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Human technical factors in FPSO-shuttle tanker interactions and their influence on the collision risk during operations in the North Sea

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Introduction

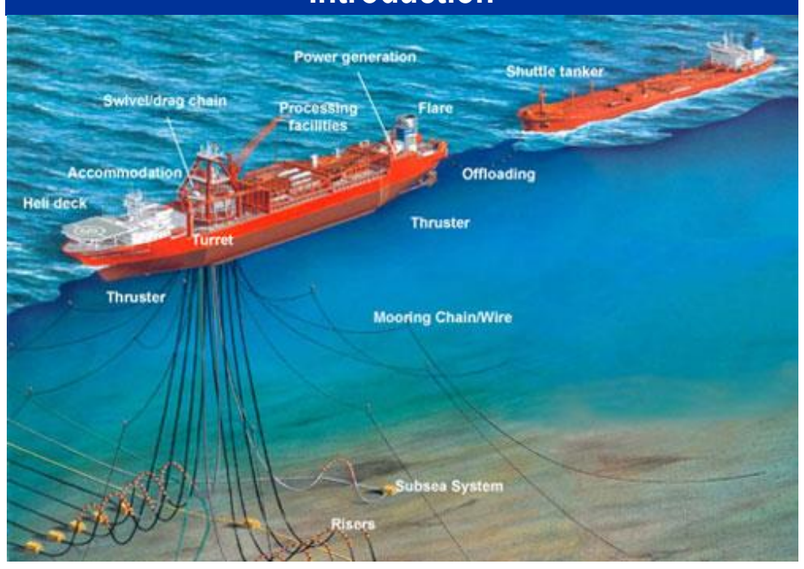

Figure 1: FPSO and shuttle tanker in tandem offloading (OET, 2014).

Floating Production, Storage, and Offloading (FPSO) units and Floating Storage Units (FSU) in the North Sea mostly rely on shuttle tankers for offloading of their cargo oil. The term *shuttle tanker* describes a trading tanker traveling back and forth between a shore terminal and a FPSO/FSU, transporting oil ashore.

Tandem configuration (shown in figure 1 and figure 2) is the most common way of performing offloading operations from such installations, a configuration which involves the shuttle tanker positioning itself at some distance behind the, FPSO/FSU and the two vessels connect by a mooring hawser and a cargo hose used for offloading (Chen and Moan, 2004).The shuttle tanker maintains its position using dynamic positioning (DP), keeping the mooring hawser free of tension, or by applying a small thrust astern, keeping the mooring hawser tensioned (Chen and Moan, 2005).

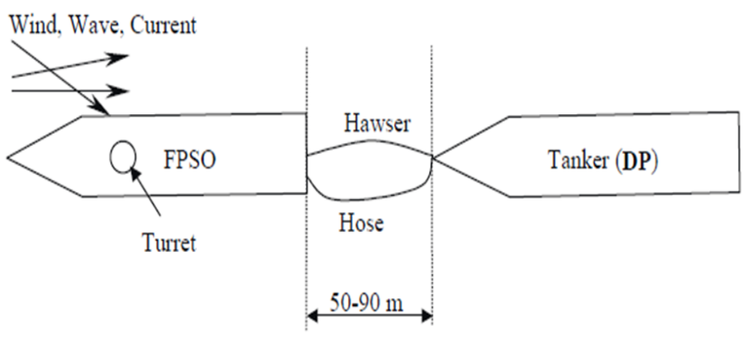

Figure 2: Tandem configuration (Chen 2003).

Following a series of collisions and near misses involving shuttle tankers and FPSOs performing tandem offloading operations in the North Sea, extensive effort was put to address the issue in the early 2000's. Several risk studies were performed, the most comprehensive being the joint industry project 'Operational Safety of FPSOs' (Vinnem et al., 2003) and the PhD study 'Probabilistic evaluation of FPSO-tanker collision in tandem offloading operation' (Chen, 2003).

As there has not been published any comprehensive follow-up study, the overall objective of this thesis is to investigate the current situation in the field of risk assessments relating to collisions between DP shuttle tankers and FPSOs during tandem offloading operations in the North Sea. Moreover, it investigates Human & Organisational factors (HOFs) and technical risk factors, considering a drive-off scenario where the DP shuttle tanker has a powered forward motion. Such a scenario involves an event where the DP shuttle *tanker "is driven away from its targeted/wanted position by its own thrusters in offloading operation. This is not a planned or wanted event"* (Chen 2003).

Methods

An extensive literature study was performed in order to provide an overview of the major research papers published on the subject of FPSO – Shuttle tanker collisions. The collision risk in FPSO-DP shuttle tanker operations was further investigated by performing both qualitative and quantitative risk analysis.

Qualitative risk analysis:
The qualitative risk analysis included an assessment of HOFs' and technical factors' influence in tandem offloading operations, covering factors relating to individuals, communication & collaboration, training of personnel, Human-Machine Interaction (HMI), and design & integration of technology. Based on the aforementioned, a simple analysis of barriers against collision in drive-off scenarios was performed using the bow-tie method. .

Quantitative risk assessment:
The collision probability was assessed using statistical data analysis, applying the practical frequency model of (Chen, 2003), as presented in equation 1.

$$Pr(collision) = Pr(UPFM) \cdot Pr(FOR|UPFM)$$

Equation 1: Practical frequency model

Where:
$Pr(UPFM)$= probability that the shuttle tanker has an uncontrolled powered forward movement (drive-off).
$Pr(FOR|UPFM)$ = probability that the recovery action proves insufficient for avoiding a collision, i.e. a failure of recovery.

$Pr(UPFM)$ and $Pr(FOR|UPFM)$was estimated from incident statistics involving DP shuttle tankers performing tandem offloading from FPSOs on the UK and Norwegian continental shelves (UKCS & NCS), covering the time period from 1995-2013, found in reports and databases for offshore accidents

The probabilities are denoted as 'per offloading', in order to account for the individual oilfield`s characteristics, i.e. the number of offloading operations per year, whilst simultaneously enabling intercomparison. The number of offloading operations was estimated using production figures from relevant oil fields.

Results from data analysis of incidents

Overall incident frequency:
In the period 1995-2013, there have been 28 reported incidents involving DP shuttle tankers performing tandem offloading from FPSO on the UKCS & NCS. The geographical distribution of the incidents is uniform, 14 incidents occurring on each of the continental shelves.

Figure 3 shows the number of incidents per offloading on the UKCS & NCS, from 1995-2013. As seen from the figure, year 2013 represents no statistically significant change in the number of incidents compared to the last 10 years. It is worth noting that there has only been one incident during the last four years, and none during the last two years, which may indicate slight improvement, however it is not possible to determine from the available data.

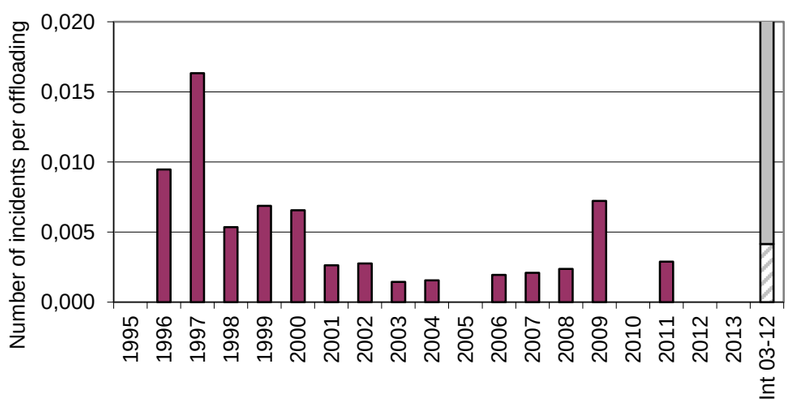

Figure 3: Number of incidents per offloading, UKCS & NCS 1995-2013.

The distribution of events between each operation phase, show that there is a predominance of incidents occurring during loading, representing 19 (68%) of the incidents. Incidents have been prone to occur during the loading phase on both the UKCS and NCS, representing 9 incidents (71%) and 10 incidents (64%) respectively. The distribution of incidents per failure cause on the UKCS & NCS, shows that DP failure (21%), PRS failure (18%) and operator error (18%) occur most frequent.

Collision frequency:
In the period 1995-2013, there have been reported 7 collisions involving DP shuttle tankers performing tandem offloading from FPSO on the UKCS & NCS. Figure 4 shows the number of collisions per offloading on the UKCS & NCS, calculated for 1995-2013. It shows that 1997 had the highest collision frequency. Moreover, there has not been reported any collisions during the last four years. However, it is not possible to observe any statistically significant increase/ decrease for 2013 compared to the previous 10 years.

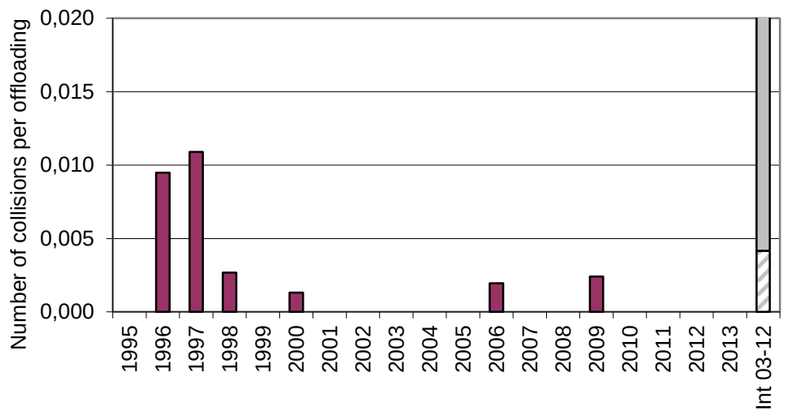

Figure 4: Number of collisions per offloading, UKCS & NCS 1995-2013.

Probabilities for events related to collisions during FPSO – shuttle tanker tandem offloading, estimated from UKCS and NCS incidents aggregated, is presented in Table 1. It shows that both the drive-off probability and collision probability has been reduced, when comparing 1995-2003 versus 2004-2013. The drive-off probability and the collision probability has been reduced by nearly 61.8%

Table 1: Probabilities for collisions and related events, UKCS & NCS.

Period	Pr(drive-off)	Pr(failure of recovery|drive-off)	Pr(collision)	Pred. interval 03-12, Pr(collision)
1995-2013	0.00322	0.25000	0.00080	0.00000-0.00416
1995-2003	0.00471	0.25000	0.00118	0.00000-0.00708
2004-2013	0.00180	0.25000	0.00045	0.00000-0.01325

Conclusion

- The interaction of HOFs and technical factors play a key role to the understanding of risk tandem offloading operations. E.g. the design of DP equipment and training of DP operators should account for such interactions.
- The drive-off probability and collision probability has been reduced, when comparing 1995-2003 versus 2004-2013.
- The collision risk may be reduced by designing the DP system`s alarms in such a way that the alarms' saliency matches their criticality.

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