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OFFLOADING OPERATION WITH A DP SHUTTLE TANKER: COMPARISON BETWEEN FULL SCALE MEASURENMENTS AND NUMERICAL SIMULATION RESULTS

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Abstract: In the present paper, full scale measurements of a DP offloading operation is presented, considering all stages of the operation: approach to the FPSO, connection, oil transfer and disconnection. Vessel motions, thruster forces and environmental agents were measured. A time-domain offshore system simulator was then used to reproduce the same conditions of that operation, and the results from the numerical code are compared to the full-scale measurements. Good agreement between numerical results and full-scale measurements was observed.

Keywords: offloading operation, shuttle tanker, dynamic positioning systems, full scale measurement.

1. INTRODUCTION

Dynamic Positioning (DP) Systems have been increasingly used by offshore industry, applied to several operations like drilling, pipe launching, surveying and supplying. Conventional DPS keeps the vessel in close proximity to a required position in the horizontal plane, through the controlled application of forces generated by installed thrusters.

In the last two decades, the development of Floating, Production, Storage and Offloading systems (FPSO's) is introducing new classes of offshore systems, in which DPS are also being applied. FPSO's are large moored tankers with oil production plant installed on deck and large storage tanks. Periodically, shuttle tankers (ST) are connected to the FPSO, transferring the oil to its tanks to bring it to shore. This operation is usually carried out in the tandem mooring arrangement, as presented in Fig. 1.

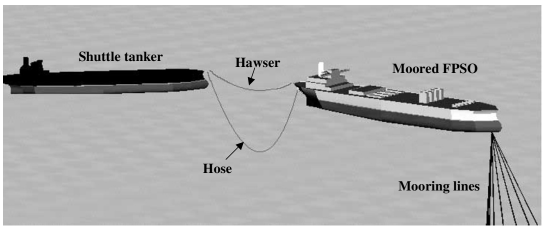

Fig. 1 Tandem mooring arrangement – offloading operation

The offloading operation takes more than 24 hours, and requires full attention of operators in order to avoid collision, fast approximation of vessels, hose disconnection and hawser overstress. During the time needed for the full cargo load, the officers are exposed to considerable mental wear, putting safety at risk (Mork, Lerstad, 1992). In a conventional operation (non-DP assisted), the distance between the ships must be controlled, by means of main propeller aft thrust, the restoration force of the hawser and tug assistance.

In bad weather, the operation must be interrupted, due to large amplitude motions of vessels, collision risk, high loads on hawser, and longitudinal forces that may exceed main propeller total thrust. The shuttle must "wait on weather" until conditions improve. These restrictions increase total operation time, and, at worst, the field may have to cease production because of a lack of storage caused by the inability to export.

As mentioned, the operation was normally performed with aid of tugboats, which "control" position and heading of the shuttle. The utilization of tugs with high bollard pull capacity increases the "weather window" for operation feasibility, as well as its total costs.

The application of DP Systems to the controlling of shuttle position during offloading operation was a natural option. Human interference is reduced, increasing overall safety and not at least minimizes operators fatigue during prolonged operation in the vicinity of another surface structure. The automation of the operation improves regularity, minimizes shuttle motions, reduces hawser loading and, consequently, forces transmitted to FPSO unit. The critical stage of hawser and hose connection operation is also simplified and becomes safer.

A DP System installed in a shuttle tanker presents special characteristics, which must be considered during control design (Bray, 1998). In conventional DP System, the reference position and heading is given by the operator, being stationary or not. For station-keeping DP System (drill-ship, for instance), the reference is stationary. For track-follow DPS (applied, for example, in pipe-laying), the reference is time-varying. However, in case of a DP shuttle tanker (DP-

ST), the reference position is related to the stern of the FPSO, what means that FPSO position must be measured somehow and that large variations of the reference point must be accepted.

The power required to keep a shuttle tanker close to a pre-defined position and heading may be unfeasible, due to large displacements of such ships, that can reach 175000 DWT. However, in offloading operation the shuttle tanker must not be positioned near a reference point and heading. The operator can define zones to connection point, inside which a safe operation can be guaranteed. Furthermore, shuttle heading can be released, leaving the ship to weathervane. Sometimes, some restrictions must be imposed to weathervane ability, since large horizontal hose-shuttle angles may damage the connection system. So, this feature reduces the required power and fuel consumption, allowing the application of DP System to large tankers. These special positioning requirements must also be considered in controller design. Several concepts of tandem DP offloading have been developed (see, for example, Bravin e Tannuri, 2004).

However, during the design phase of a DP System a good prediction of the dynamic of the vessel is important. In general, this prediction is not easy to be made theoretically since the mathematical model is a set of complex nonlinear equations. So, tests in ocean basin with scale model have been performed to evaluate the performance of DP System but the solution is not completely satisfactory due to difficulties related to scale effects. Therefore, an analysis of the signals recorded during the operation of a DP vessel and a comparison with those obtained theoretically or experimentally is quite useful in order to check all mathematical models and results obtained during design phase.

In the present paper, full scale measurements of an offloading operation is presented, including DP-ST motions, thruster forces and environmental agents. All stages of the operation were considered, including the approach to the FPSO, connection, oil transfer and disconnection.

Furthermore, a time-domain offshore system simulator is used to reproduce the same conditions of that operation, and the results from the numerical code are compared to the full-scale measurements.

In section 2, all data of the shuttle tanker and the platform are exposed. In section 4, the full-scale measurements are detailed, including the trace plots of the vessel and the platform during the whole operation, as well as time-series of position and thrusts. Section 5 details the Numerical Offshore Tank (TPN), a time-domain simulator that was used to reproduce the same conditions of the monitored operation. The numerical results and the comparison between the measured and numerical results are presented in the section 6.

2. PLATFORM AND SHUTTLE TANKER DESCRIPTION

The DP Shuttle Tanker (Aframax Vessel) and FPSO (Mono-Column Platform) main characteristics are presented in Table 1. The DP Shuttle Tanker is equipped with 5 thrusters, indicated in Table 2.

Table 1 ST and FPSO Main Characteristics

Property	FPSO	Shuttle
Length	65.1m	229.0 m
Beam	65.1 m	42.0 m
Draft Full	18.0m	14.3 m
Draft Ballasted	11.2m	5.3 m
Depth	27.0 m	21.3 m
Displ. Full	54276 MTons	117020 MTons
Displ. Ballasted	34315 MTons	39900 MTons

Table 2 DP-ST Thrusters

Thruster	Thrust	Power
1- Tunnel Bow	28tonf	1935kW
2- Azimuth Bow	36tonf	2000kW
3- Azimuth Stern	36tonf	2000kW
4- Tunnel Stern	16tonf	1050kW
5- Main Propeller	220tonf	18891kW

4. FULL SCALE MEASURENMENTS

During the monitoring campaign, it became possible to monitor a complete offloading operation through the BLOM system installed on board the shuttle tankers hired by Petrobras. This system, when active, can record several parameters of the ship, including ship's position, relative position, dynamic positioning parameters, etc… Environmental conditions were also measured by means of appropriate instrumentation installed in the FPSO (Fig.2).

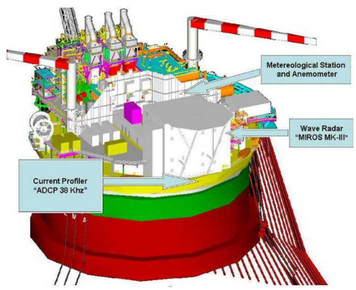

Fig. 2. Monitoring equipment location in FPSO Piranema (adapted from Saad et al., 2009)

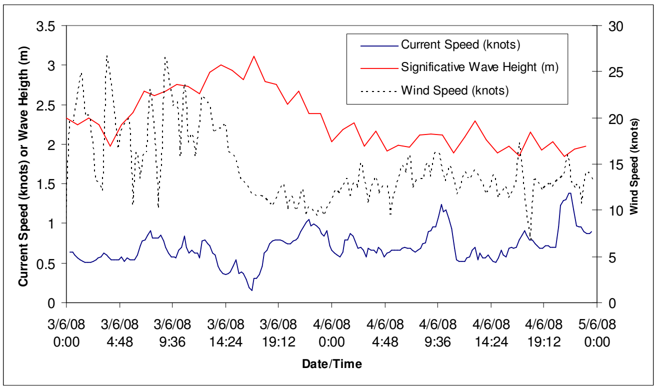

Fig. 3. Significant wave height, wind and current speed during offloading operation.