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ICE TESTING SESSION

DP Ice Model Test of Arctic Drillship

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Abstract

The paper presents the results from a series of ice model tests performed in order to evaluate the station keeping performance of Stena DrillMAX ICE under varying ice drift conditions. The main purpose of the tests was to identify the capability of the DP system to respond to ice loading events that are to be expected to occur in real life.

The model tests were performed in the ice model basin at HSVA using a vessel model with scale 1/36 fully equipped with 6 azimuth thrusters. The DP system was modified differently from normal open water DP operations in order to cope with the highly varying ice drift loads acting on the vessel. Instrumentation in the ice model basin provided accurate position and heading measurement to the DP system. Ice sheets were prepared in order to reproduce the results from ice management by ice breakers as closely as possible.

The paper focuses on the thrust utilization and associated station keeping performance and associated as a function of varying ice drift loads.

Introduction

In January / February 2011 Stena Rederi AB performed a series of model tests in the ice model basin at HSVA. For the first time a model test in ice conditions was performed with a DP system. The DP system was configured specifically for operations in ice in order to cope with the expected large variations in ice drift forces.

The major purpose of the tests was to assess the operational limits of Stena DrillMAX ICE for operation in ice drift conditions. A secondary goal was to evaluate the performance of the specially tuned DP system in order to be prepared for full scale operations.

Kongsberg Maritime collected data from the DP system during the model tests. The data was analysed in order to collect statistical properties of position and heading deviations and in particular for the applied thruster forces. The intention of the analysis is not to estimate exact ice drift forces, but rather to evaluate the data series with respect to operational margins for a DP class 3 operations.

Arctic drillship

The Stena DrillMAX ICE is designed for arctic conditions by several adaptations from the other vessels in the DrillMAX series. These modifications include:

- Ice class hull, PC-4
- 6 *5.5MW Azimuth thrusters, ICE-10
- De-Icing or Anti-Icing of decks, gangways, piping etc.
- Extra environmental protection around main deck, BOP work area, Dual Hoisting Tower, Pipedecks and Emergency Escape routes
- Tautwire and ROV operated through moonpool instead of over vessel side
- Moonpools heated through hot sea-water wash-down system

Main particulars of the vessel:

- Displacement 98,000 Mt
- Overall length 228.0 m
- Breadth 42.0 m
- Operation draught 12.0 m

Figure 1: Illustration of Stena DrillMAX ICE

Further specifications of the vessel can be found at the Stena Drilling website, ref [1]

Ice model basin and DP interface

The model tests were performed in the large Ice model basin at HSVA. The test basin has a length of 78 meter, breadth of 10 meter and a depth of 2.5 m, ref. Figure 2.

All interfaces between the DP system and the instrumentation at HSVA was realised as analogue +/-10 Volt signals. The DP system received Position measurements (Local North/East) and Heading from the Qualisys optical motion capture system. Qualisys consists of 4 cameras fixed on the tow carriage and 5 markers mounted on the model. These markers can be seen in the picture in Figure 5. Based on triangulation, Qualisys records motion in all six degrees of freedom.

Thruster setpoints (RPM; azimuth) from the DP and feedback from the tank instrumentation was also based on an analogue +/- 10 Volt interface.

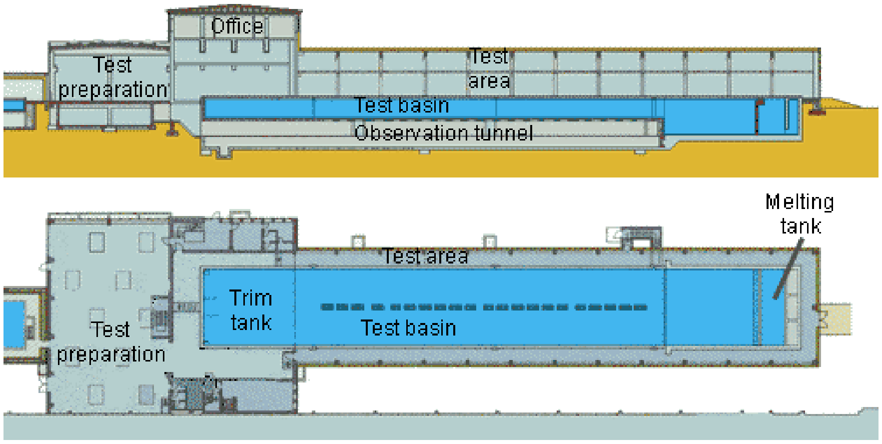

Figure 2: HSVA Ice model basin

The HSVA data acquisition system (DAS) recorded all data described above together with position and heading setpoint from the DP. In addition, all tests were filmed with three video cameras. A synchronization system was used in order to make it possible to synchronise the video time with Qualisys and thruster data.

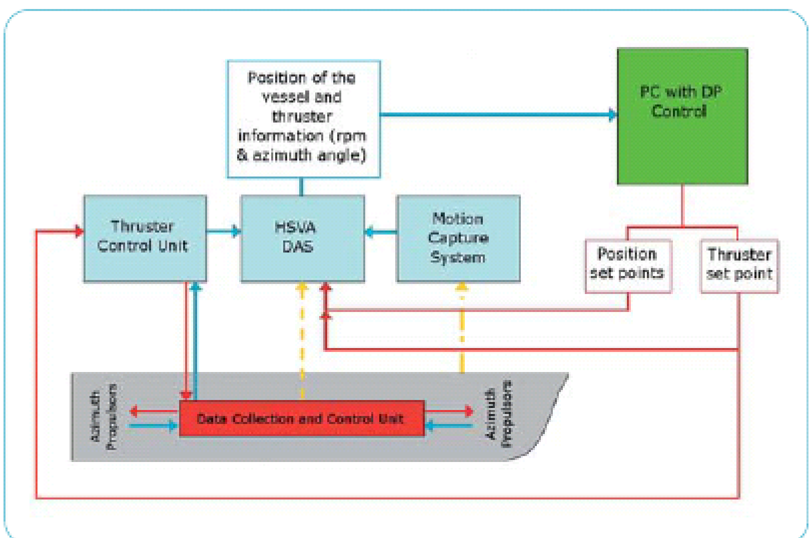

Figure 3: Interface between tank instrumentation and DP system

DP Configuration

The DP system was configured with the same settings in terms of vessel model, thruster data, controller gains etc. as presently used for DrillMAX vessels in open water operations. However, settings for update of unknown external forces acting on the vessel were significantly altered in order to cater for the large variations in ice drift forces. A further explanation of the need for improved tracking capability of unknown external forces can be found in ref. [2].

The thruster allocation mode was set to “Free variable” for all tests. This mode gives highest available force / moment. The implication is that the three thrusters in the bow and the three thrusters in the stern are treated as two groups where the thrusters within the same group will have the same force / direction apart from small azimuth deviation due to “forbidden zones”.

A model scale of 1/36 implies that the DP computer needs to run 6 times faster than in normal operation.

Test Program

The tests were split up into a one week pre-test phase (in air and in open water) and into a two week ice testing phase. All tests in ice were performed in managed ice. The ice drift was simulated by moving the vessel through the ice. (The carriage is moving at a predefined speed). Different ice drift angles are realised by changing heading of the DP controlled vessels. In this way the model is always close to the centre line of the tank as illustrated in Figure 4. Wall effects (ice floes interacting with wall of the basin) are thereby minimized.

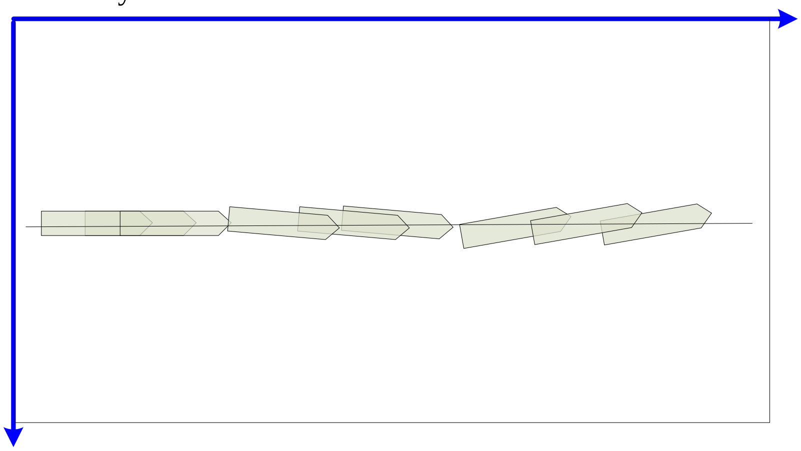

Figure 4: Different ice drift angle realized through heading change of vessel

The test matrix consisted of tests with varying:

- ice thickness (from 0.7 to 1.3 m)
- ice drift angle (from 0 to 10°)
- ice drift velocity (from 0.3 to 1.0 knot)
- ice concentrations (all above 8/10)
- ice floe size distribution

Ice floe distributions had been determined from full scale observations during ice management for earlier arctic operations. Those were then transferred into HSVA’s ice tank. Unlike most other model tank tests, the ice consisted of a combination of floes of different size and of brash ice. The distribution of different floe sizes was varied between the different tests. Figure 5 shows an example with the vessel in one of the tested ice conditions.

More than 40 test series were performed during the two week test period. 16 of these tests were used for formal analysis of performance in a well documented ice sheet. Pictures were taken of the complete ice sheet prior to each test making it possible to get a precise definition of ice concentration and ice floe size distribution.

Figure 5: Model of Stena DrillMAX ICE in the model tank at HSVA

In addition to the “formal” tests in well documented ice sheets, tests were also performed by turning the vessel 180° at zero ice drift speed at the end of the test basin. These tests confirmed that the vessel was capable of performing this type of operation in all of the ice conditions covered.

The return runs to take the vessel back to the start of the model basin were used to test change of position setpoint and some alternate positioning strategies. These tests provided valuable insight into the DP performance, although the actual ice sheet was reduced by the forward run and hence not fully documented. Ice concentration for these return runs was generally above 6/10.

Results and analysis

Example results from two of the tests are presented in Figure 8 and Figure 9. The first figure shows the entire test series for a 0° drift angle test run. The time is equivalent to approx 50 minutes full scale. It can be observed that even though the vessel is moving directly towards the ice, the variable build-up of ice on the port and starboard sides of the vessel is resulting in a significant lateral force which is varying during the test run. The short periods where thrusters are loaded above 67% (solid red line in thruster plots) are due to build-up of large floes and hence large transverse ice forces acting on the vessel.

The second figure shows a 6 minute transition period where ice drift angle changes from 5° to 0° (realized by changing the heading of the drillship). During the start of this transition the thrusters are frequently saturated, but the resulting heading and position is OK. As the drift angle is reduced it can be seen that the sway forces are reduced.

Snapshot from the DP screen during similar conditions are included in Figure 6 (zero ice drift angle) and Figure 7 (Transition from 5° to 0° ice drift angle). The figure with an oblique angle clearly illustrates that the dominant force is in sway direction even with a small ice drift angle.

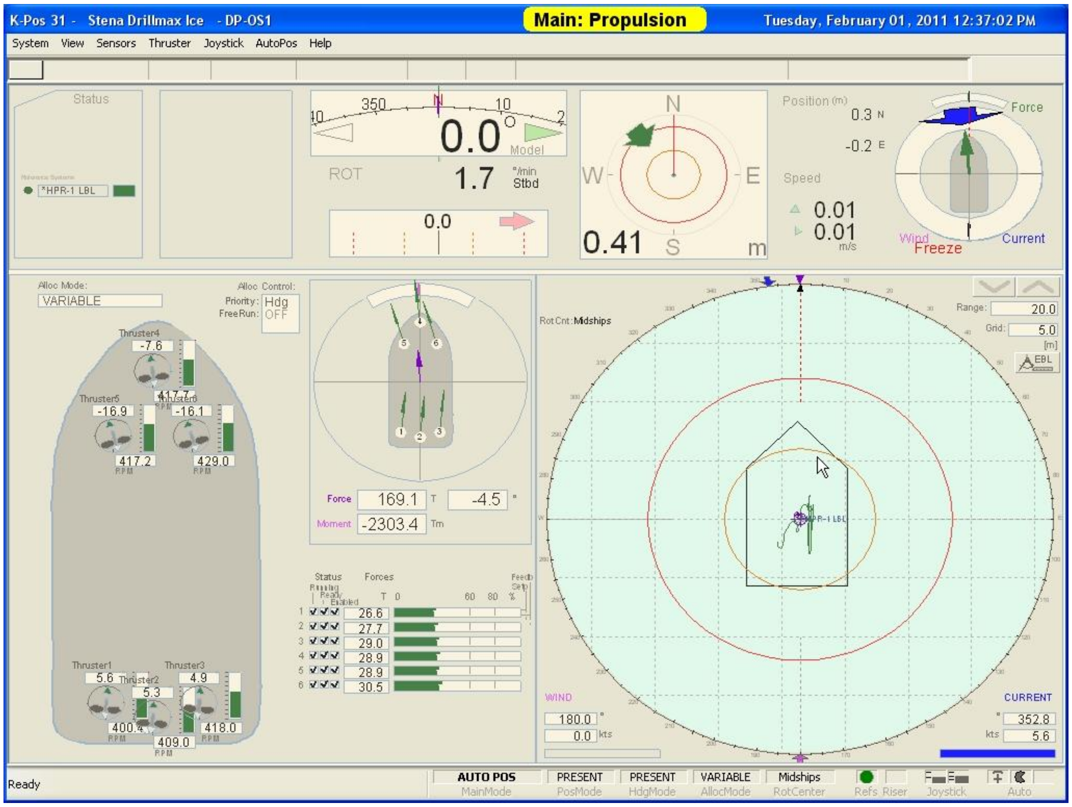

Figure 6: Screenshot from DP during zero drift angle test run

Figure 7: Screenshot from DP under transition from 5° to 0° drift angle

As part of the data analysis the statistical properties for each individual test run were computed. This includes average values, standard deviations, Max/Min values and upper and lower 5% value for Force / Moment and Position / Heading Deviation.

A summary chart of the average values and the 90% interval (from lower 5% to upper 95%) is presented in Figure 10. The figure does not include all test runs, but includes zero drift angle tests (ends with the letter a) and oblique tests (ends with the letter c). The presented data is for sway position deviation and sway forces. The large increase in sway force for oblique angle test runs is clearly visible. It can also be seen that the variations in sway forces can be large also for zero ice drift angle.

Test runs with thrust utilization beyond DP class 3 requirements are highlighted in the figure. A red area indicates test runs with frequent “Insufficient thrust” periods, a yellow area indicates periods where thrust utilization (accounting for additional wind load at 17% thruster capacity) would have been beyond 67% and hence above class 3 limits. The vessel has a 3-split power generation and distribution system.

During the model tests at HSVA the only forces acting on the vessel was the ice drift forces and the sea current in the exactly same direction and speed as the ice drift. In a real life operation the vessel must also be able to compensate for the wind load on the vessel. Allocating 17% of the thruster capacity is equivalent to 42 knot wind speed on the bow and 20 knot wind speed on the beam. Please note that the results can be analysed for any additional wind load, the presented values are included to illustrate the methodology.

The summary chart reveals large variation in forces between the different tests, and thus illustrates that the test matrix has covered a variety of ice conditions inclusive limiting conditions for the vessel.

The analysis of the results also confirmed one of the earlier assumptions from analysis of oblique towing test data: When operating on DP the peak ice loads are slightly reduced compared to towing test data.

Conclusions

Presently there is no experience in arctic DP operations in heavy ice conditions. Unfortunately we do not have sufficient modelling tools (qualified by full scale validation) for readily designing a DP control system in terms of thruster sizing according to ice field condition specification. At present we need to rely on ice model basin tests.

The tests and results presented in this paper illustrates the validity of such tests, and clearly indicate that arctic DP operations are feasible, provided efficient and effective ice management is available and the DP system is designed and capable of compensating for the quickly changing ice forces.

Furthermore, these types of tests will clearly contribute to further development of modelling tools for qualifying DP vessels for different types of arctic DP operations under specified conditions.

References

[1] http://www.stena-drilling.com/pdf/60584_Stena_DrillMAX%20ICE_lo.pdf
[2] “DP in ice condtions”, *N.A.Jenssen, S. Mudusetti, D.Phillips, K. Backstrom. MTS DP Conference, October 13-14, 2009*.

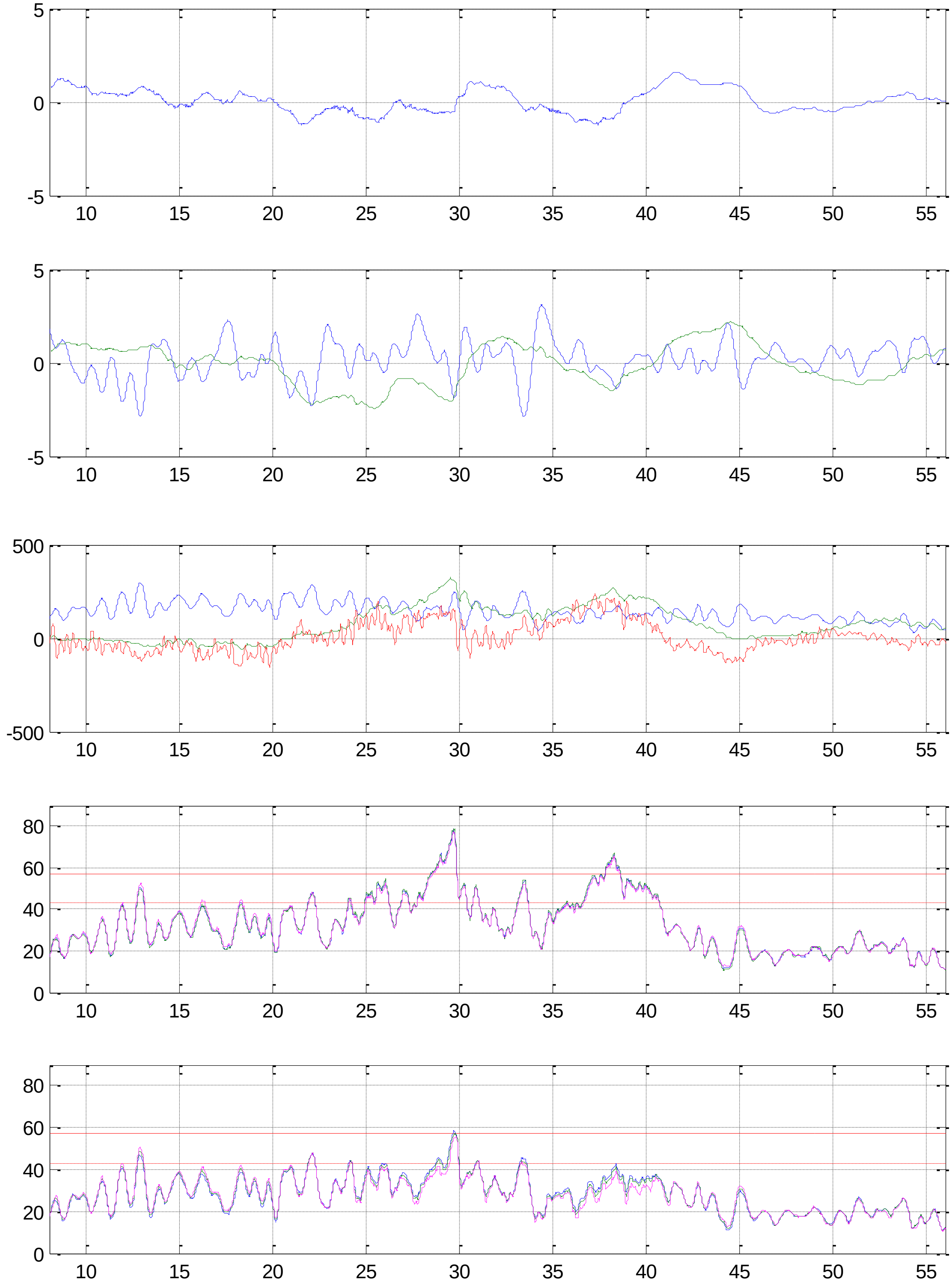

Figure 8: Results from zero ice drift angle drift test run:
From top to bottom: 1) Heading (blue), Heading setpoint (green). 2) Position deviation (m) surge (blue)/ sway (green), 3) Thruster force (T) / moment (Tm) (surge,-blue, sway-green, yaw-red), 4) Bow Thruster force (Tm), 5) Stern thrusters force (Tm)

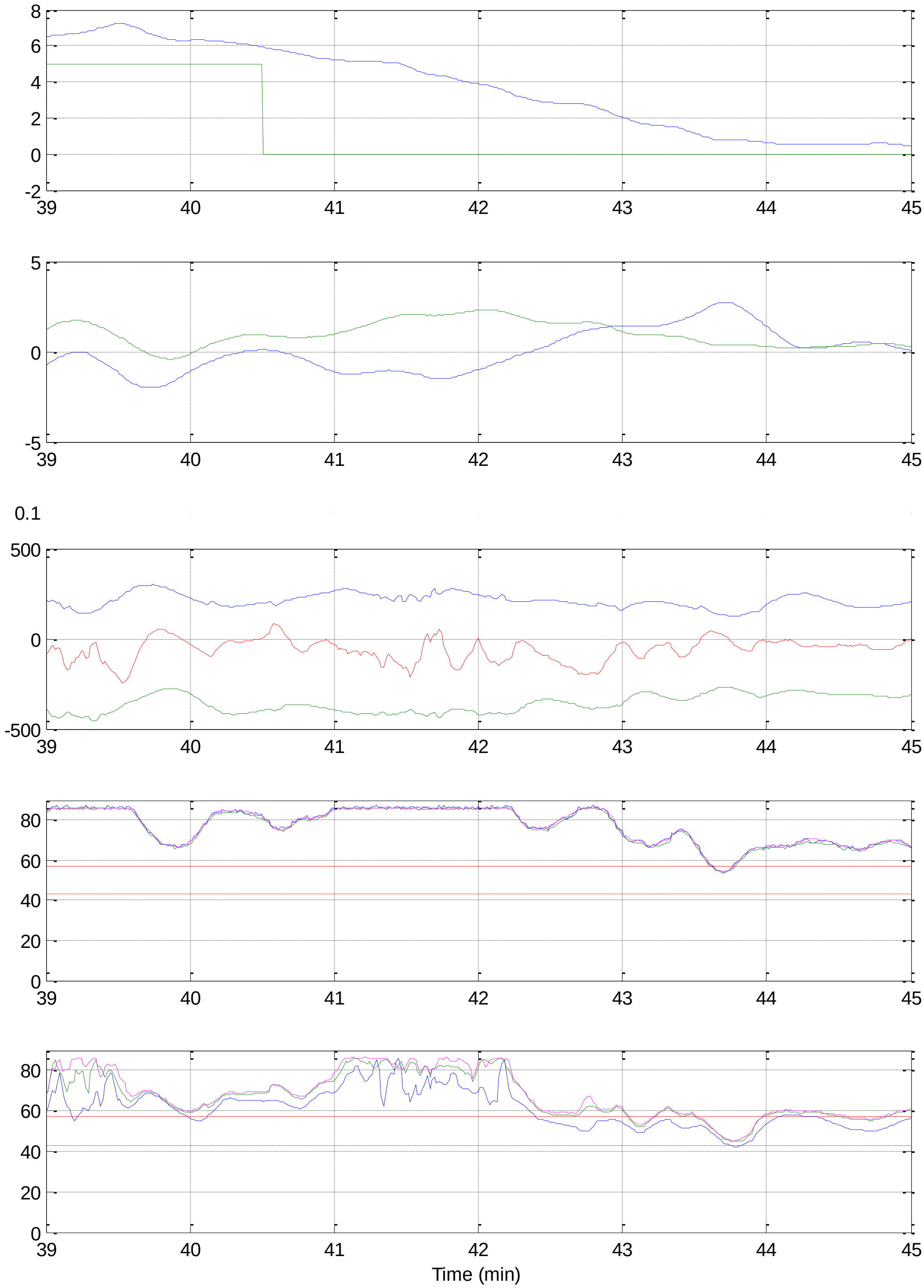

Figure 9: Results from test with transition from heading 5° to 0°:
From top to bottom: 1) Heading (blue), Heading setpoint (green). 2) Position deviation (m) surge (blue)/ sway (green), 3) Thruster force (T) / moment (Tm) (surge,-blue, sway-green, yaw-red), 4) Bow Thruster force (Tm), 5) Stern thrusters force (Tm)

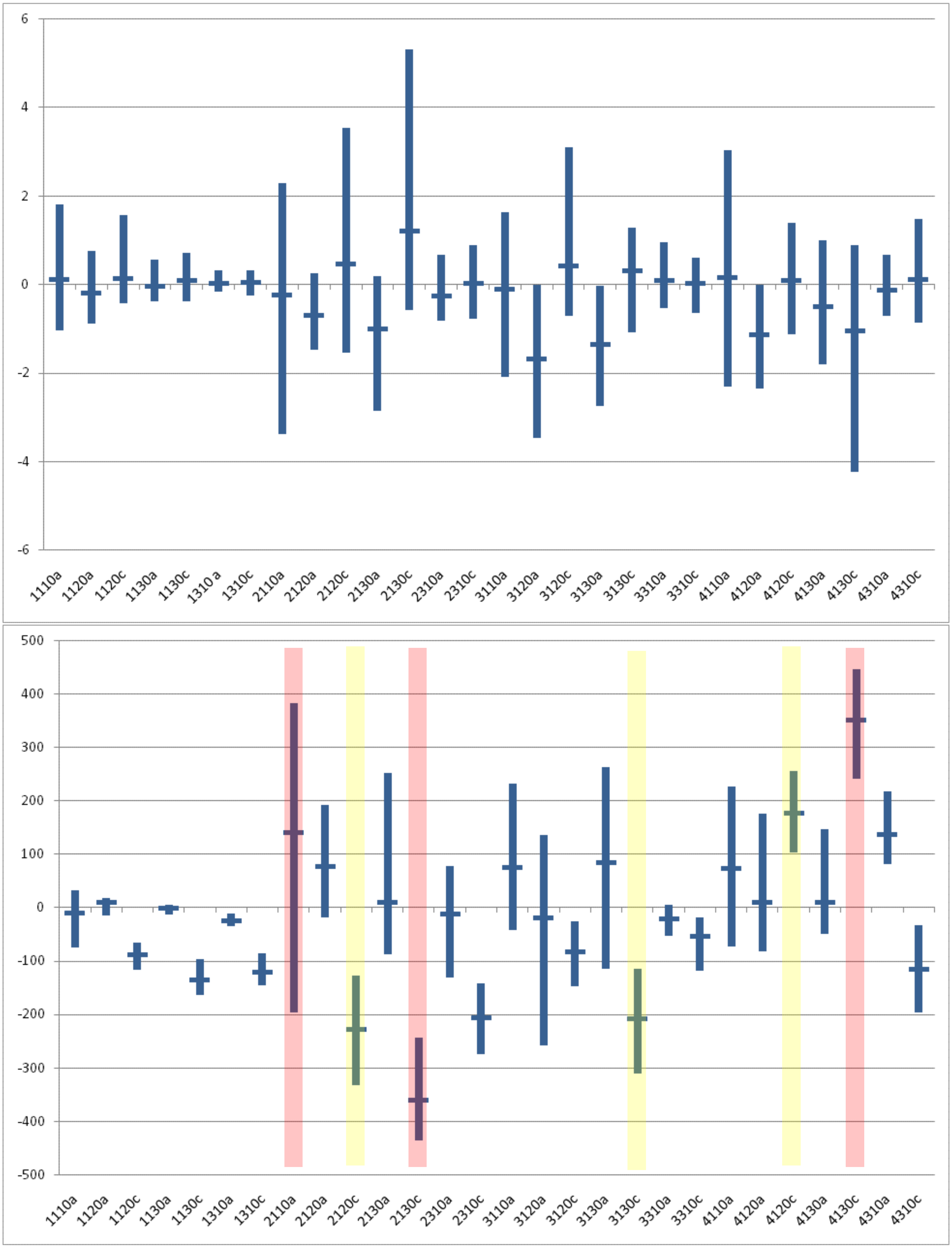

Figure 10: Result summary Sway Pos Deviation (m) and Force (T) for some zero drift (a) and oblique (c) test runs. Average Sway Deviation and 90% interval (top). Average sway force and 90% interval (bottom). Test run with "Insufficient" thrust highlighted in red. Test runs with "Consequence Analysis" warning highlighted in yellow.