Multiline Ring Anchor system for floating offshore wind turbines

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Background

- The trend in the offshore wind industry:
  - Stronger, more consistent wind resources
  - Installation in deeper & farther water
  - Mitigation of aesthetic issues
- Nevertheless, the high capital cost of the support system remains a primary obstacle
- A need for cost-effective FOWT system

Introduction

- Considerations for development of anchors for mooring FOWTs:
  - Fewer & lighter anchors
  - Maximizing geotechnical efficiency
  - Deployable in the wide range of soil conditions → many potential sites

Cost

- Material cost ↓
- Transport cost ↓
- Installation cost ↓

Soil condition

- Precise positioning → Robust performance under unintended loading conditions
- Deep embedment depth

Thus, multiline ring anchor (MRA) developed to address the above considerations [1, 2]

A. The concept of the MRA

- An embedded ring with up to 6 mooring lines
- Optional wing plates or keying flaps (Fig. 2)
- Enhancing horizontal & vertical load capacity

B. Potential advantages of the MRA

- Install in the wide range of soil → wide potential resources sites
- Multiline potential → reduced costs for geotechnical investigation, transport, material, fabrication, and installation
- Geotechnical efficiency: less than most
- Deep embedment & precise positioning → high reliability

Example Comparative Study

- Comparison to conventional suction caisson (SC) anchors can be instructive (Fig.4).
- A typical soft clay (e.g. Gulf of Mexico, [3]): $s(z) = 5 + 2kPa/m^2$

A. Load capacity comparisons

- Consider SC and the MRA designed to provide load capacity equal to that of SC (Appendix)

  Horizontal load capacity, $H$ (Fig. 5)
  - $H_{max}$: Parity can achievable without increasing $D$.
  - The MRA has less moment resistance than SC due to shorter length ($Moment, M = H | L - L_{pipe}|$).

  Vertical load capacity, $V$ (Table 1)
  - $V_{max}$: The MRA diameter needed to be increased to 4m to achieve parity in $V_{max}$ with the SC.

B. Comparative efficiency

- Geotechnical efficiency ($\eta_H = H_{max}/W$)
  - Horizontal loading: MRA $\eta_H = 29$, SC $\eta_H = 17.9$
  - Vertical loading: MRA $\eta_V = 9.8$, SC $\eta_V = 9.2$
- Motivate to further research about keying flap
- Weight efficiency: ex) AHV transport operation
  - 1 SC = 3 or 4 MRA → fewer trips or smaller AHVs

The pile is penetrated to a certain embedment depth using driving or suction installation. Then the pile is extracted, leaving the ring anchor adequate depth (Fig. 3)

Figure 2. Strategies for enhancing load capacity: (a) keying flaps, (b) wing plates

Figure 3. The installation procedure of the MRA

Figure 4. Suction caisson and MRA in clay

Figure 5. Horizontal load capacity of MRA in clay

Table 1. Comparative evaluation of suction caisson and MRA load capacity

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<th>Feature</th>
<th>Caisson</th>
<th>MRA matching horizontal capacity</th>
<th>MRA matching vertical capacity</th>
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Concluding Comments

- The MRA provide a means for significantly reducing the number of foundation footprints, with associated cost reductions.
- Installation cost for the MRA are medium (suction) to high (driving). However, the multiline potential may tend to offset its greater installation costs.
- Deep embedment & precise positioning can ensure robust performance under unintended loading and reliable prediction.
- Compared to SC, the MRA has a clear advantage under horizontal loading, future research is needed to improve the vertical load capacity by introducing keying flaps.

Appendix

- The MRA load capacity parity can be achieved by increasing $D$ or $W_{max}$ of wings.
- The design procedure is to (1) evaluate the MRA capacity using the same $D$ as the suction caisson, (2) add wing plates to a maximum dimension $W_{max} = D/2$, and (3) if the previous step does not produce the target load capacity, incrementally increase $D$.
- Estimated using a plastic limit analysis [4]

References