## Technical Presentation

# HYDRODYNAMIC CHALLENGES RELATED TO LARGE VOLUME FLOATING PRODUCTION PLATFORMS.

by

Finn Gunnar Nielsen and Gudmund Olsen
Norsk Hydro Research Centre, Bergen, Norway

At the Norwegian continental shelf we observe a trend towards increased use of floating production platforms. These platforms have a displacement almost one order of magnitude greater than the conventional drilling platforms. Examples are: The Snorre platform (tension leg platform, TLP) appr. 110 000 tons, the Troll Oil platform (catenary mooring, CAT) appr. 190 000 tons and the Heidrun platform (TLP) appr. 290 000 tons. Several other solutions have also been proposed as for instance the Deep Draft Floater (CAT) with displacement in the range 150 000 - 300 000 tons. Conventional semisubmersible drilling plattforms have a displacement in the range 20 000 to 40 000 tons.

Common to all these production platforms is that they are optimised with respect to minimum first order motions (CATs) or first order forces in the tethers (TLPs). An other common feature is that they are to be installed in deep waters. All the examples above are to be installed at approximately in 300 - 400 m water depth. However, the future calls for installations at more than 1000 m water depth. An optimised design of the mooring system becomes thus increasingly important. In the following we will restrict ourself to discussion of some aspects related to Catenary Moored platforms.

An illustration on different contributions to the total design mooring forces for a large volume CATs is given in Figure 1. The mean environmental force has contributions from current, waves and wind. As for conventional drilling platforms, wind is the largest mean force component. However, we realize that the mean wave drift force is more important than the current force ( A term on the form $.5\rho C_D A U_c^2$ due to skin friction and separeted flow). The mean drift force is normally computed without taking into account the wave current interaction effects.

Surge drift force coefficients computed for different current velocities are shown in Figure 2. A typical design wave spectrum has the peak in the range 0.4 -0.6 rad/sec. From Figure 2 it is thus obvious that the mean drift force will be very sensitive to current. The normal procedure of estimating the mean drift force at zero current velocity may thus be questionable. The two curves given for $U = 0$ m/sec are obtained by independent computions with different computer codes. The deviation in the estimates is much less than what could be expected from the FPS2000 project /1/. Similar agreement has been found for other quantities. This is probably due to a careful dicretization of the platform geometry and use of a very fine panel mesh. The high values of the mean drift forces are closely related to the large diameter of the columns. For this kind of production platforms the diameter at the water line may be in the range 25 - 30 m.

On top of the mean horizontal displacement of the platform, first order and low frequency motions must be added to obtain maximum excursion. First order motions are straigth forward to obtain. However, for these kind of platforms, the first order motions are small compared to the low frequency motions. In Table no. 1 some charecteristic values for the ratio between the standard deviaton of the first order (wave frequency) motion and the low frequency moitons are shown. As seen from the table, the low frequency motions are of particular significance in moderate sea states. For the surge / sway / yaw motions it is assumed that the normal procedure of using the Newman's approximation /2/ to obtain the slow drift motions from the drift forces is quite accurate. However, slow drift heave / pitch and roll may be important as well, in particular for the deck clearance. As the natural period in these modes of motions is in the range 30 - 60 sec. the validity of Newmans approximation is more questionable. To which extent current modify the validity of Newman's approximation is not known.

Large efforts have been put into the task of establishing accurate estimates on the low frequency exciting forces. However, accurate estimates on the damping is equally important, as realized from the expression giving the variance of the motion response from the slow drift excitation force spectrum:

$$\sigma_x^2 = \frac{\pi}{2cb} S_F(\omega_0)$$

Here c is the stiffness of the mooring system and b is the linearized damping. The damping has several contributions: Wave drift damping, mooring line damping ( due to change in geometry of to mooring lines as the platform is moved horizontally) and viscous forces on the hull. For the last two contributions the interaction between current, wave frequency motions and low frequency motions is important. Even if acceptable estimates on the standard deviation of the low frequency motion are obtained, reliable estimates on the extreme values are much more uncertain. This is illustrated in Figure 3 where the ratio between the most probably maximum value and the standard deviation of the process is plotted as function of linearized damping ratio. The Rayleigh estimate is representative for the wave amplitude process and the exponential distribution is representative for the slow drift excitation force. The estimates based upon Næss' method /3./ and Stansberg's method /4/ are representative for the low frequency motion response. A considerable difference is obtained in the estimates depending on the extreme value distribution applied.

In addition to the above aspects, shortcrestedness of the waves may affect the low frequency excitation forces as well as the damping and the extreme value distribution, as reported by e.g. Sterndorff and Skourup /5/. In Figure 4 computed slow drift surge motion is shown as function of the spreading parameter of the waves. A cosine$^{2s}$ $\theta$ distribution of the wave energy is assumed. Both time domain and frequency domain methods have been applied in establishing the estimates. All methods shows consistently a reduced motion response when shortcrestedness is accounted for. However, the prediction of the relative reduction in the response as compared to the response in long crested seas as well as the absolute level of the response both do differ significantly between the different methods applied.

To summerize, the following tasks seems to be the most important for improvement of the estimates on the extreme low frequency motions:

> Excitation forces: Effect of current and short crested seas. Importance of off-diagonal terms in the low frequency excitation force matrix.
> Damping: Combined effect of current, wave frequency motions ( and particle velocities) and low frequency motions.
> Extreme value statistics: Estimation of extremes. Establishing proper probability distribution function. Taking into account nonlinearities in damping as well as restoring forces. Combining low frequency extremes and first order extremes taking properly care of correlation.

To establish the extreme loads in the mooring lines, dynamic load effects in the lines must be accounted for. This effect has not been considered in the above.

## References:

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4. Stansberg, C.T.:" A Simple method for Estimation of Extreme Values of Non-Gaussian Slow-drift responses". Proc. 1st . ISOPE Conference, Vol. III, Edinburgh, Scotland, 1991

5. Sterndorff, M.J. and Skourup, J.: " Long Duration Model Tests for Low Frequency Behaviour of Floating Offshore Structures in Long and Short Crested Waves." Proc. of the Sixth Int. Conference On Behaviour of Offshore Structures (BOSS), London 1992.

Low-frequency v.s. first order motion response $\sigma_{LF} / \sigma_{WF}$

| Sea state | | Surge | Heave | Pitch |
|---|---|---|---|---|
| $H_s$ (m) | $T_P$ (sec) | | | |
| 5 | 10 | 6,2 | 1,8 | 3,2 |
| 10 | 13,5 | 4,2 | 2,1 | 2,9 |
| 12 | 15 | 2,6 | 1,3 | 1,9 |
| 16,5 | 19,5 | 1,5 | 0,95 | 1,1 |

Table 1. Ratio between the standard deviation of the low frequency motion and the wave frequency motion as obtained in model tests with a Deep Draft Floater.

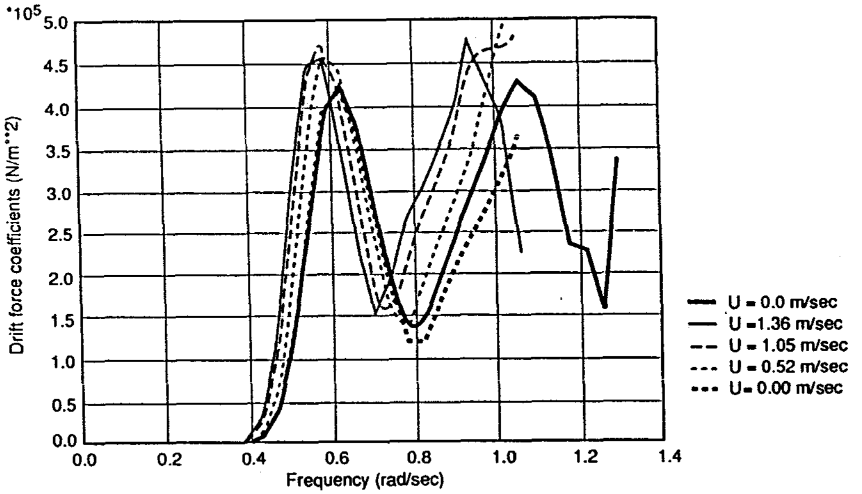

Figure 2. Surge drift force coefficient as computed at different current velocities. Results for U = 0 are shown for two independent computations.

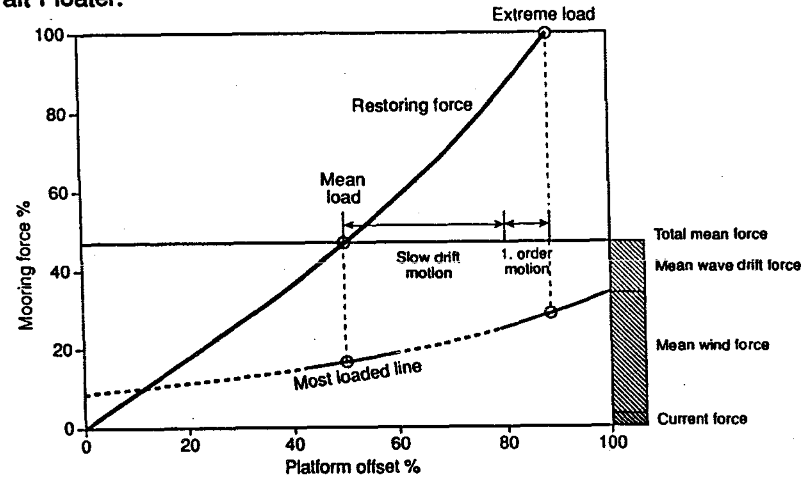

Figure 1. Contributions to total mooring loads. Illustration of total load as well as load in most loaded line.

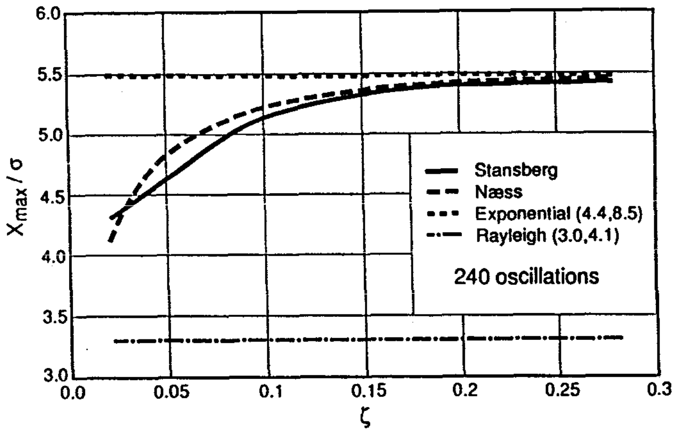

Figure 3. Ratio between most probably maximum value and standard deviation as obtained by different methods. ς is the damping ratio. Figures in paranthesis corresponds to 90% confidence limits.