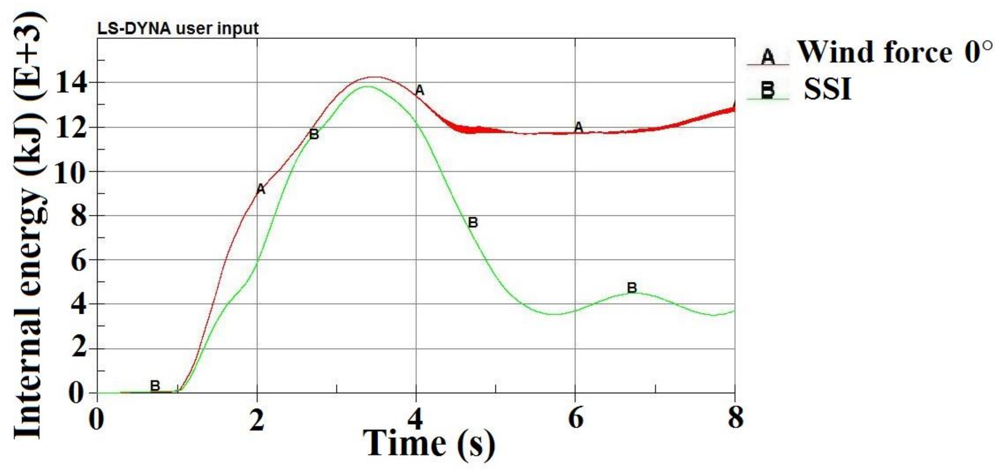


Soil-structure interaction

In the first two cases analysed, the soil stiffness was assumed to be infinite, but in reality the soil will undergo some deformations. For this reason, a sensibility analysis was performed in order to investigate the influence of the soil stiffness on the behavior of the structure. Two cases are analysed: wind force 0° and SSI.



For a structure with a clamped base, when the collision occurs, the structure starts deforming in the crushed area and also at the bottom of the monopile, near the mudline. However, for the case in which spring elements are used in order to model the soil rigidity, the bottom of the monopile rotates due to the elasticity of the soil. For a 2 m/s impact velocity, no deformation occurs at the bottom of the monopile.



When considering SSI, less energy is dissipated through plastic deformations and therefore, the internal energy is lower and more energy is returned to the system by means of oscillations.

Bibliography: A. Bela, H. Le Sourne, L. Buldgen, Ph. Rigo (2015). Numerical crashworthiness analysis of an offshore wind turbine monopile impacted by a ship. MARSTRUCT 2015 5th International Conference on Marine Structures pp. 661 - 669