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VIBRATIONAL PROBLEMS DURING DRILLING OPERATIONS

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Abstract. *In order to establish an access from a well to a mobile offshore drilling unit (MODU), a marine riser is needed. The marine riser is used as a safe conduit from the sea bed to the sea surface and the drilling unit. During drilling operations, the dynamical behaviour of the riser, in terms of forces/moments and displacements/rotations, is very important to guarantee safe operations.*

Drilling operations are performed in several phases. The first phase, when installing the conductor and wellhead, is performed in open sea; it means that the drill pipe is exposed to the sea. Once the wellhead and blow out preventer (BOP) are installed and the drill pipe has been retracted, the remaining phases of drilling are performed inside a large bore marine riser after it has been installed. The combination drill pipe and marine riser is usually referred as marine drilling riser.

The present paper presents some vibrational problems observed during exploratory drilling of a well located in the North Sea. Real time data collected from the marine riser are investigated and possible causes and consequences discussed. Data measurement are collected at critical positions along the marine riser such as flex joints, BOP, first pup joint above the BOP. The interaction between the drill pipe and the marine riser is very important in order to avoid accidents during drilling operations.

1 INTRODUCTION

This paper summarizes experiences and observations gathered from a monitoring campaign on a marine riser. The structural monitoring, carried out in 2011, was performed during exploratory drilling operation in a well located in the North Sea. The goal of the structural monitoring was to condense the measured riser response data into a limited set of parameters that could be continuously monitored and displayed, with the purpose to make on-board personnel aware of the status of the riser and wellhead during the operation, such that any potentially detrimental or dangerous situation can be detected and managed as early as possible. The paper includes measured data, relevant observations related to instrumentation, real time monitoring, acquisition and distribution of sensors data and synchronization issues.

During the monitoring campaign, among other instruments, strain gauges were used and a comprehensive explanation to transforms electrical signal from the strain gauge to forces and moments is given in [1].

The real time monitoring systems give important input to optimal positioning of the MODU both for drilling and completion operations [2].

2 GENERAL ARRANGEMENT OF INSTRUMENTS

The riser system and location of the relevant sensors are shown in Figure 1. The elevations are given relative to wellhead datum for riser fixed sensors, and relative to MODU datum for MRU's above outer barrel. MRU's are oriented with local X-axis in MODU forward direction, except for the MRU-PUP, which is oriented with local X-axis in MODU port direction. An overview of the sensors used in the real time monitoring is given in Table 1.

Sensor position	Sensor name	Sensor type	Output	Coordinate system
PGB	MRU-PGB	MRU	Rotations/ translations	Riser
LMRP (top)	MRU-LMRP	MRU	Rotations/ translations	Riser
10ft Pup-joint	MRU-PUP	MRU	Rotations/ translations	Riser (Rotated)
10ft Pup-joint	DACOS-1	Strain sensor	Strain	-
10ft Pup-joint	DACOS-2	Strain sensor	Strain	-
10ft Pup-joint	DACOS-3	Strain sensor	Strain	-
10ft Pup-joint	DACOS-4	Strain sensor	Strain	-
NGI data	-	-	-	-
Diverter	MRU-TOP1	MRU	Rotations/ translations	Riser
Slip-joint	MRU-TOP2	MRU	Rotations/ translations	Riser
Outer-barrel	MRU-TOP3	MRU	Rotations/ translations	Riser
Vessel	FUGRO data	Weather mon.	Hs/ Tp	-
Vessel	FUGRO data	Weather mon.	Wind speed	-
Vessel	FUGRO data	Weather mon.	Current velocity	-

Table 1: Sensors Utilized for Online Monitoring.

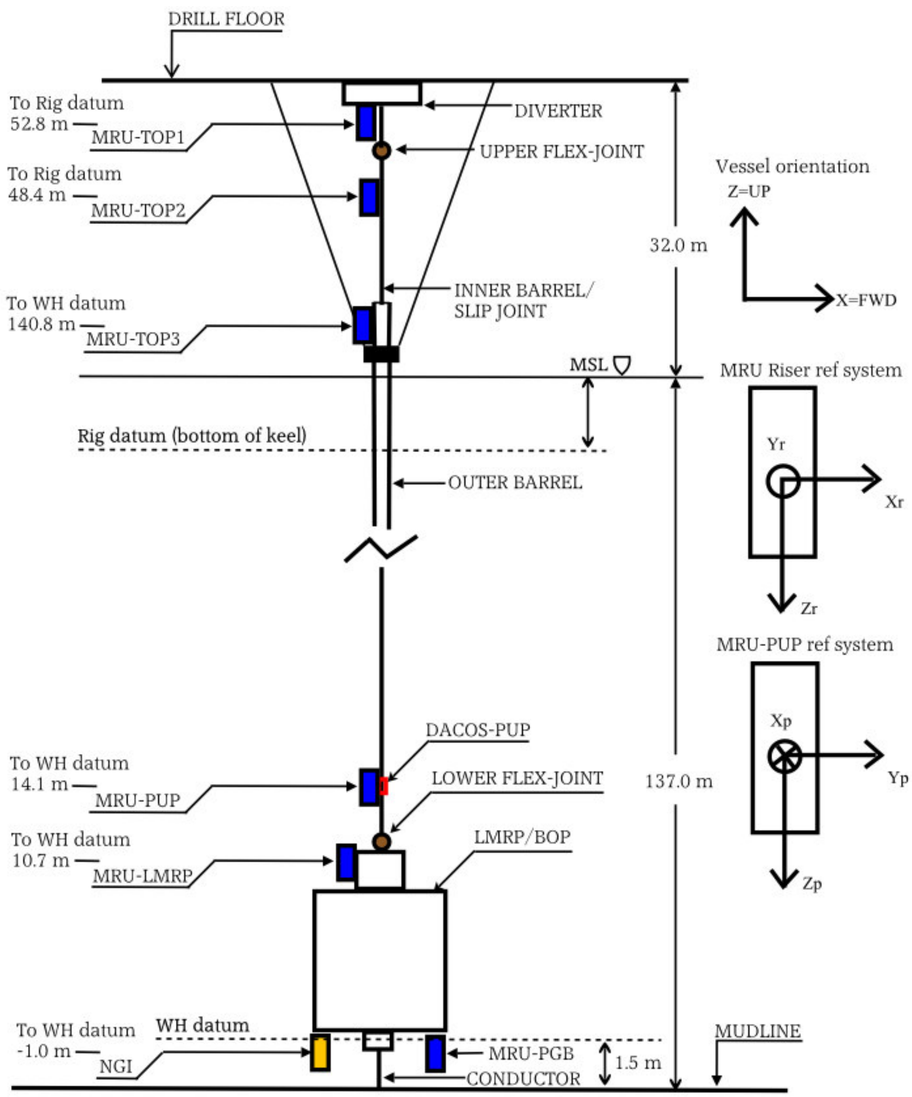

Figure 1: Riser Sensors Overview.

3 REAL TIME MONITORING

The monitoring was done on a daily basis and included an evaluation of parameters related to standards and operator's guidelines. The report generation was automated by using a combination of Matlab data-processing and Latex text processing. Parallel to the reporting, the main offshore operation stages related to both MODU operational issues and the real time monitoring were stated in a log.

3.1 Software

The software used for real time monitoring of the riser was developed specifically for this project. Important parameters related to the riser were displayed on computer screen in real time and summarized in reports issued in a daily basis. The online monitoring system software was designed to display key parameters related to the riser limits as angles, displacements and forces at critical points in the riser. The parameters were either displayed as moving plots of raw data or mean value. The interface was designed to allow continuous monitoring and as a tool for optimizing vessel position. The application was programmed using LabVIEW software. The most important displayed parameters were flex joint angles, tension variation, LMRP inclination/displacement and MODU heave speed.

3.2 SiteCom

SiteCom is an online web-based data acquisition, storage, retrieval and presentation supplied by Kongsberg. In order to understand and explain some physical phenomenon observed during the monitoring, it was necessary to collect data of other relevant parameters (such as pressure, temperature, hook load, hook high, etc.) which came from different companies involved in the drilling operation, Figure 2. The data collected were logged in local time and synchronized in order to avoid some shifted time.

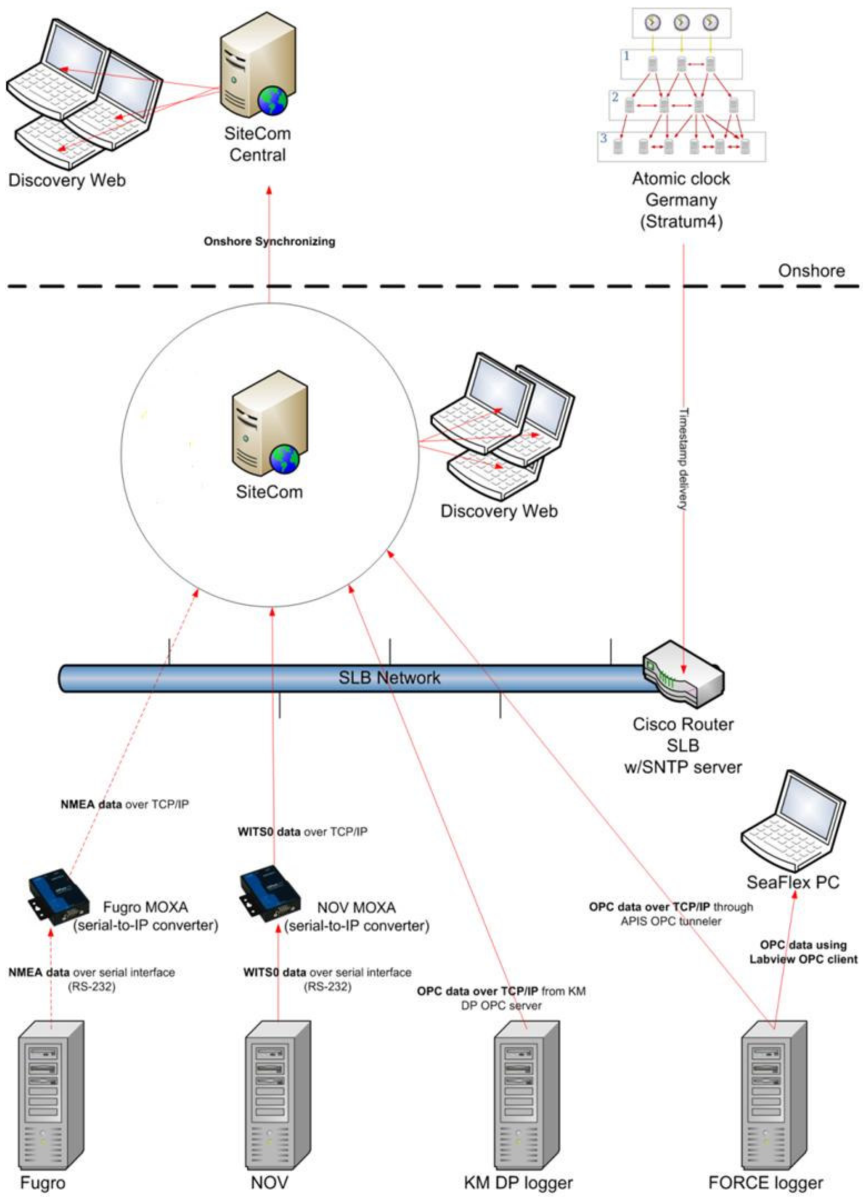

Figure 2: Data Transfer from Different Companies to SiteCom.

3.3 Synchronization

Different logging time was a sort of headache when KOGT tried to generate reports including data from other sources. Therefore, KOGT strongly recommends that all data, from all companies involved in monitoring projects, must be logged using UTC time.

All computers shall be synchronized to UTC by use of signal from a common network time base, synchronized to GPS. Notice that UTC time is not affected by the start/end of the daylight saving time.

In order to avoid conflict with other operational/logging issues, all parties involved in the data acquisition should be notarized about the necessary steps to be carried out to ensure time synchronization, in advance of project start.

4 COLLECTED DATA DURING DRILLING OPERATION

4.1 Sensors Status

A status summary of sensors used in the monitoring software is shown in Table 2. Note that time series received from sensors were checked for peaks and other errors as part of the post-processing task.

Sensor name	Status	Comments
PGB-MRU	OUT	Disconnected, no data is collected
MRU-LMRP	OK	-
MRU-RISER	OK	-
DACOS-1	OUT	Sensor does not respond
DACOS-2	OK	-
DACOS-3	OK	-
DACOS-4	OK	-
MRU-TOP1	OK	-
MRU-TOP2	OUT	The sensor is in maintenance
MRU-TOP3	OK	-
Dweb data	OK	Data from discovery web is used

Table 2: Status of Sensor.

5 TIME HISTORY PLOTS

The plots shown further below are mean values calculated for blocks of 10min intervals, unless otherwise noted.

Each 24hr series of measured data consists of *(24hr)*(3600s/hr)*(10Hz)=864000* data points for one day period. Plots of raw measurement data were therefore omitted to speed up post processing. Max/Min or average within a given time period or re-sampling is used for plots. MODU’s pitch and roll angles are defined as bow up=positive pitch and roll towards SB= positive roll.

6 PLOTS

6.1 Wave and Wind Data

Wave and wind data for the specific day is shown in Figure 3 for 24hr period.

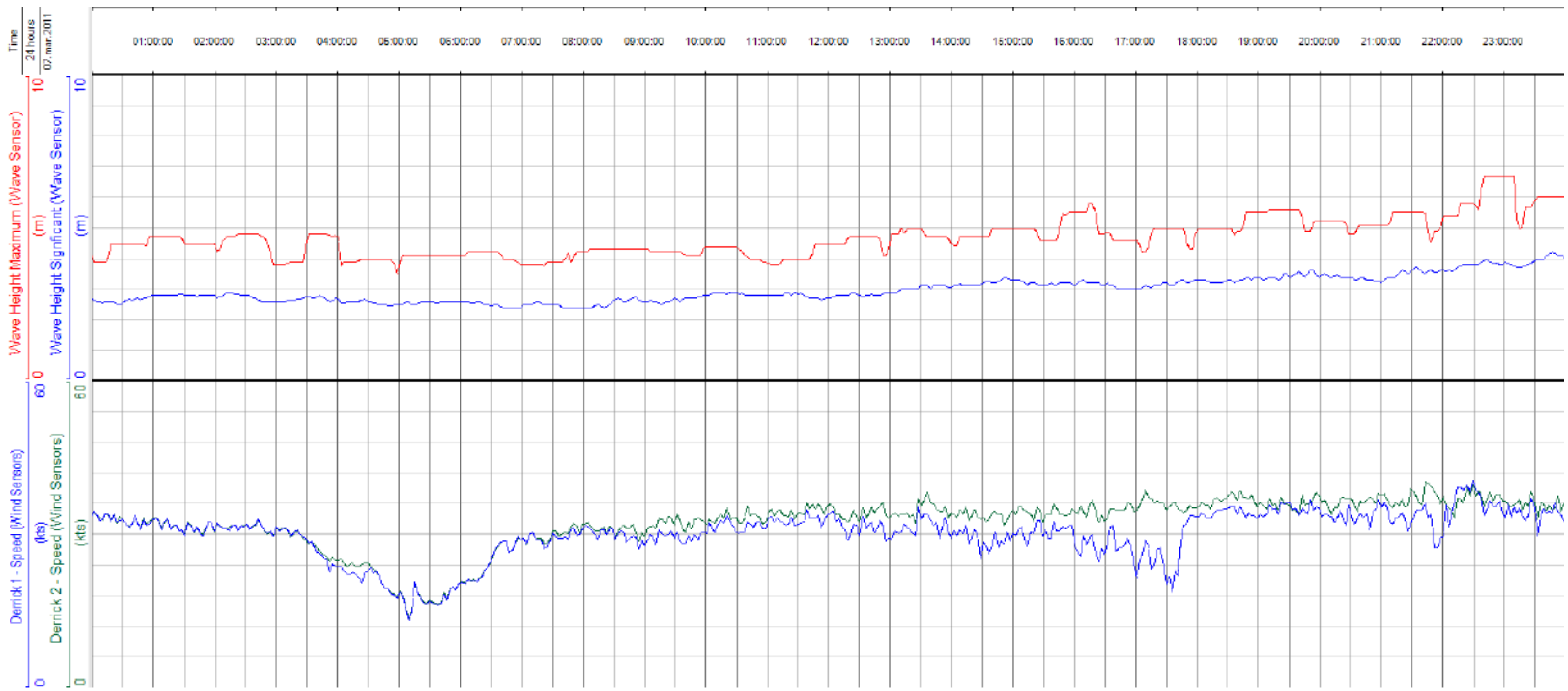

Figure 3: Wave and Wind Data.

6.2 Pup Joint Tension

Figure 4 shows tension variation *Tmax-Tmin* value within 30s periods. The tension variation is calculated in the following way: for each 30s of the time series, tensions *Tmax* and *Tmin* were found and tension variation calculated. SPP pressure and mud temperature measured at topside are also included as reference.

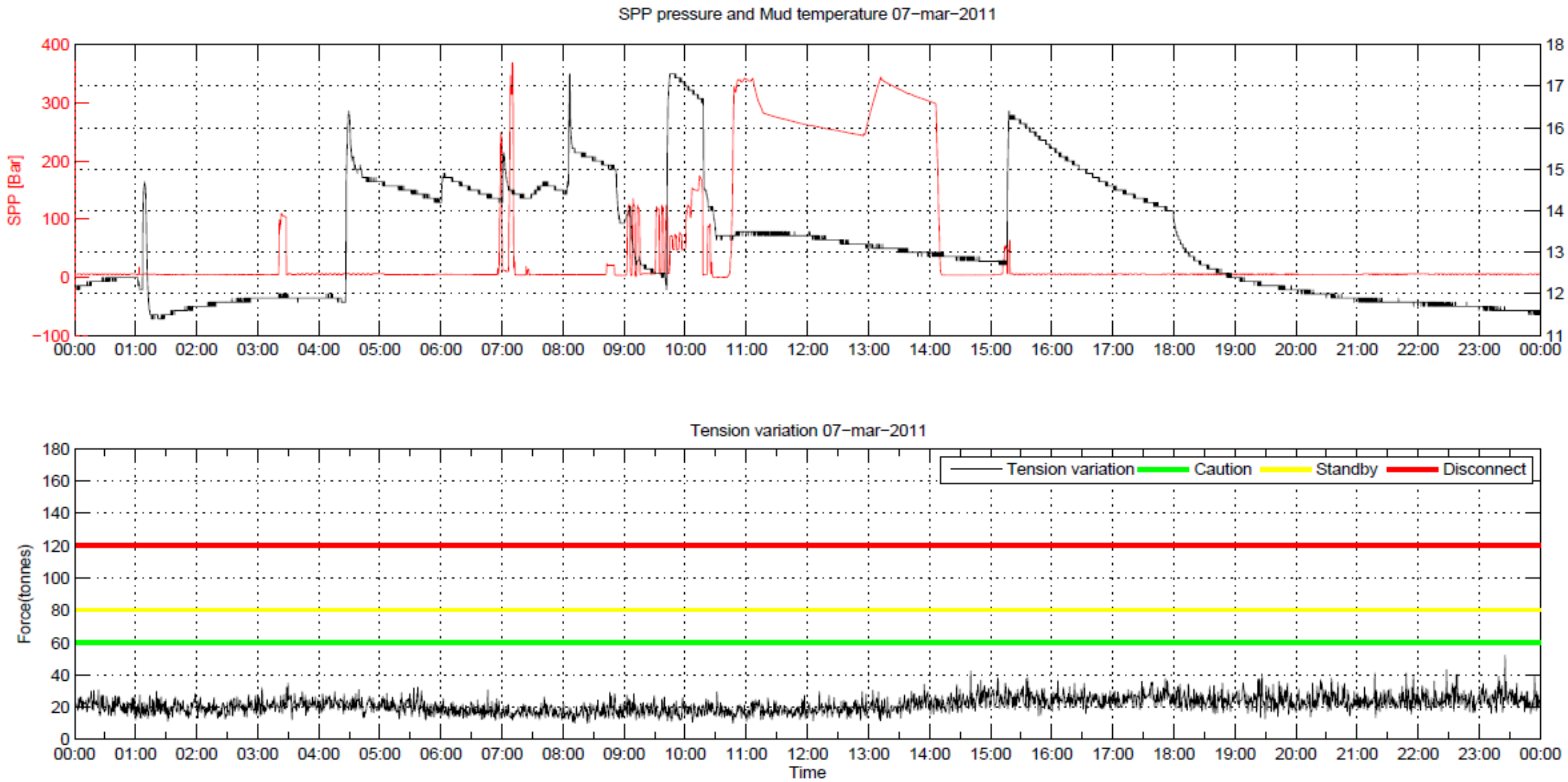

Figure 4: Pup Joint Tension Variation Within 30s Periods Calculated from Riser Pup Joint Strain Measurements.

6.3 LMRP Displacement

Figure 5 shows the horizontal displacement of the LMRP, both as orbit and as time series plot. These displacements are calculated in the following way: for each 10min period of the time series, the max, min and combined displacement is plotted.

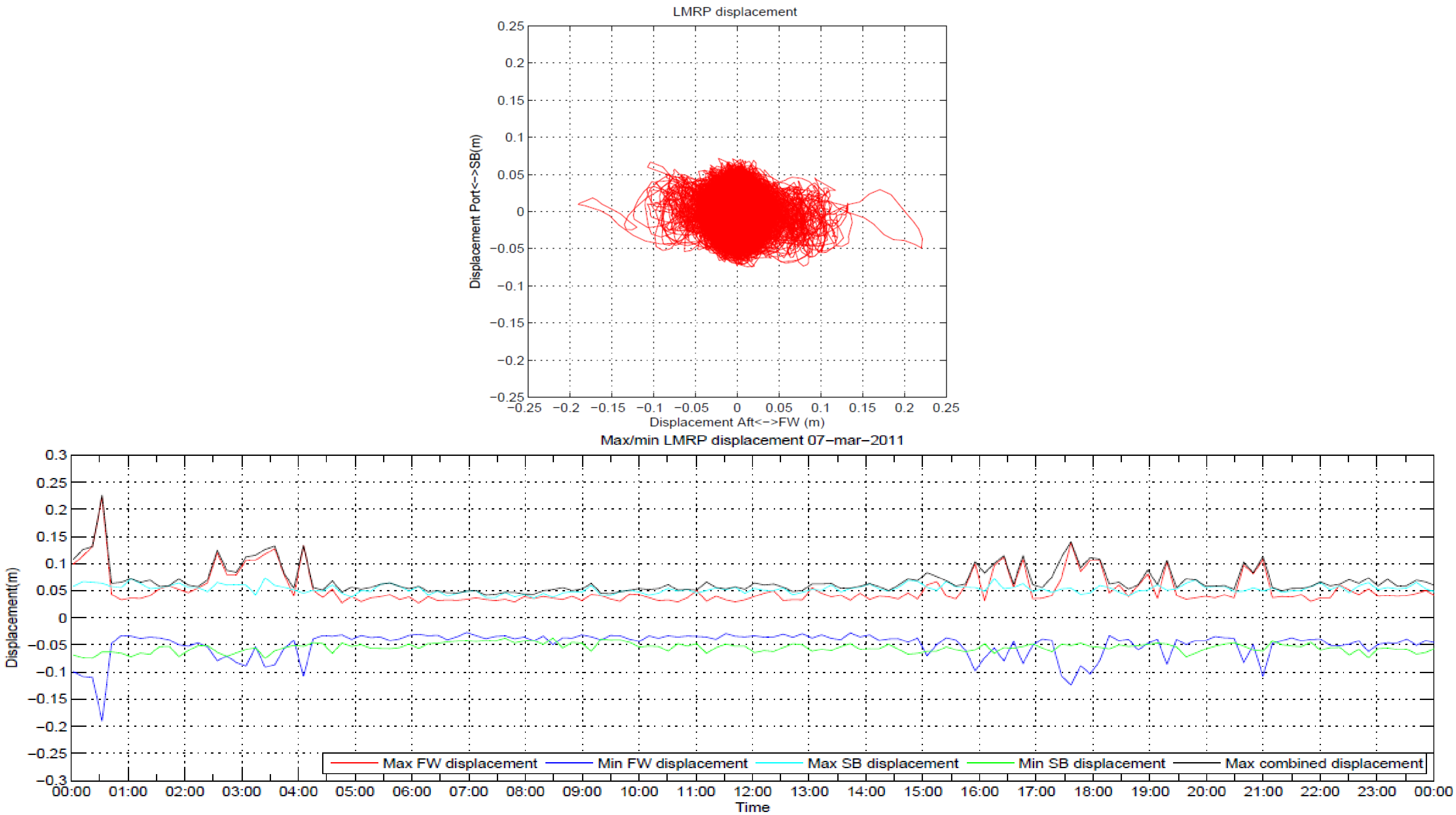

Figure 5: LMRP Displacement Shown as Orbit and Time Series.

6.4 Hook Behaviour, LMRP Rotation and Displacement

Below are plots of load and height at the hook (Figure 8) as well as LRMP/PGB rotation and displacement. The plots are zoomed in at period during large LMRP displacements, see Section 6.5.

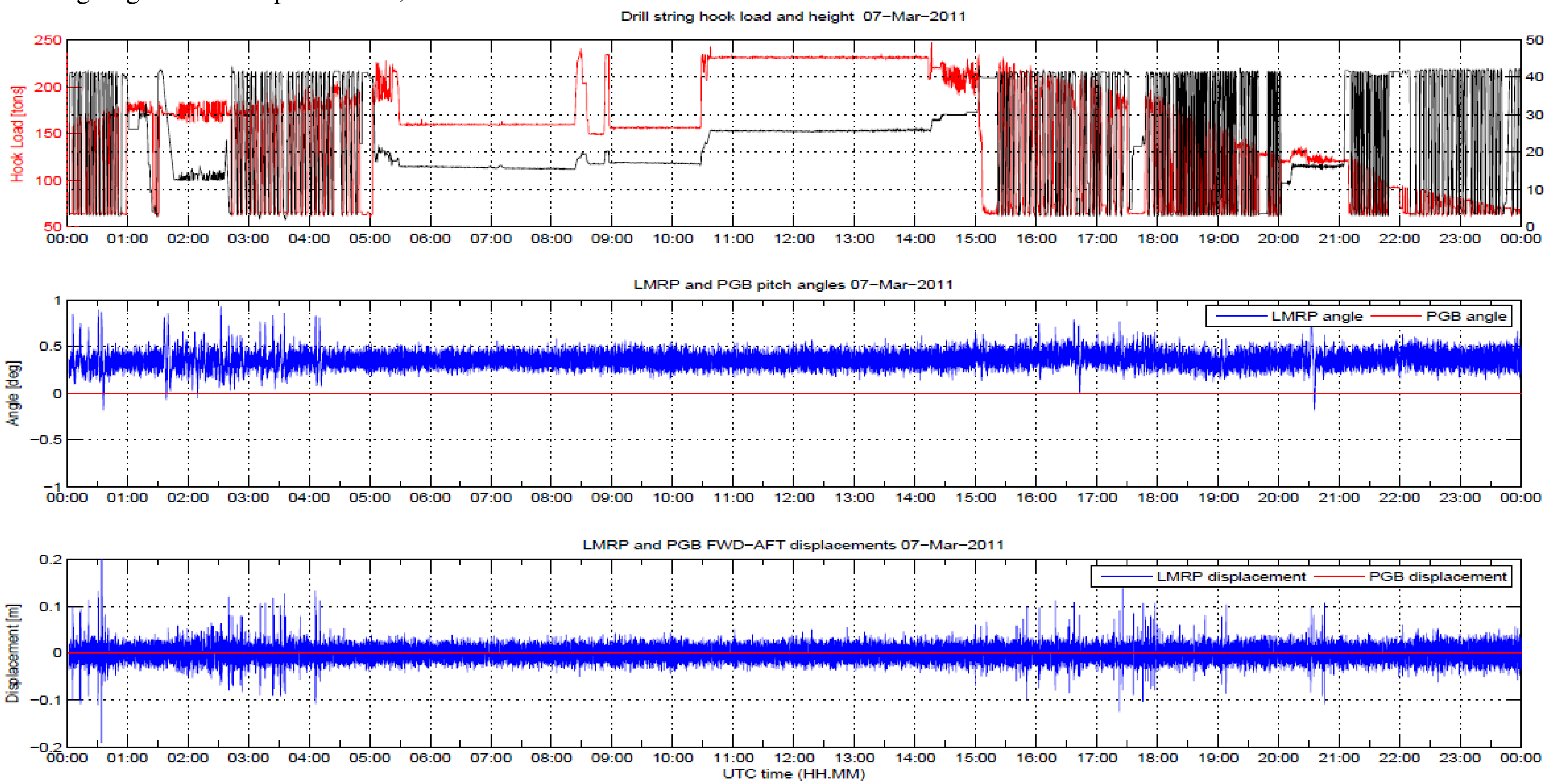

Figure 6: Hook Load and Height - LMRP Rotation and Displacement.

6.5 Hook Behaviour, LMRP Rotation and Displacement – ZOOM IN

Below are zooming in plots (during large LMRP displacements) of hook load and height as well as LMRP rotation and displacement.

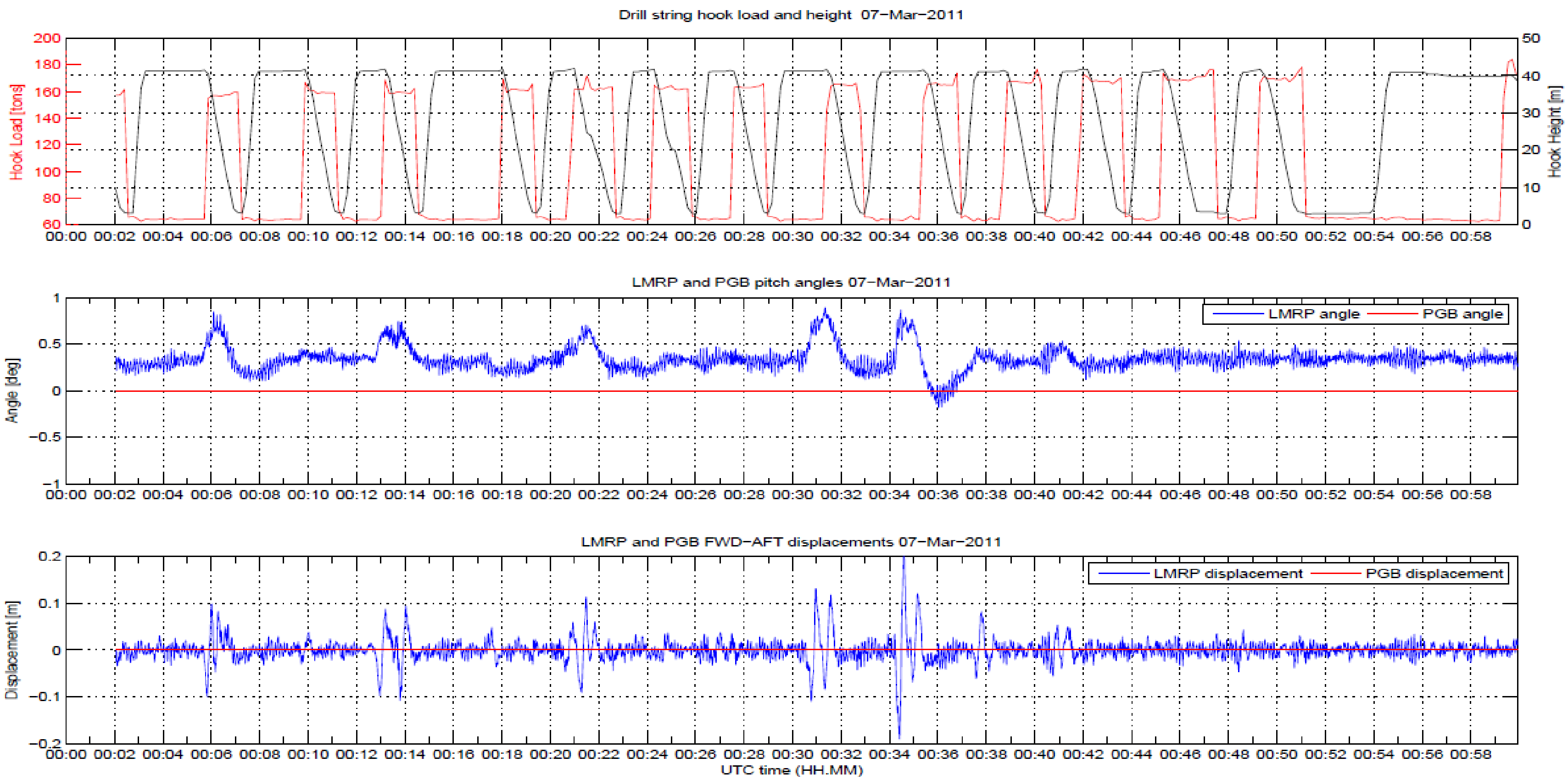

Figure 7: Hook Load and Height - LMRP Angles and Displacements from 00:00:00 to 01:00:00.

7 MAIN SUMMARY OF THE COLLECTED DATA

All reported data and time series shown are for one specific day, from 00:00 to 24:00 hours. Observations and comments regarding the drilling operation of that day are as follow:

- LMRP displacement of 0.226 meters is observed. Large displacements of the LMRP most likely are related to operational issues as tripping up/down the drill pipe or running/installing casings, Figure 9 and Figure 10.
- The monitoring day, the MRU-PGB and MRU-TOP2 sensors were out of service, therefore, no data was collected and the results are presented by zeroes.
- The strain sensor DACOS-1 had problems. Strain values on the pup joint were frozen and the sensor didn't respond. This sensor was not used to compute the tension variation.
- Summary of extreme values observed during the 24hr period is shown in Table 3.

Parameter	Measured/ calculated value	Unit	Limits exceeded
Max Hs	4.1	m	-
Max dynamic tension variation	+/-26	tons	-
Max combined dynamic LMRP inclination from neutral	0.59	deg	SOL Standby
Max LMRP combined dynamic horizontal displacement from neutral	0.226	m	Not defined
Max combined dynamic PGB inclination from neutral	-	deg	-
Max combined dynamic PGB displacement from neutral	-	m	Not defined
Highest combined mean LFJ angle	0.96	deg	SOL Advisory
Max LFJ angle combined	2.5	deg	Advisory
Max UFJ angle combined	3.5	deg	Not defined
Max UFJ angle FWD-AFT	2.3	deg	Not defined
Rig roll	–0.58 to 3.1	deg	-
Rig pitch	–1.7 to 2.3	deg	-
Max heave range	2.2	m	-
Max/Min heave velocity	-0.68 to 0.75	m/s	-
Wind speed 1-min	21	m/s	Advisory

Table 3: Summary of Key Parameters for 24hr Period Measurement.

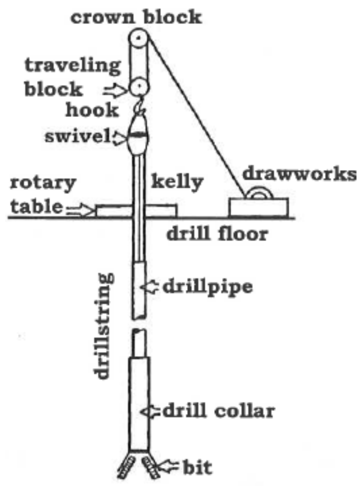

Figure 8: Rotating System [3].

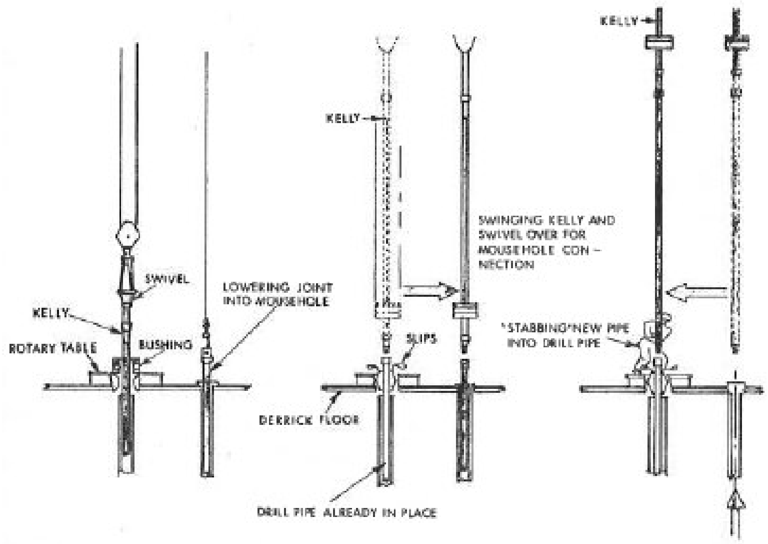

Figure 9: Drill Pipe Tripping [3].

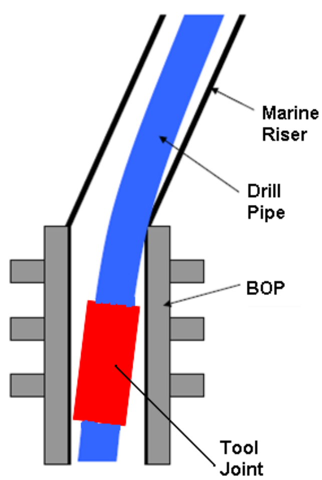

Figure 10: Tool Joint Passing the BOP.

8 CONCLUSIONS

It has been seen that the LMRP displacement is very large during several short periods of the drilling operation. An evaluation of the data gathered during the online monitoring of the marine riser system indicates that the reason for this large movement is probably related to tripping up/down the drill pipe. During this operation most likely a tool joint is passing through the BOP/LFJ and this generate a sort of contact which is observed as vibration of the LMRP. Beside this, excessive angles in the LFJ might have contributed in the LMRP vibration. The contact forces will increase with increasing angle. These contact forces will result in wear when the e.g. the drill pipe or casing is inserted or pulled and also in case they rotate relative to the marine riser. Therefore, when performing drilling operations, special emphasis on measures has to be taken to avoid unnecessary wear and tear inside the marine riser and critical components such as flex joint and LMRP.

Tear and wear inside the marine risers is known to occur close to flex joints. The main reason for it is excessive angles at the LFJ mainly caused by erroneous positioning of the MODU relative to the wellhead for the actual loading conditions. Too low riser tension may also lead to unnecessary large LFJ angles.

To obtain optimal vessel position with respect to the wellhead one needs an online real-time riser monitoring system that can translate the measured riser behaviour directly into MODU's advice system in terms of the distance and direction the MODU should be moved to obtain an optimal global positioning of the riser.

Determining optimal position should not require any measurements or estimation of external loads on the riser system such as current loads. It is recommended to install a standard riser monitoring system in order to facilitate optimal operation of the drilling riser under all operational conditions that may occur. A description of the main components of such a system and riser monitoring system is given in [4].

ABREVIATIONS

AFT	Afterwards
DP	Dynamic positioning
Dweb	Discovery web
FW	Forward
LFJ	Lower flex joint
LMRP	Lower marine riser package
MRU	Motion Reference Unit
NGI	Norges Geotekniske Institutt
PGB	Permanent Guide Base
SB	Starboard
SPP	Stand Pipe Pressure
UFJ	Upper flex joint

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