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DESIGN SESSION

New Methods for DP Assisted Tandem Loading

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Abstract

Offshore oil loading with DP controlled shuttle tankers has been performed for more than 15 years in the North Sea. The overall loading arrangement is designed so that loading operations can be performed up to 4.5m significant wave height. Compared to other loading types, tandem loading gives specific challenges due to the movement of the FSU (or FPSO) during the loading operation. This lead to the development of enhanced DP functionality aimed at minimising the consequences of surge and fishtail movement of the FSU, and at the same time providing improved operator guidance on the actual operational situation. A "FSU Heading" function is designed with the aim of aligning the two vessels This function will be of greatest benefit when loading from FSU's with no position or heading control. The "FSU Surge/Sway" function minimise the effect of surge movement, and the function will be of benefit on all FSU's, even though the actual surge movement is dependent on the stiffness of the anchor pattern. Both functions can be used (alone or together) to reduce the effect of FSU fishtail movement.

The new algorithms are based on simultaneous utilisation of absolute and relative position reference systems. The operator defines the limits for FSU movement and for heading difference between the tankers. Absolute position reference systems are used for the actual DP model of the shuttle tanker and relative systems are used for monitoring the relative position between shuttle tanker and FSU.

Background

Offshore oil loading with DP controlled shuttle tankers has been performed for more than 15 years in the North Sea. The shuttle tanker operator Navion, former Statoil transport division, has alone performed more than 9.000 loading operations. (6.500 operations from traditional loading buoys such as OLS and SPM and approximately 2.500 Tandem Loading operations). The operation is designed for 4.5m significant wave height for the hook-up phase and 5.5m significant for loading. The "Weather Vane" DP mode and the different loading buoy types are described in the following sections.

Weather Vane Principle

When loading offshore, it is possible to reduce the thruster/propeller force required to retain the vessel's position, relative to the offshore loading buoy, by utilising the stabilising effect of the wind and wave forces acting on the vessel's hull. In order to achieve this reduction, the vessel's bow must always face the environmental forces. Therefore the DP system includes special Weather Vane operation modes which cause the vessel to always point towards the environmental forces.

The Weather Vane operation modes cause the vessel to act like a weather vane. The vessel is allowed to rotate with the wind and waves around a fixed point called the terminal point. Neither the heading nor the position of the vessel is fixed. The heading of the vessel is controlled to point towards the terminal point, while the position is controlled to follow a circle, called the set point circle, around the terminal point. Weather Vane is illustrated in the following figure.

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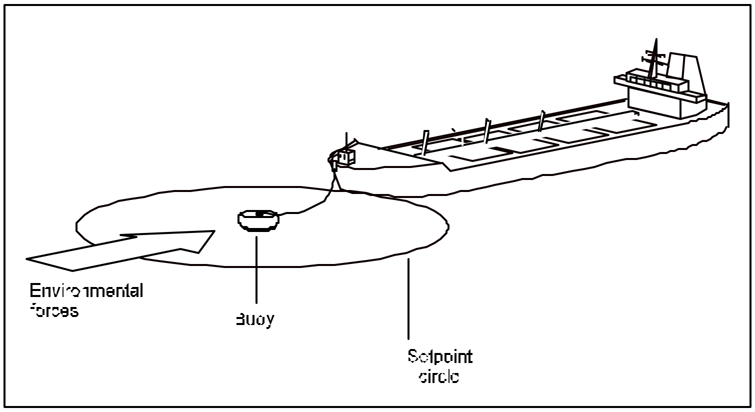


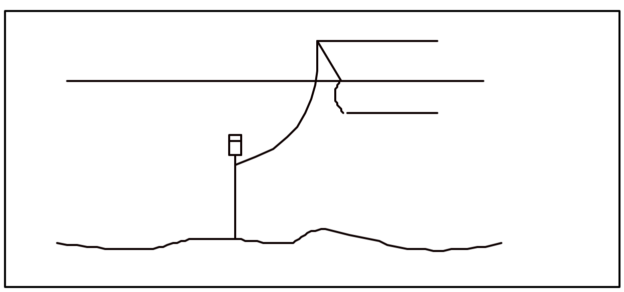
This kind of Weather Vane operation requires a minimum sideways holding force, and the available thruster capacity on the vessel is used for maintaining the correct distance and heading towards the terminal point. In the sideways (sway) direction, the vessel position is not controlled; the vessel motions are only damped.

Predefined set-up for each loading buoy defines the terminal point and the maximum and minimum distance that the vessel may move from the terminal point. The operator sets the wanted set-point radius within the limits. The distance from the terminal point is monitored and an alarm is given if one of the limits is exceeded.

Loading Buoy Types

A brief description of two of the different "Loading Buoy" types in use in the North Sea is presented below. In addition to the presented types, there are also oil fields where Submerged Turret Loading (STL) and Single Anchor Loading (SAL) is utilised. STL requires special models for the connection phase as well as models similar to Position Mooring systems for the loading phase. For SAL buoys it is required to keep a high level of tension in the "anchor line" in order to turn the SAL loading buoy around when the vessel weather vanes.

OLS (Loading Buoy without Mooring)



Absolute position reference systems such as HPR and DGPS are used for positioning the shuttle tanker relative to the fixed geographic position of the loading buoy. Alarm limits are defined both for close and far distance from the loading buoy.

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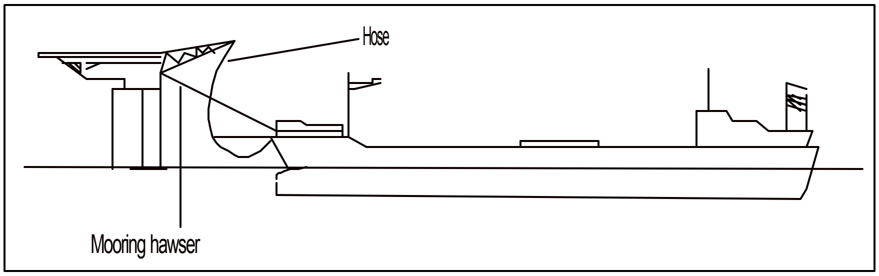
SPM (Single Point Mooring)

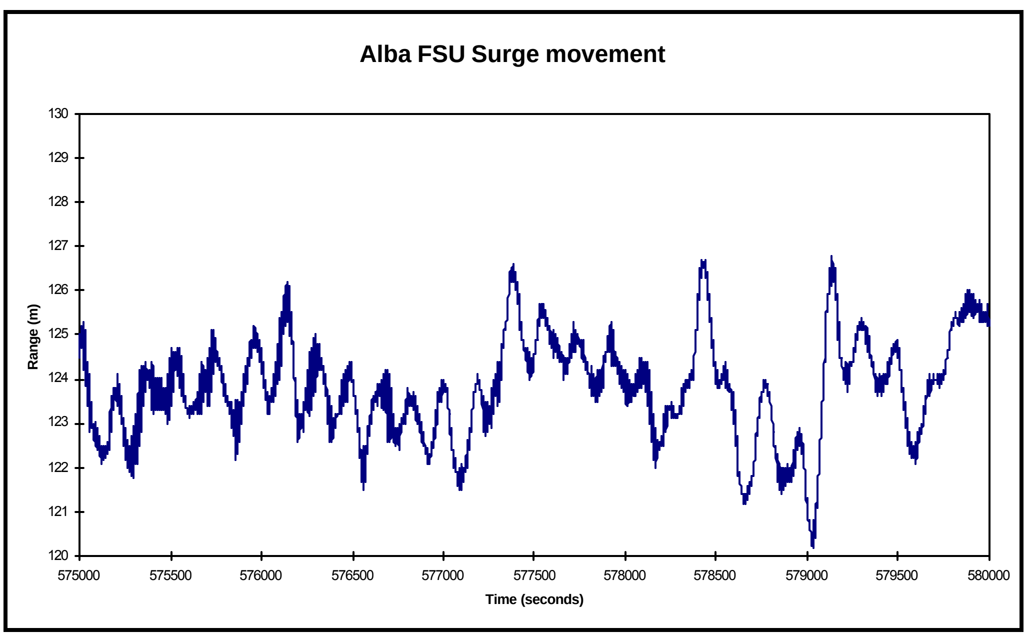


Relative position reference systems such as Artemis and Relative GPS are used to position the vessel relative to the boom tip of the loading buoy. This implies that the DP model treats the boom tip as a fixed reference point, i.e. all relative movement between the vessel and the boom tip is seen as shuttle tanker movements. A mooring hawser is connected between the buoy and the shuttle tanker. The hawser tension is therefore taken as input to the DP model. Alarm and warning distances are defined for close distance to the buoy. An alarm is also defined for high hawser tension.

Tandem Loading

When DP assisted Offshore Loading from FSU's and FPSO's was introduced in the North Sea in mid nineties the DP model was similar to the model used for SPM loading. I.e. utilisation of relative position reference systems such as Artemis and Relative GPS to position the vessel relative to FSU. This model worked quite well for most loading conditions, but during the years some weak points have been revealed.

The major weak point in applying an SPM type DP model for Tandem Loading is that the FSU stern is treated as a fixed point. This implies that any FSU surge and fishtail movement is treated as shuttle tanker movement. This will again lead to wrong current estimates and potentially unstable DP positioning. Another effect is that the shuttle tanker uses much energy to follow FSU surge movement, which really is insignificant for maintaining safe distance between the vessels.



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A figure showing surge movement of Alba FSU in moderate weather is included on the previous page. The amplitude in this case can be seen to vary between ±1 m and ±3 m at a period of approximately 170 seconds. Amplitudes of up to ± 8m at shorter time periods have been reported for more adverse weather conditions at or beyond the operational limit for loading.

Another problem is rapid heading changes of the FSU. When the draught of the two vessels is very different, i.e. one is full and the other is empty, the optimum (Weather Vane) heading can be quite different. This can constitute a problem for the loading hose and may also lead to safety problems if heading difference becomes very large. This problem will be more noticeable when offloading from an FSU with no position or heading control. Heading changes of 90° in approximately 30 minutes have been reported during calm weather at the change of tidal stream. Fishtail movement of ±5-10° at a period of approximately 15 minutes is also commonly experienced.

New DP functions

Two new DP functions have been designed to overcome these problems:

- An "FSU Surge/Sway" window can be established where the stern of the FPSO is allowed to move freely without affecting the wanted position of the shuttle tanker. This requires that the position reference systems are treated different from the "SPM model".

- An "FSU Heading" function is designed to align the two vessels during rapid heading changes of the FSU. Unlike the standard "Weather Vane" function, a sideways thrust demand is allowed when this function is active. This function requires the heading of the FSU to be available on the shuttle tanker.

FSU Surge/Sway

The principle of this function is to monitor the actual position of the FSU stern position, and then adjust the setpoint of the shuttle tanker when the FSU moves outside a "Surge / sway window". The operator can define the size of the surge/sway window according to actual conditions.

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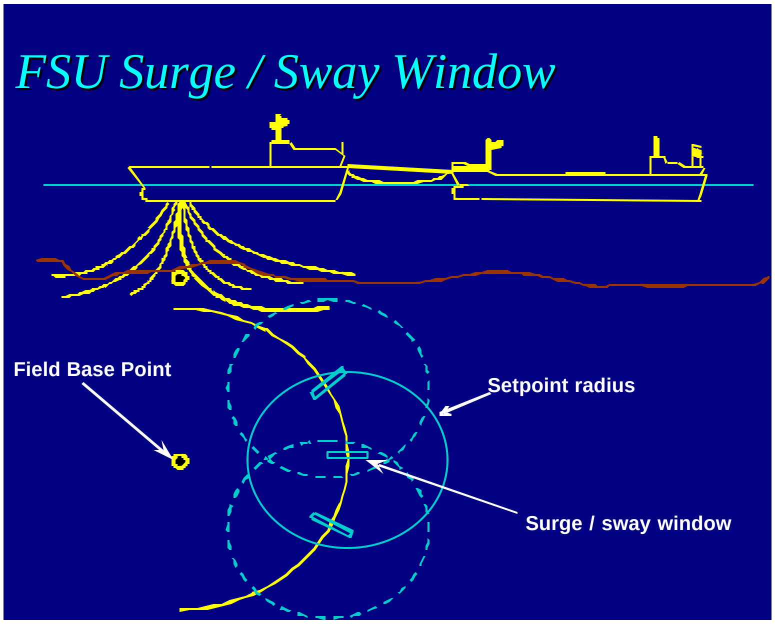

When surge movement of the FSU is allowed (within limits) this leads to significantly reduced thruster utilisation on the shuttle tanker. Like the ordinary Weather Vane mode, the heading of the shuttle tanker must always be kept pointing towards the stern of the FSU. Some sideways thrust demand is allowed in order to align the two vessels in the case of fishtail movement of the FSU

Absolute position reference systems are used for shuttle tanker DP model, while relative position reference systems are used for monitoring FPSO movement relative to the shuttle tanker. New methods of quality assessment of these relative position reference systems have been developed. The normal quality assessment is related to the DP model and no DP model exists for the FSU movement. The new quality control of “mobile reference systems” consist of the following elements:

- Variance estimation of the relative reference systems
- Rejection of measurement outliers
- Warnings to the operator in the case of large systematic deviation between the reference systems

FSU Heading

This function is based upon monitoring of FSU / Shuttle tanker heading difference. The heading of the shuttle tanker is presently received over the data-link of the DARPS relative GPS system. When the operator defined heading difference is exceeded the thrusters are activated in order to align vessels. The resulting force is mainly in sway direction, but the heading is continuously adjusted to keep the bow of the shuttle tanker pointing towards the FPSO stern. The operator defines the limits for turning the active control on and off.

This function is particularly useful during quick FSU heading changes, as for instance a change of tidal stream in calm wind conditions. The function is also valuable when difference in draught of the two vessels gives large deviation between optimum headings, and during severe FSU fishtail movement.

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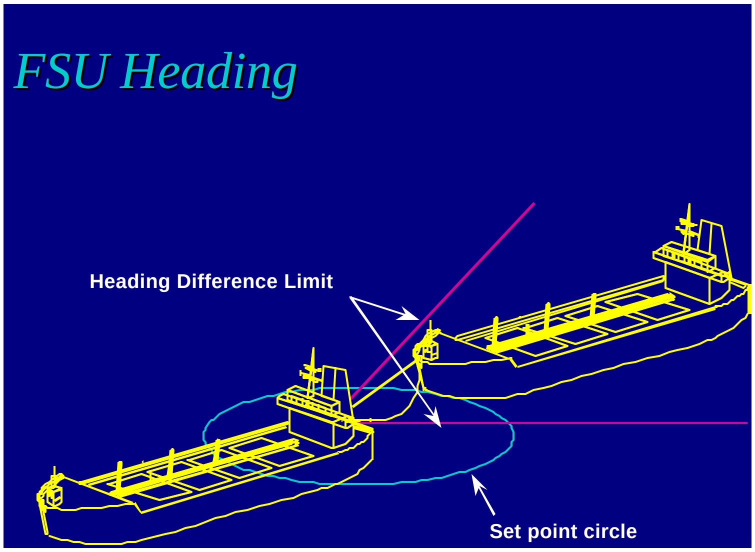

Improved operator guidance

The operator guidance was improved on the following points when the new functions where designed:

- Graphical presentation of FSU and shuttle tanker in true scale and heading
- Display of FSU heading and the actual distance between the vessels
- Simple menus to change the operational limits for the Surge / Sway window and the heading difference between shuttle tanker and FSU.
- Accompanying alarms for error situations such as:
  - ✓ Failure in absolute or relative position reference systems
  - ✓ Missing FSU heading data
  - ✓ Heading difference between vessels above limit
  - ✓ Failure in Gyro reading on FSU (Based on two independent inputs to DP)

Verification of new functions

The new functions have been through a lengthy verification process. The functions where first designed and implemented in the DP system according to functional specifications from Navion. The SDP simulator was extended to simulate FSU surge and fishtail movement. The simulated relative reference systems provide data according to this movement with the possibility of adding random or systematic noise. The FSU heading was simulated in order to follow the dominant wind direction. By adding current and waves from another direction, we were also able to simulate situations where the shuttle tanker optimum heading could be quite different from the simulated FSU heading.

Navion defined different test scenario for verification of the new functions. Among others, these included strong surge movements combined with rapid wind changes as well as quick FSU heading changes due to changing tidal stream. These test scenarios were based on actual experience from Alba, Fife etc.

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Implementation on Navion Clipper followed the verification towards the test scenario. A two-day test-program was set up, which commenced with an ordinary loading operation.

Before implementation on other vessels the system with the new functions operated on Navion Clipper for some months. After this operational verification period, the quality control of the relative position reference systems and the mechanisms for alarm checks between computers in a redundant DP configuration have been improved.

Summary and conclusions

Major improvements

Significant modifications to the standard weather vane principle was needed in order to implement the new "Tandem Loading" function. These modifications can be shortly summarised as:

- Only absolute position reference systems used for the shuttle tanker DP model
- Relative position reference systems utilised for monitoring the stern position of the FSU
- Quality control of "mobile transponders" added
- Sideways (sway) thrust demand allowed in order to align vessels

The major benefits from the new functions are:

- More stable positioning of shuttle tanker
- Reduced thruster utilisation
- Improved operator guidance including graphical presentation of FSU and shuttle tanker in true scale and heading

Acknowledgements

Thanks to Navion for help during specification and test of the new functions. Special thanks to Captain Bjørn Hammersvik of Navion Clipper for providing detailed test scenario for the simulations and for valuable feedback during the final verification tests on Navion Clipper.