POSITION SIGNAL FILTERING FOR HYDRAULIC ACTIVE HEAVE COMPENSATION SYSTEM

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ABSTRACT

In the paper a new position signal filtering method with position prediction is presented along with test results using a simulation tool. The complete active heave compensation system performance with input signal filtering is also shown. The control system uses an input acceleration signal taken from the motion reference unit, which usually contains noise that is not acceptable for the position controller. Currently, a Kalman filter is used which is okay to use for certain conditions. The filter works similarly to how it is used for autonomous applications where two input positions are necessary, one from position sensors and another one taken from the model. The challenge is that there is no physical wave model available for the Kalman filter used for offshore position control and the waves are not predictable. It was found that a Kalman filter with a special signal prediction instead of the model input can be used. This position prediction helps to avoid system delays and the potential of missing the signal for a short period of the time.

Keywords: Signal Filtering, Position Control, Hydraulic Active Heave Compensation System

1. GENERAL ASSUMPTIONS

The idea is to make a new motion reference unit signal filtering algorithm and rig velocity forecast used as “physical model” for Kalman filter. The aim is to protect the system during a short period of the time when the signal is missed and to avoid signal peaks for a good accuracy controlling of active heave compensation systems by using:

- Acceleration special filtering with values forecasting.
- Velocity forecasting and filtering with Kalman filter**.**
- Continuous velocity offset calculation used for acceleration integration**.**
- Continuous position offset calculation used for velocity integration.

2. SIGNAL FLOW

The signal flow from Motion Reference Unit (MRU) to the hydraulic pump or proportional valve is shown in **Figure 1**. The FILTER forecasts acceleration values by using measured acceleration from Motion Reference Unit. The programmable logic controller (PLC) samples the acceleration input data with constant sampling period. INTEGRATOR calculates velocity which is forecasted and filtered. It also calculates movement. Velocity is the most important parameter for the controller so that special attention must be paid here. Controller calculates the signal to the hydraulic device to make the hanging load still. Relative movement measurement of the load to the ship position is used by position controller to avoid load drift.

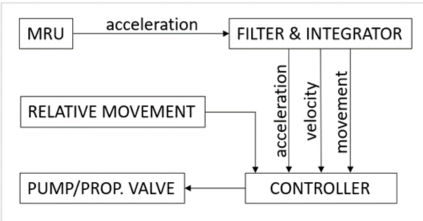

Figure 1: Simplified signal flow scheme

3. FILTER BLOCK DIAGRAMS

3.1. Acceleration forecasting

The diagram shown in **Figure 2** presents the acceleration forecasting algorithm. Deviation value of measurements at_n is calculated first from a_n value. In case of nonacceptable at_n value, the arithmetic string is used for forecasting the proper output acceleration value af_n. Average value of at_n is calculated to get as_n. The arithmetic string with values difference ks_n for forecasting as_n is chosen here, then output af_n is computed. For acceptable acceleration deviation value, the measurement a_n is taken as final.

3.2. Velocity filtering and forecasting

The diagram is shown in **Figure 3**. On the base of acceleration value af_n the velocity v_n is integrated and offset velocity $v0_n$ for certain period of the time for integration calculation is computed. Average vs_n value of velocity deviation vt_n is calculated. In case of nonacceptable vs_n deviation defined as dvs_n, the arithmetic string with previous dvs_{n-1} value is used for forecasting the proper velocity value ve_n. If dvs_n is acceptable the current dvs_n value is used for forecasting. The ve_n value and v_n value from measurement are used than in Kalman filter to calculate vf_n velocity.

3.3. Position calculation

The diagram is shown in **Figure 4**. On the base of velocity value vf_n the position sf_n is integrated with offset s0 implemented. Offset s0 is calculated for certain period of the time.

4. FILTERS SIMULATION TEST RESULTS

MRU acceleration values from real measurement for the simulation have been taken. The measurements quality is degraded manually then and presented together with results from the filter in **Figure 5**. Velocity results are shown in **Figure 6** and zoomed out in **Figure 7**. For the situation with bad acceleration signal input the results are promising. The filter doesn't cause the signal delay or significate errors.

5. MODULE HENDLING COMPENSATOR SIMULATION

The module handling compensator (MHC), shown in **Figure 8**, is usually used on the board of the ship or platform when the load should smoothly land on the seabed during the ship movements. It contains passive and active cylinders. Active cylinders are controlled by closed circuit pumps when passive cylinders support the load with almost constant pressure, provided by high volume gas accumulators. Theoretically the load should be kept still but the whole signal measurement way and hydraulic control errors cause the load position deviation. For the simulation 1000 [mT] compensator is used with 1000 [mT] load. The "Real" acceleration input is taken from Jonswap model (no errors in such a case for comparison). The vertical ship acceleration "Real" quality is degraded manually for the filter input first to get a_n values. The inputs for the controller are taken from the filters described in chapter 3. The acceleration measured a_n, acceleration filtered af_n and real acceleration "Real" are shown in **Figure 9**. The "Real" acceleration is used for the ship movements when acceleration af_n, velocity vf_n and position sf_n values are used for the controller. The simulation model of MHC contains all important mechanic, hydraulic and controller parts. Simulation load position error (without rope elasticity influence) is shown in **Figure 10**.

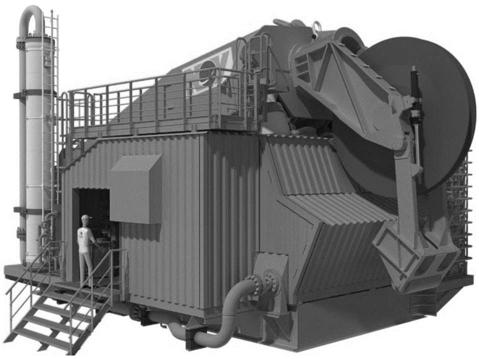

Figure 8: Module handling compensator 3D model

6. CONCLUSION AND OUTLOOK

The simulation results show the usefulness of the filter algorithm. The value forecasting together with the measured values and Kalman filter allow to avoid big controller input errors by avoiding filtered signal delay and big signal deviation caused by unexpected signal noise. Filter needs additional work for checking its correctness in different situation before implementation. During the simulation period of 1 [s] the lack of signal was checked. It must be decided the emergency procedure when the lack of the signal period is longer then assumed. This assumed maximum period shouldn't be so long. Depends on PLC sampling period of the time the value numbers for calculation average values must be carefully defined. This should be work out by further simulation work and tests on real object.

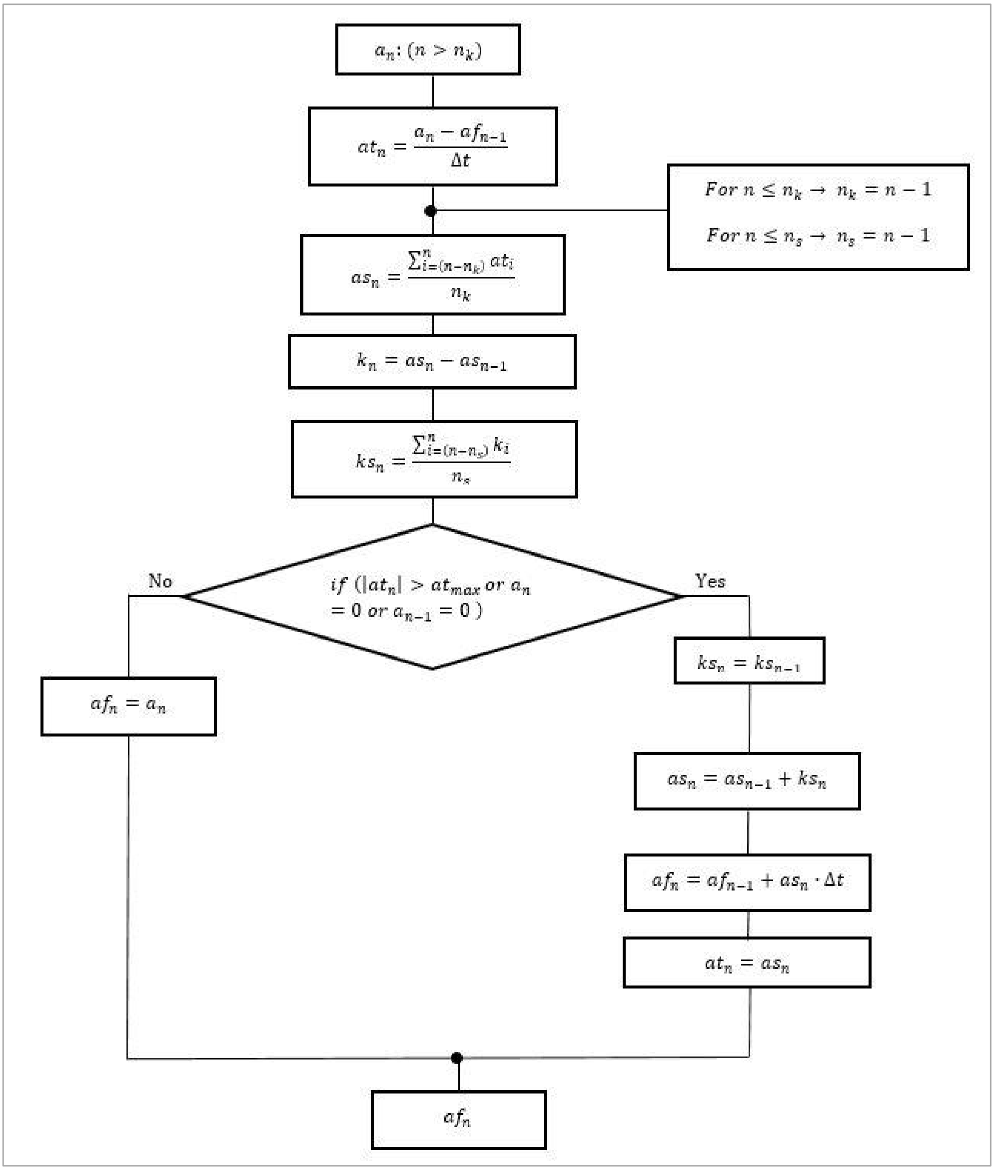

Figure 2: Simplified acceleration filter block diagram with forecasting function

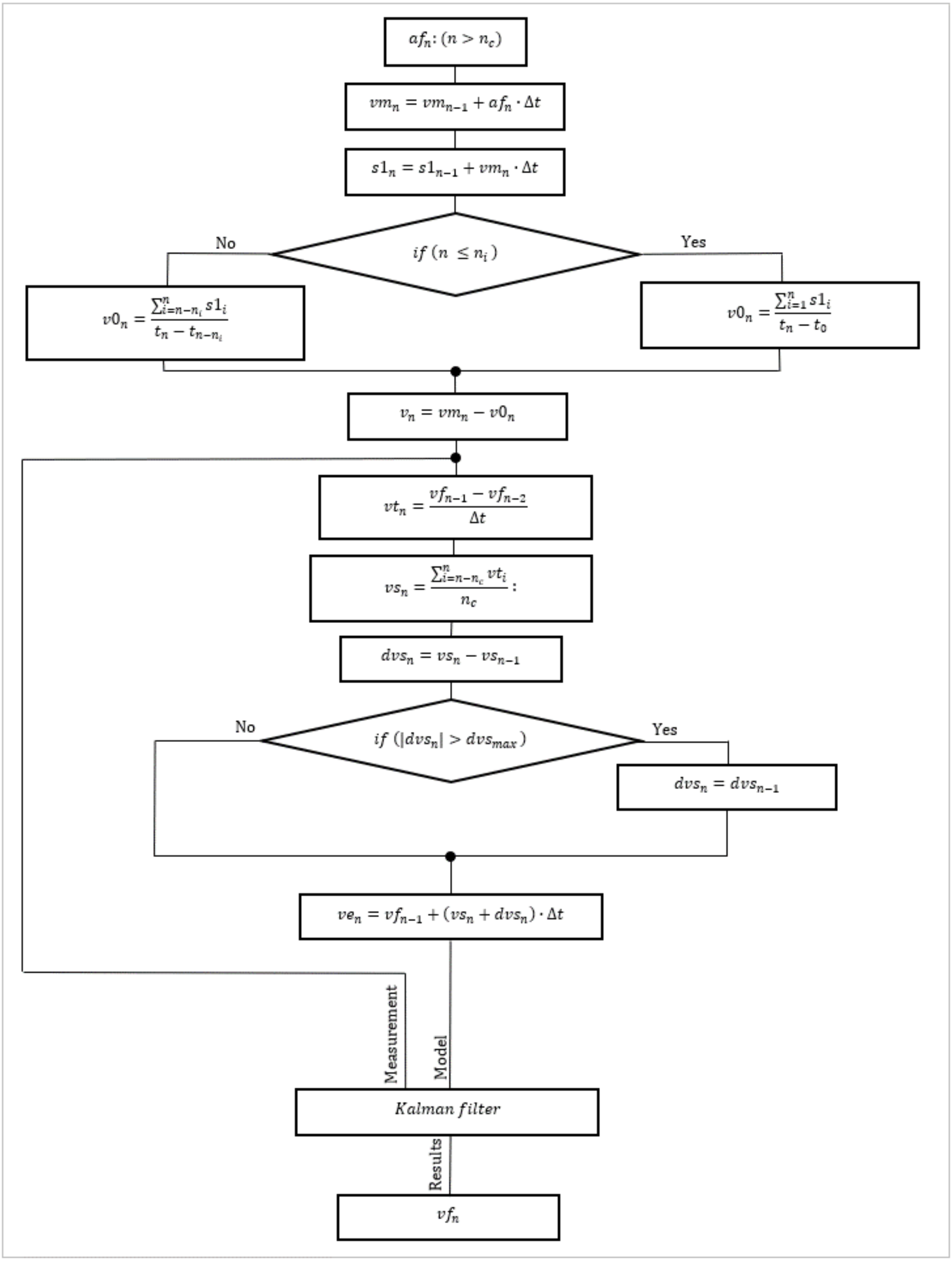

Figure 3: Simplified velocity filter block diagram with forecasting function

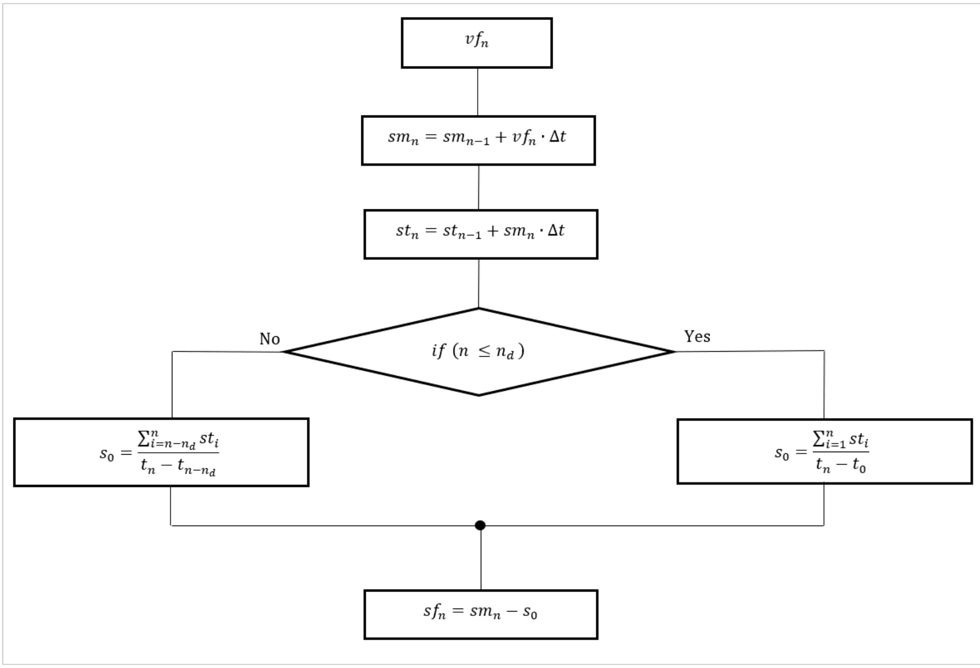

Figure 4: Simplified position calculation block diagram

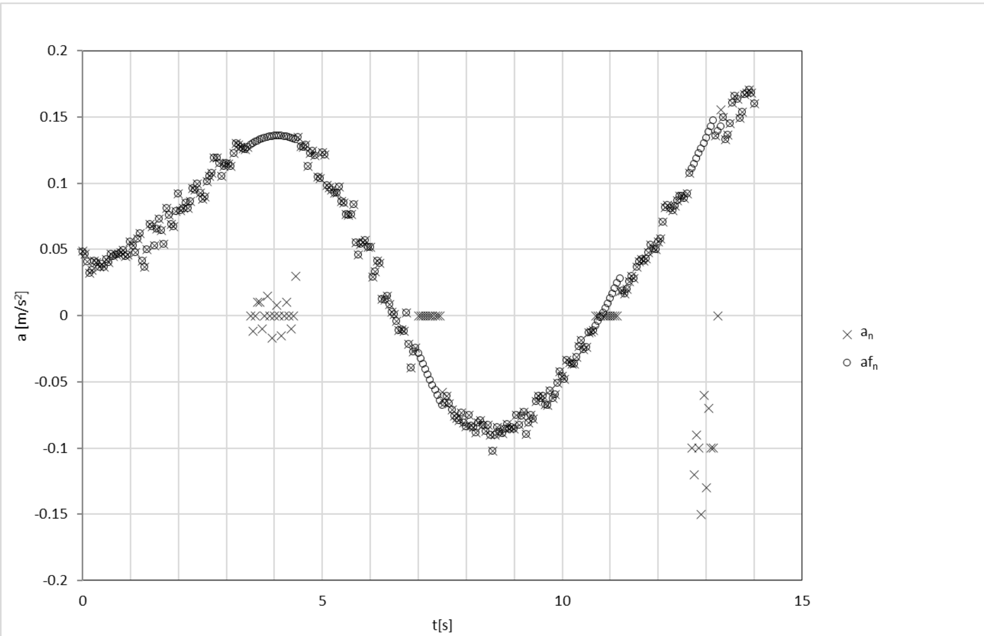

Figure 5: Input acceleration values a_n and after filter forecasting af_n

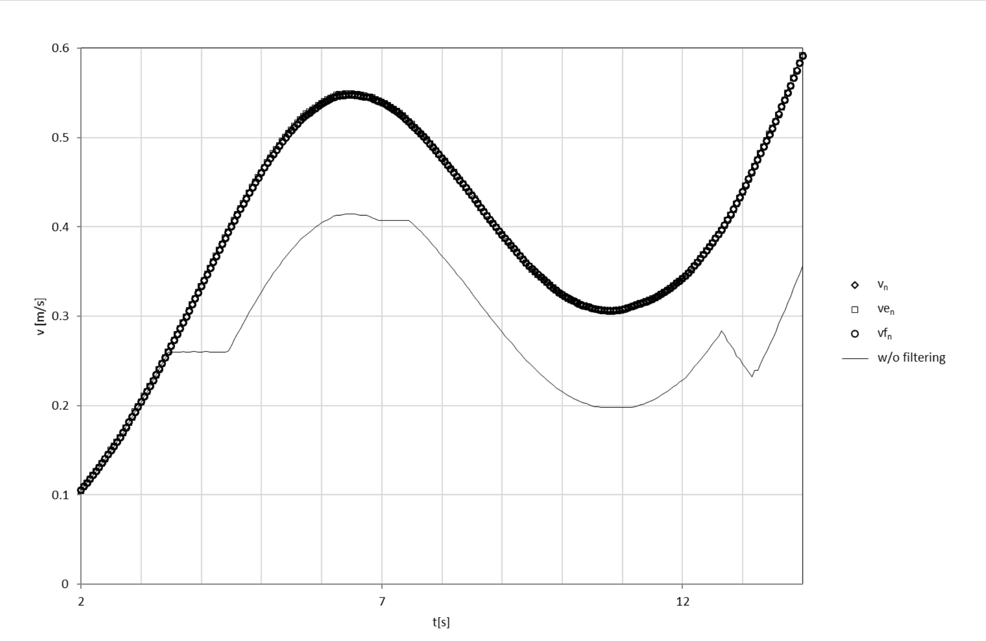

Figure 6: Calculated input velocity v_n, forecasted velocity ve_n, filtered velocity vf_n and without treatment "w/o filtering" comparison

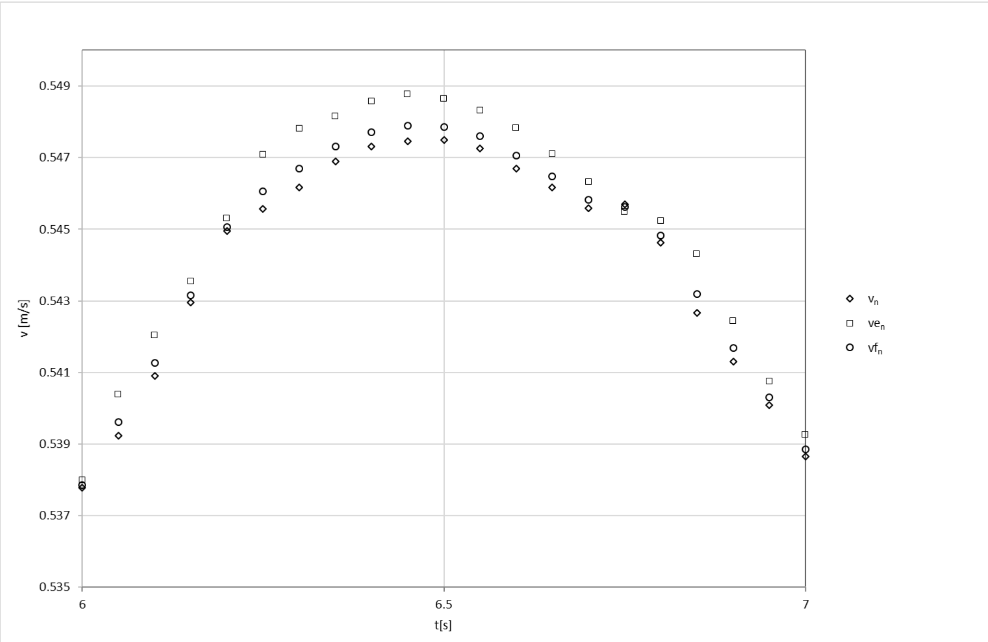

Figure 7: Zooming of the **Figure 6**

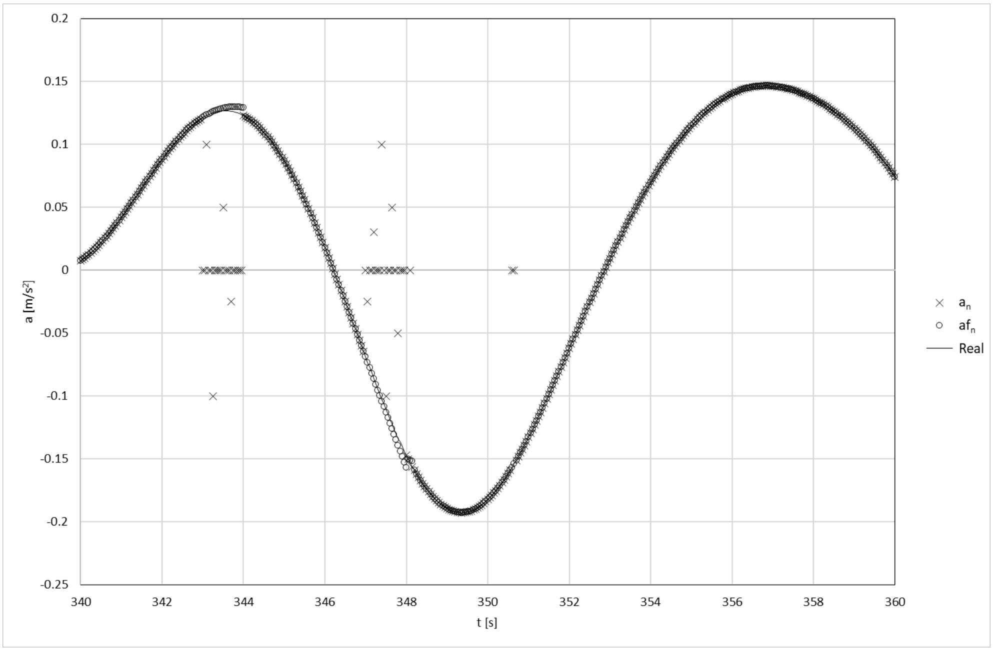

Figure 9: Input acceleration values a_n, after filter forecasting af_n and real acceleration "Real" comparison – values used for MHC simulation

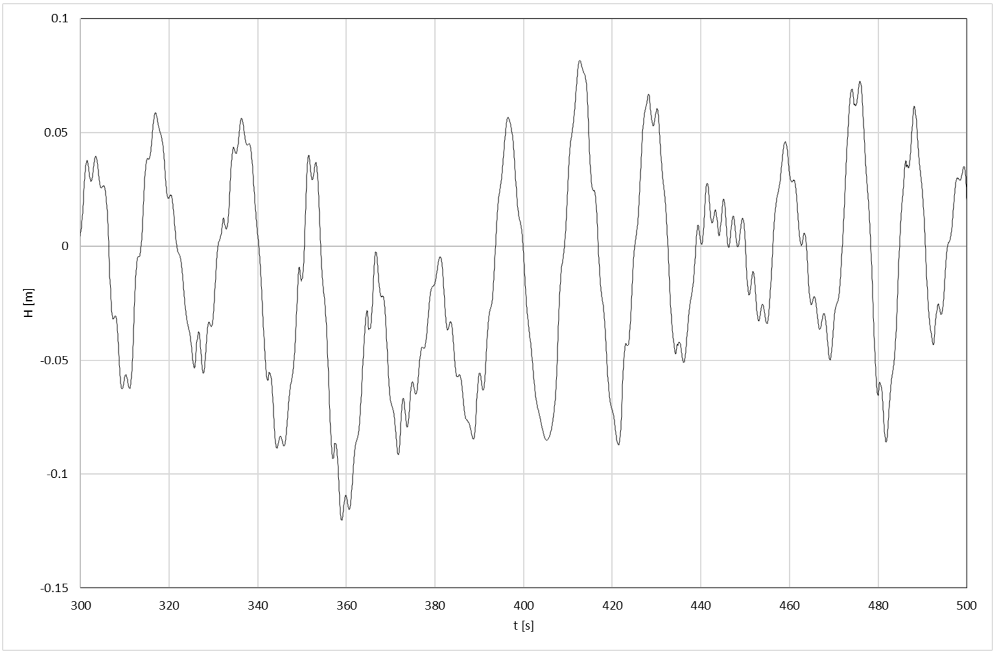

Figure 10: Load position error MHC simulation results with 1000 [mT] load hanging