Design of Mooring Systems in Extreme Seastates with focus on Viscous Drift Force Modelling

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Introduction

Based on the reported incidents and model test results in recent years, an underestimation in Low-Frequency (LF) excitation forces and damping forces due to ignorance of viscous effect is uncovered.

Floatel Superior, a semi-submersible with 12 evenly spread mooring lines, is researched in 150 meter-depth water and under 100-year return period seastates. This paper mainly focuses on viscous drift force modelling in time domain in SIMA. Structural motion in surge and mooring line tension are used as characteristic-parameters to show the difference between models with and without viscous effect.

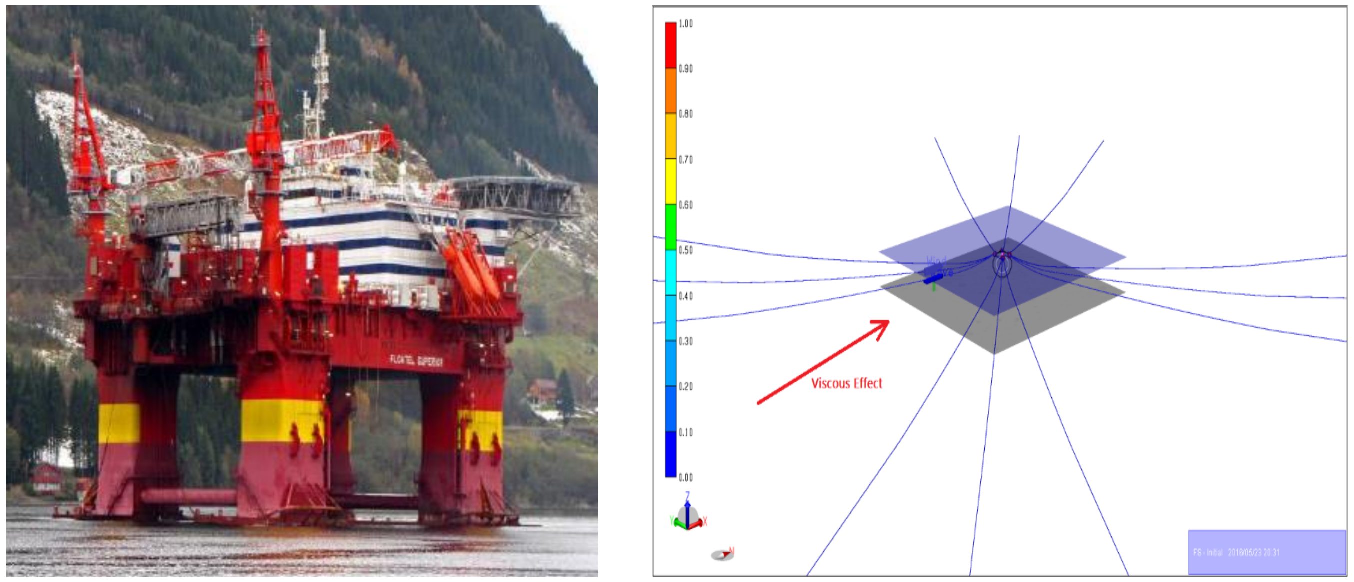

Figure 1: Floatel Superior and simulated model in SIMO

Methods

Two methods are applied in order to take viscous effect into account:

- *Slender Element Method* (SEM)

  Create slender elements along columns and pontoons, select proper drag coefficients from regulation and calculate the external effect on the slender elements. Morison Equation is used as the theory base.

$$f_D = \frac{1}{2}\rho D C_D |u| u$$

  For column, the viscous effect is due to free surface and wave-current interaction; for pontoon, the viscous effect is due to the influence of cross-flow on pitch motion.

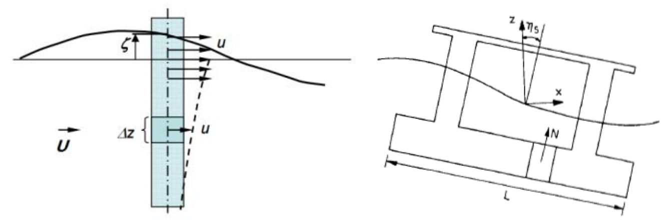

Figure 2: Viscous effect models

- *Correction Formula Method* (CFM)

  An empirical formula is used to correct the original wave drift coefficient, which is only based on potential flow. The added part is due to viscous-induced wave drift force.

$$f_D = F_D(\omega, U, H_s)/A^2 = [f_{d,pot}(1 + C_p * U) + B(G * U + H_s)]$$

  This method considers all viscous force only impacts on environmental excitation.

Objective and Scope

- Describe the difference between Frequency Domain Analysis and Time Domain Analysis
- Establish characteristic vessel offset and mooring line tensions according to recipes in rules and regulations; a thorough comparison of the FD and TD results is obtained.
- Discuss the contribution of the viscous effects to the resulting response.

Results

Three cases are summarized in the comparison group, which consists:

- Original case: with no viscous effect; the input file obtained from model test.
- SEM case: use SEM to add viscous effect; used as the viscous base case; later the drag coefficient will be adjusted for a sensitivity test.
- CFM case: use CFM to add viscous effect.

The time series of offset in surge and mooring line tension in 3-hour simulation length are obtained for all cases as Figure 3. In order to find a more accurate result, 20 simulations are set and the data series are fitted to Gumbel distribution. The 90% maximum value is chosen as the characteristic value as Figure 4. The following workflow process in Figure 5 is applied.

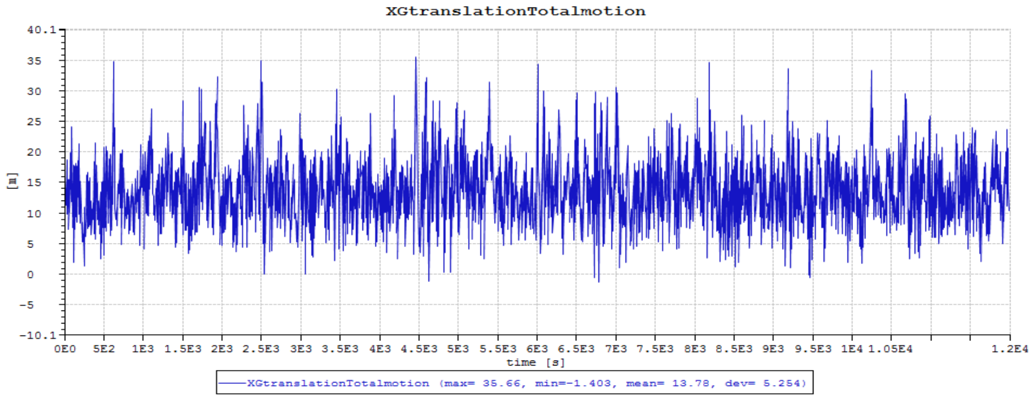

Figure 3: Motion time series in 3-hour simulation

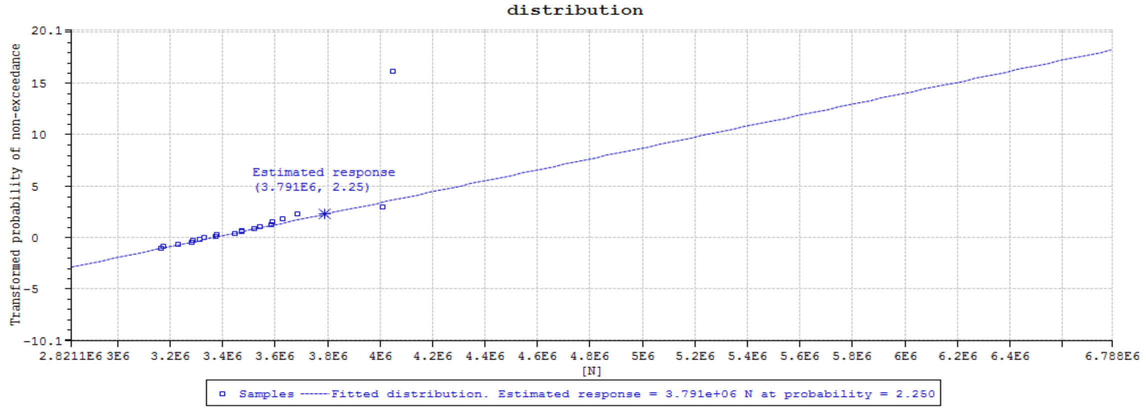

Figure 4: Gumbel distribution of most-loaded line

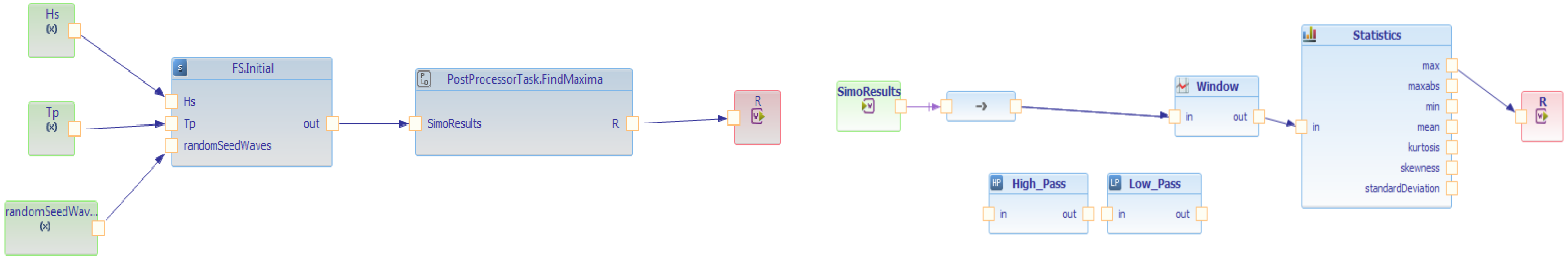

Figure 5: Workflow and post-processor in SIMO

Since viscous effect mainly has impact on LF response, then frequency filter is used to find the corresponding response in LF band and WF band separately. The motion comparison is in Table 1 and the change in tension are plotted in Figure 6.

Table 1: Motion components [m]

Case	Max	Mean	LF_{max}	WF_{sig}
Org.	38.27	12.27	29.99	3.3
SEM	42.38	13.9	34.73	3.26
CFM	53.45	15.65	42.91	3.35

Figure 6: Tension comparison of 3 cases

There is obvious increase in both motion and tension result when comparing the original case with the other two with viscous effect. It shows that both methods bring extra viscous-induced excitation and damping to the whole system, while CFM has more obvious increase.

Conclusions

- Viscous force is really important in real practice, especially for structures with small cross-section in extreme seastates. It cannot be ignored in the estimation of LF excitation or damping term.
- Both methods for taking viscous effect into account are valid and useful, since both motion and tension result have an obvious increase.
- SEM shows higher reliability and accuracy than CFM, since SEM counts the viscous effect both on excitation and damping term, while CFM only counts excitation.

References

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