Mooring line materials for mini-TLP platforms

Antonios Peppas, Dimitrios Tsakalomatis,
Sofia Papadopoulou, Alexandra Trompouki

BU Offshore Department, ETME engineering solutions, Athens, Greece

EERA DeepWind CONFERENCE 2024

Introduction

Within the framework of the project “FloatMastFORWARD” ETME proceeded to make a study regarding the mooring system of the mini-TLPs. Specifically, this paper delves into a comprehensive analysis of the alternatives of mooring line materials and their application in mini-TLPs. As the industry continually pushes the boundaries of offshore exploration and production, the selection of appropriate materials for mooring lines becomes an imperative facet of engineering design.

So far in TLP applications, steel and synthetic ropes have been the prevailing choices. Particularly, while steel ropes offer high tensile strength, temperature resistance, durability and reliability, they increase significantly the structure’s weight and thus the overall cost.

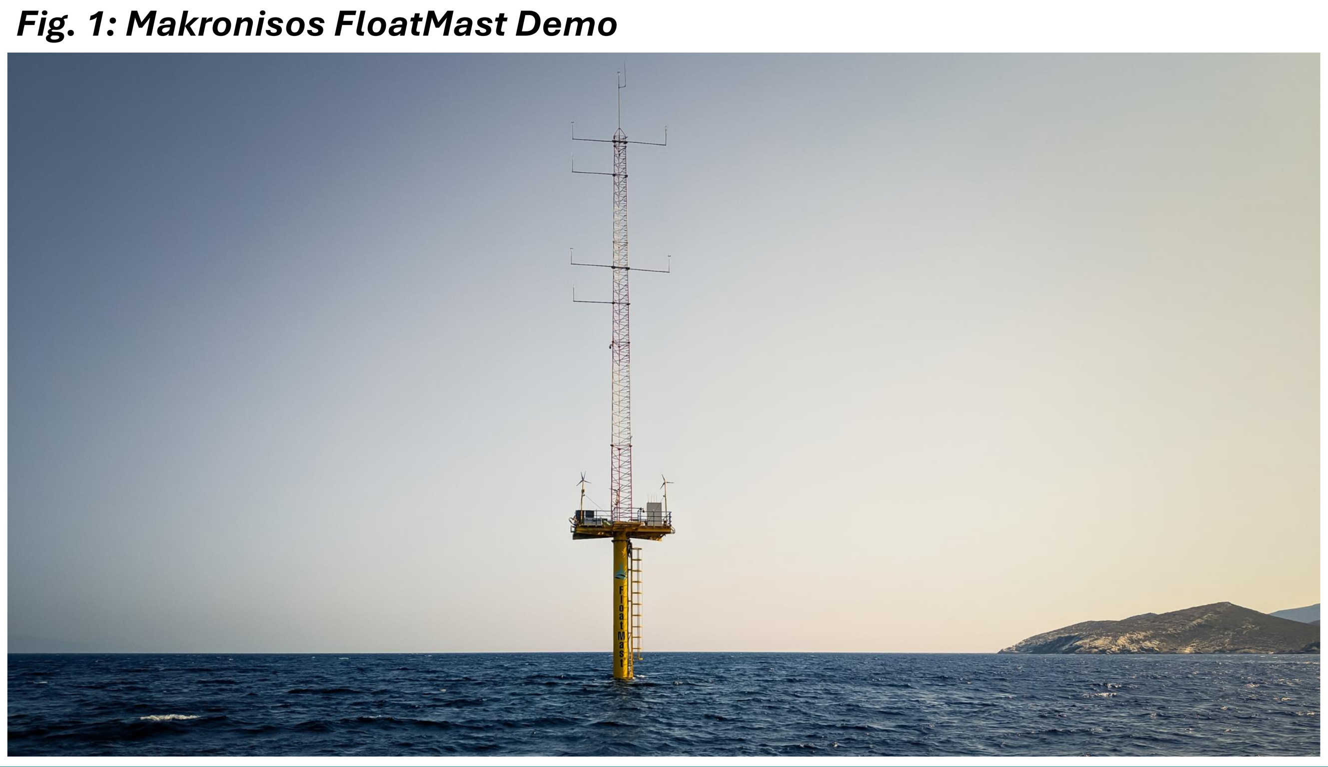
The paper will compare the use of wire and synthetic tendons in a mini-TLP concept, using DNV’s software suite for hydrodynamic analysis of offshore structures SESAM, and especially the modules Genie, HydroD, SIMA. This software achieves an holistic simulation by integrating several key functionalities and features: hydrodynamic analysis, mooring system modelling, coupled analysis and visualization, reporting and integration with industry standards. An extra assessment is conducted from the demo project measurements.

Analytical Model: FloatMast®

The first deployment of the FloatMast Platform was near Makronisos island in the Aegean Sea (Greece) at a depth of 65 m. This mini-TLP structure was designed to serve as a full-equipped meteorological mast in open seas and harsh weather conditions. FloatMast platform’s design (**Fig.1**) survived storms (28.8m/s 10min-average wind speed, 35.3m/s wind gust, 4.7m max wave height) and successfully completed a 12-month measurement campaign with 97% data availability. The measured wind conditions were fully compliant to IEC 61400-50-1 requirements and MEASNET guidelines; a world’s first for a floating met mast**.**

In this study, two objectives are set: (a) to create a model of the FloatMast structure in SESAM (**Fig.2**) and (b) to compare different mooring material types, in operating and extreme conditions. (**Table 2**)

Fig. 1: Makronisos FloatMast Demo



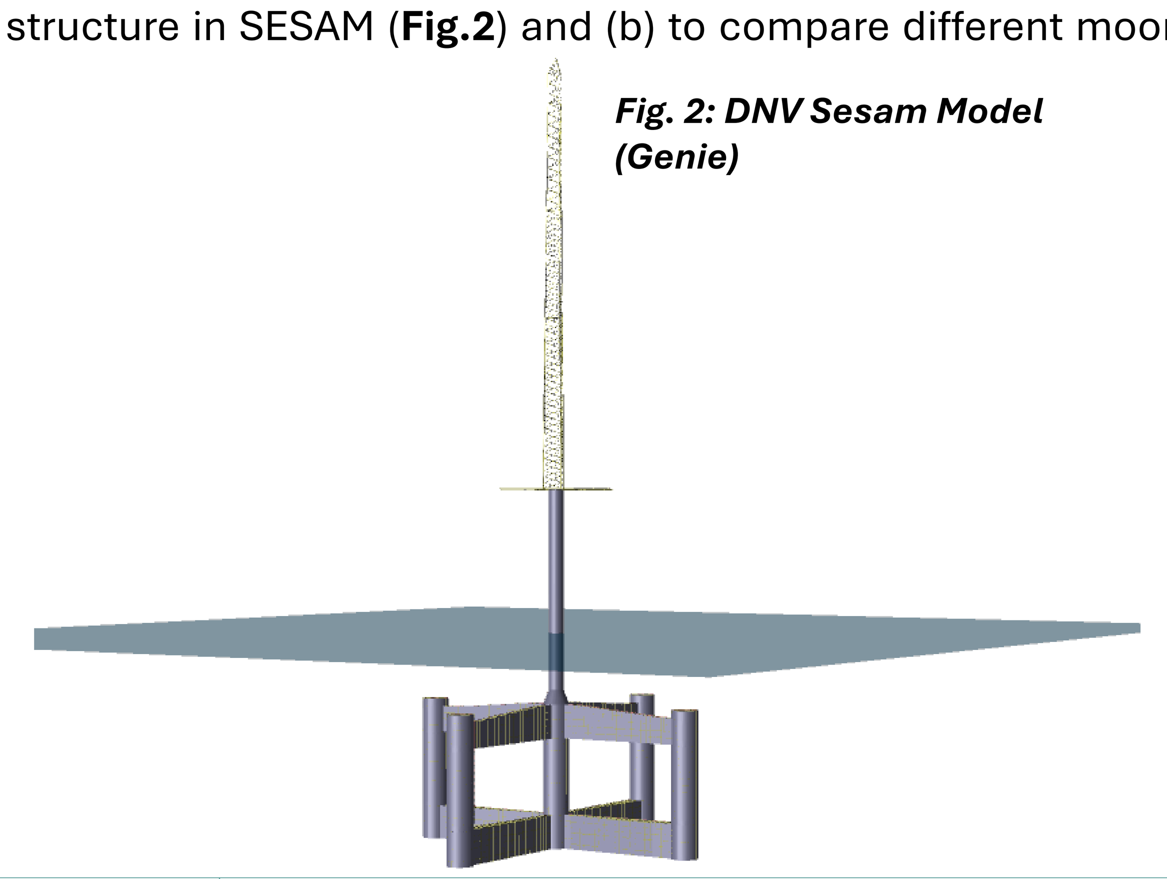


Fig. 2: DNV Sesam Model (Genie)

Table 1: Main Platform characteristics

Designation	FloatMast Structure
Pontoon Diameter (m)	2.0
Draft (m)	15
Tower diameter (m)	1
Mast Height (m)	30

Table 2: Environmental conditions

Case	Wave Conditions		Wind Conditions
	Hs (m)	Tp (s)	Vw (m/s)
Operating	3.0	6.5	14
Extreme	11	10	25

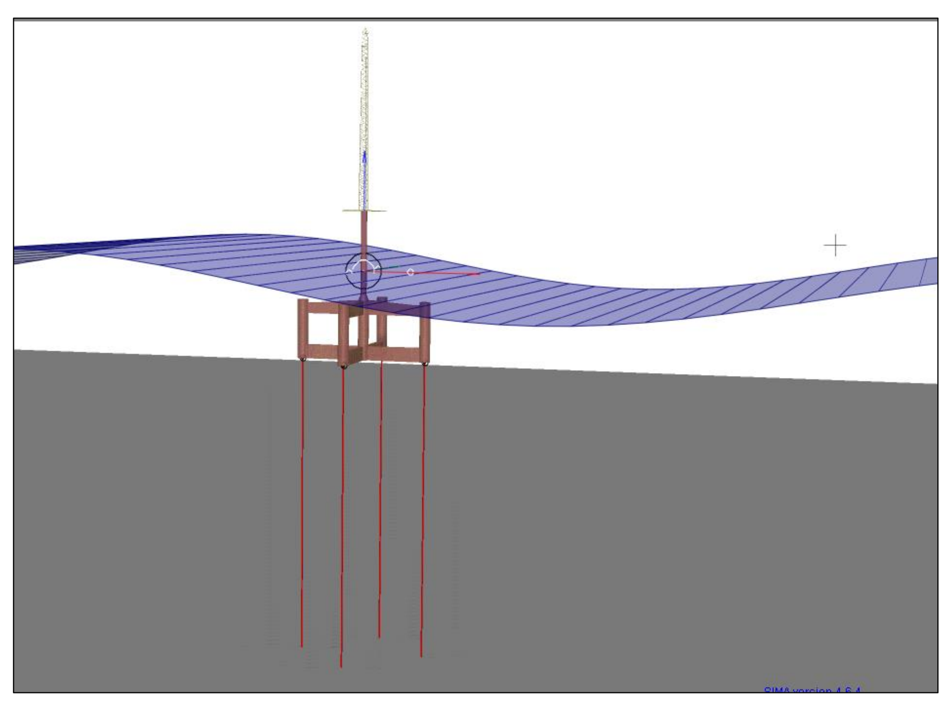
Mooring Alternative materials

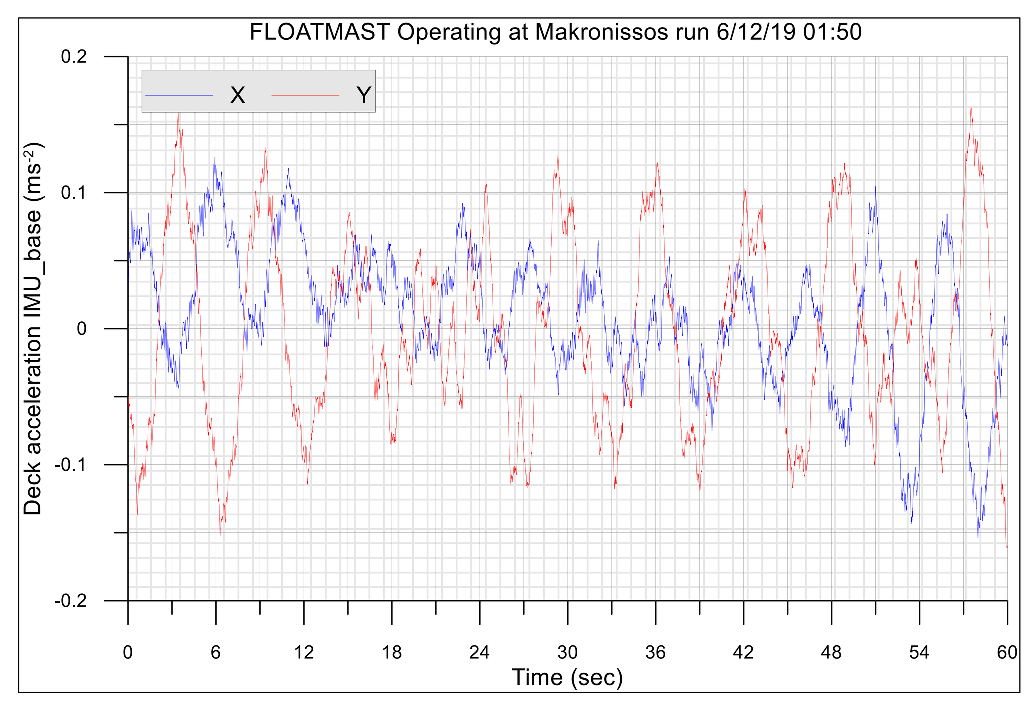
For the second part of the analysis, both **steel** and **synthetic** materials were evaluated, and their technical characteristics are summarised in **Table 3**.

Table 3: Mooring Types Alternatives

No.	Mooring Material	Name	Tensile Stress (E)	Diameter (D)	Stiffness
			N/m2	m	N/m
1	Wire Rope	Steel Wire Rope 6x41 with IWRC	9.65E+10	0.076	4.32E+06
2	HMPE	PLASMA HiCo 12x12	2.55E+10	0.084	2.82E+06
3	HMPE	TORO 12X12	1.25E+10	0.088	1.52E+06
4	UHMWPE	NikaSiri	1.48E+10	0.08	1.48E+06
5	HMPE	PLASMA LoCo 12x12	1.27E+10	0.084	1.41E+06
6	LCP	VECTRAN 12 STRAND	1.33E+10	0.08	1.34E+06
7	UHMWPE	Dyneema ® (SK78)	1.07E+10	0.088	1.30E+06
8	UHMWPE	SPECTRA 12Strand &12x12	8.85E+09	0.096	1.28E+06
9	UHMWPE	Dyneema ® (SK75)	1.02E+10	0.088	1.24E+06

Assessment of In-Situ FloatMast measurements





Comparison for the FloatMast mooring line alternatives for operational and extreme conditions

The following tables present a comparative analysis of synthetic versus steel mooring lines, highlighting the percentage differences between them.

Operational Conditions

Materials	Tension at Fairleads [tn]				Surge [m]				Heave [m]				Pitch [°]			
	Max	Dif (%)	Min	Dif (%)	Max	Dif (%)	Min	Dif (%)	Max	Dif (%)	Min	Dif (%)	Max	Dif (%)	Min	Dif (%)
Steel Wire Rope 6x41 with IWRC	39.37	-	19.97	-	1.45	-	-1.18	-	0.04	-	0.01	-	0.03	-	-0.03	-
PLASMA HiCo 12x12	39.55	0.5%	20.23	1.3%	1.46	1.0%	-1.20	1.1%	0.13	214.0%	0.07	564.3%	0.09	231.8%	-0.09	233.5%
TORO 12X12	40.42	2.7%	19.89	0.4%	1.49	2.8%	-1.21	2.3%	0.24	484.5%	0.14	1203.0%	0.20	622.6%	-0.17	511.7%
NikaSiri	40.39	2.6%	19.64	1.6%	1.49	3.0%	-1.21	2.3%	0.25	497.6%	0.14	1228.9%	0.21	649.3%	-0.17	503.3%
PLASMA LoCo 12x12	40.03	1.7%	19.07	4.5%	1.49	3.3%	-1.21	2.6%	0.26	531.9%	0.15	1297.4%	0.23	708.0%	-0.18	541.8%
VECTRAN 12 STRAND	40.03	1.7%	19.07	4.5%	1.49	3.3%	-1.21	2.6%	0.26	531.9%	0.15	1297.4%	0.23	708.0%	-0.18	541.8%
Dyneema® (SK78)	40.09	1.8%	18.62	6.8%	1.49	3.3%	-1.22	2.9%	0.29	584.7%	0.16	1417.2%	0.24	759.8%	-0.21	647.0%
SPECTRA 12Strand &12x12	40.17	2.0%	18.58	6.9%	1.49	3.2%	-1.22	2.8%	0.29	592.5%	0.16	1436.6%	0.24	762.1%	-0.21	663.7%
Dyneema® (SK75)	40.27	2.3%	18.57	7.0%	1.49	3.1%	-1.22	2.7%	0.30	617.9%	0.17	1496.9%	0.25	766.5%	-0.23	734.3%

Extreme Conditions

Materials	Tension at Fairleads [tn]				Surge [m]				Heave [m]				Pitch [°]			
	Max	Dif (%)	Min	Dif (%)	Max	Dif (%)	Min	Dif (%)	Max	Dif (%)	Min	Dif (%)	Max	Dif (%)	Min	Dif (%)
Steel Wire Rope 6x41 with IWRC	66.04	-	2.15	-	10.95	-	-7.90	-	0.06	-	-1.20	-	0.20	-	-0.09	-
PLASMA HiCo 12x12	66.35	0.5%	2.33	8.6%	11.00	0.4%	-7.93	0.4%	0.19	209.4%	-1.17	3.0%	0.34	71.1%	-0.29	230.4%
TORO 12X12	68.20	3.3%	1.45	32.3%	11.07	1.1%	-7.95	0.6%	0.35	473.9%	-1.13	5.6%	0.65	223.4%	-0.54	520.9%
NikaSiri	68.29	3.4%	1.37	36.1%	11.07	1.1%	-7.96	0.8%	0.35	486.6%	-1.13	5.8%	0.64	221.1%	-0.56	545.1%
PLASMA LoCo 12x12	68.31	3.4%	1.35	37.3%	11.08	1.2%	-7.96	0.8%	0.37	519.3%	-1.13	6.1%	0.69	243.7%	-0.61	605.7%
VECTRAN 12 STRAND	68.31	3.4%	1.35	37.3%	11.08	1.2%	-7.96	0.8%	0.37	519.3%	-1.13	6.1%	0.69	243.7%	-0.61	605.7%
Dyneema® (SK78)	68.02	3.0%	0.43	79.9%	11.10	1.4%	-7.97	0.9%	0.40	570.1%	-1.12	6.5%	0.73	261.7%	-0.69	693.4%
SPECTRA 12Strand &12x12	67.93	2.9%	0.43	80.1%	11.10	1.4%	-7.97	0.9%	0.41	577.4%	-1.12	6.5%	0.74	271.5%	-0.70	704.4%
Dyneema® (SK75)	67.68	2.5%	0.30	86.1%	11.11	1.5%	-7.98	1.0%	0.42	602.5%	-1.12	6.8%	0.75	273.8%	-0.73	744.8%

Conclusions

Conclusions were drawn based on the evaluation of: (a) the **Tensions at the fairlead** of mooring lines and (b) **Platform Motions**.

1. The DNV Software can simulate adequately the hydrodynamic and hydrostatic effects on mini-TLP structures.
2. There's no substantial disparity in tension between synthetic and steel mooring lines under both operational and severe conditions.
3. The platform exhibits larger motion amplitudes with synthetic mooring lines compared to those with wire ropes. Despite the greater movement of the mini-TLP with synthetic lines, these motions still comply with the standards and requirements necessary for a stable floating met mast in harsh conditions.

References

1. *Hsu, Weiting & Litton, Richard & Vasala, Haritha & Anderson, David & Sheppard, Robert. (2019). Beneficial Wave Motion Response for Wind Turbine Support TLPs with Synthetic Rope Tendons. 10.4043/29573-MS.*
2. *Weller, Sam & Johanning, Lars & Davies, Peter & Banfield, Stephen. (2015). Synthetic mooring ropes for marine renewable energy applications. Renewable Energy. 83. 1268–1278. 10.1016/j.renene.2015.03.058.*

European Union European Structural and Investment Funds
HELLENIC REPUBLIC MINISTRY OF DEVELOPMENT AND INVESTMENTS SPECIAL SECRETARIAT FOR ERDF & CF PROGRAMMES
EPAnEK 2014-2020 OPERATIONAL PROGRAMME COMPETITIVENESS ENTREPRENEURSHIP INNOVATION
ΕΣΠΑ 2014-2020 Partnership Agreement 2014 - 2020
Co-financed by Greece and the European Union

«Co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE - INNOVATE (project code:ΤΑΣΦΡ-06360)

SCAN ME