*Journal of KONES Powertrain and Transport, Vol. 21, No. 2 2014*

**ISSN:** 1231-4005
**e-ISSN:** 2354-0133
**ICID:** 1133875
**DOI:** 10.5604/12314005.1133875

# UTILIZATION OF AN ACTIVE AND/OR PASSIVE HEAVE COMPENSATION IN THE EQUIPMENT OF DYNAMIC POSITIONING VESSELS

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***Abstract***

*DP vessels have a possibility to maintain their position or heading by using thrusters and propellers but the heave compensation is not possible that way. Heave compensation is a technique used to reduce the influence of waves on a hull or only a part of an equipment inside the hull. There are two types of heave compensation: passive (PHC) and active (AHC). Due to limit, the energy demand the hybrid heave compensation (HHC) is often in use.*

*The offshore activities needed the compensation to some extend (level) could be drilling, handling loads in cranes or pipe laying. Different types of Heave Compensator Systems (HCS) are used to compensate for these movements. Safety of these offshore activities is so important that the area of power (using external energy) and non-power (using only the energy of wave movement) drives are quickly developed. The heave compensators allow increasing the weather window and better making use of the offshore vessels. The expected level of decreasing the vessel heave in compare to work equipment is from 5 to 50 times. Active compensation by hydraulic motor needs its active run for motion compensation and the system ought to be equipped with accelerometer senses of ship movement. Computing algorithms and the choice of control method are principal in HCS performance. In the article, it was shown examples of different types of compensators with their advantages and disadvantages and their utilization.*

***Keywords:*** *heave compensation, DP systems, passive heave compensation, active heave compensation*

## 1. Introduction

The purpose for use heave compensators is to keep a load, held by equipment on a moving vessel, motionless with regard to the seabed or other vessel. This is impossible to reach it by using vessel thrusters. The heave compensation system tries to compensate for any movement at a specific point, using control system or other special equipment.

One of the possibility is using the electric winch system. The wave movement is compensated by automatically driving the winch in the opposite direction at the same speed. More often, it may be met by using hydraulic winches. They control the oil flow from pumps to the winch so the target position is reached. Hydraulic winch system for heave compensation can use accumulators (the kinetic energy of movement is accumulated) and passive heave compensation to form a semi-active system with both an active and passive components.

The idea of a passive heave compensation (PHC) is to accumulate the kinetic energy during movement and next to use the accumulated energy for compensation the change position between vessel and a load. This is a reactive device. Using an air (or compressed nitrogen) cushion the PHC attempts to isolate for example the drill string from the vessel heave. An idea of PHC is presented in the Fig. 1.

An active heave compensation is the other possibility where the hydraulic power assist device overcomes the passive heave compensator friction and the friction of other elements of load (drill string, equipment for divers etc.) as it has been shown in the Fig. 2 [1, 2, 7, 10]. The hydraulic forces by changing the length of rope counteract the vessel vertical movement. The tension value should not be less than zero in order to avoid slack rope situations. The AHC system is often more effective than PHC but needs more power. This is a reason for an implementation the energy accumulators to decreasing the required power of AHC system. It is possible to utilize a hybrid heave compensation system (HHC) which has two independent compensation systems: PHC and AHC.

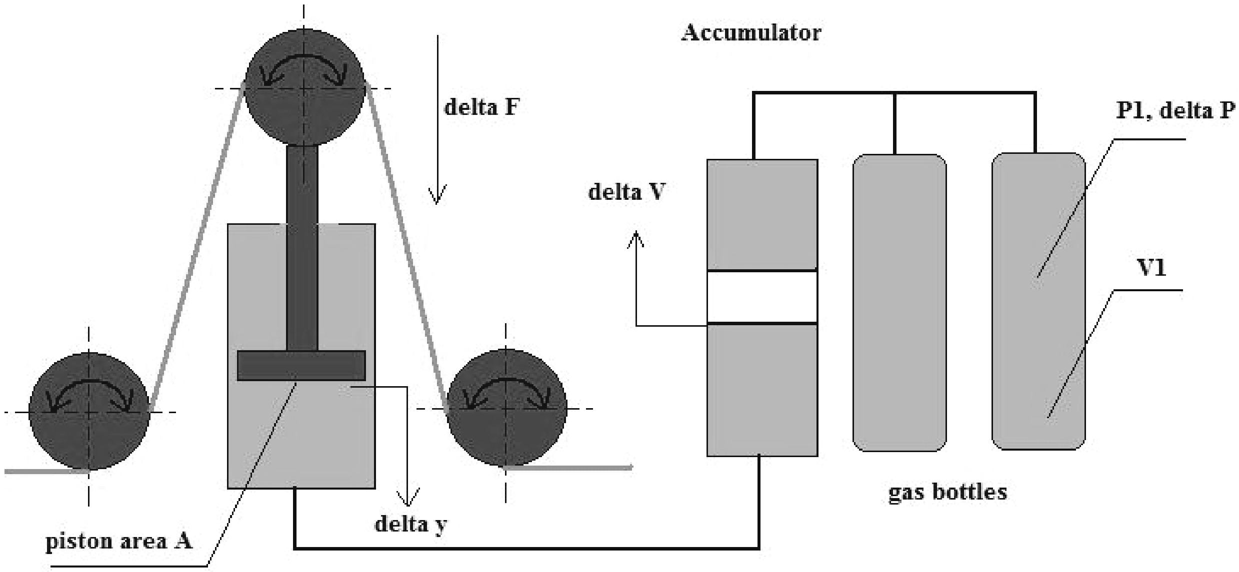


*Fig. 1. An idea of a passive heave compensation*

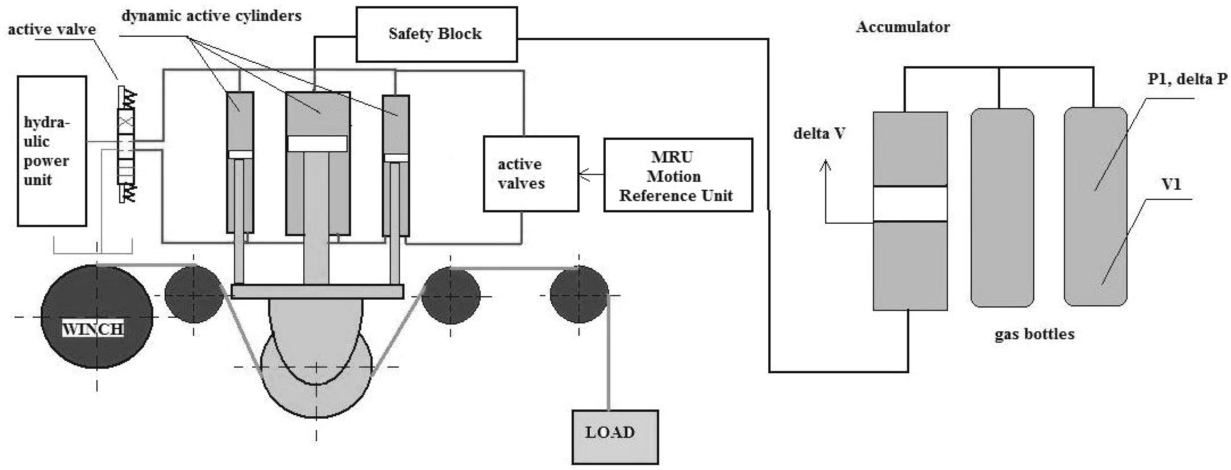


*Fig. 2. An idea of active heave compensation with energy accumulation*

The target of heave compensation is to reach the maximal effect (Fig. 3). The real compensation obtains from 5 to about 50 times decreased position change of load in comparison to vessel vertical movement (heave) [4, 12, 13]. In deep-water installations and lift, amplified vertical motions of equipment can be caused by axial resonance of wire, representing in the Fig. 3 by elastic (spring) and damping behaviour of the wire. This can occur even in operational sea state. So during the deep-water lifting operation, a heave compensation system can be employed to mitigate the vertical resonant motion of the lifted equipment, which reduces the dynamic loads in the hoisting wire system.

The one from first ones was the heave compensated landing system (HCLS) patented 1993 by Flowline Group of Shell Deepwater Services. It had been developed to enable the repair of deep-water pipelines in the case of replacement of a small section, or recovery from a pipe buckle during installation of the pipeline [4].

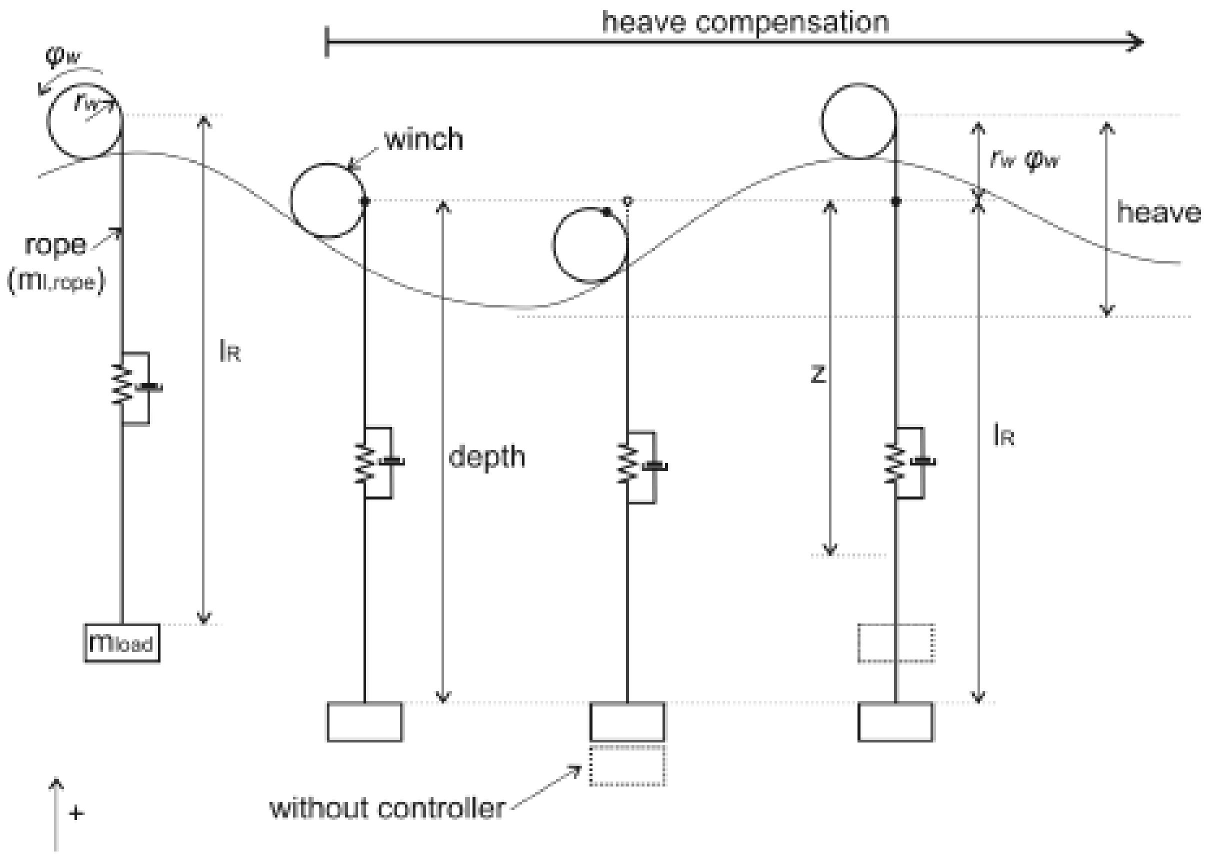


*Fig. 3. The expected effect of heave compensation [12]*

## 2. Utilization of an active heave compensation

An active heave compensation has some characteristic features:
- vessel movement sensed electronically,
- information interpreted by computers,
- computers determine the control signal and send to make necessary changes,
- system is similar to car ABS.

The main application of AHC systems is for any offshore cranes or winch where it is beneficial to reduce the amount of vessel motion transmitted to the hook load [3]. The advantages of AHC system are increasing the working weather window and safer deep-water seabed interfacing. The results of simulation AHC is presented in the Fig. 4. The level of heave was decreased about 20 times.

Active compensation by hydraulic motor needs its active run for motion compensation and the system ought to be equipped with accelerometer senses of ship movement. The controller calculates the heave motion compensatory value according to the moving signal of a ship.

Relating the disturbance observation to control proportional directional valve, the heave motion track of winch is realized [5]. When the accelerometer detects the vessel sinkage under ocean disturbance load, the controller calculates the compensation value and makes proportion direction valve work on the underside. The hydraulic motor makes the winch running in counter-clockwise direction and the umbilical cable is taken back (Fig. 2).

On the other side, when the accelerometer detects the vessel raise under ocean disturbance load the controller calculates the compensation value and makes proportion direction valve work on the upside. The hydraulic motor makes the winch running in clockwise direction and the umbilical cable is released.

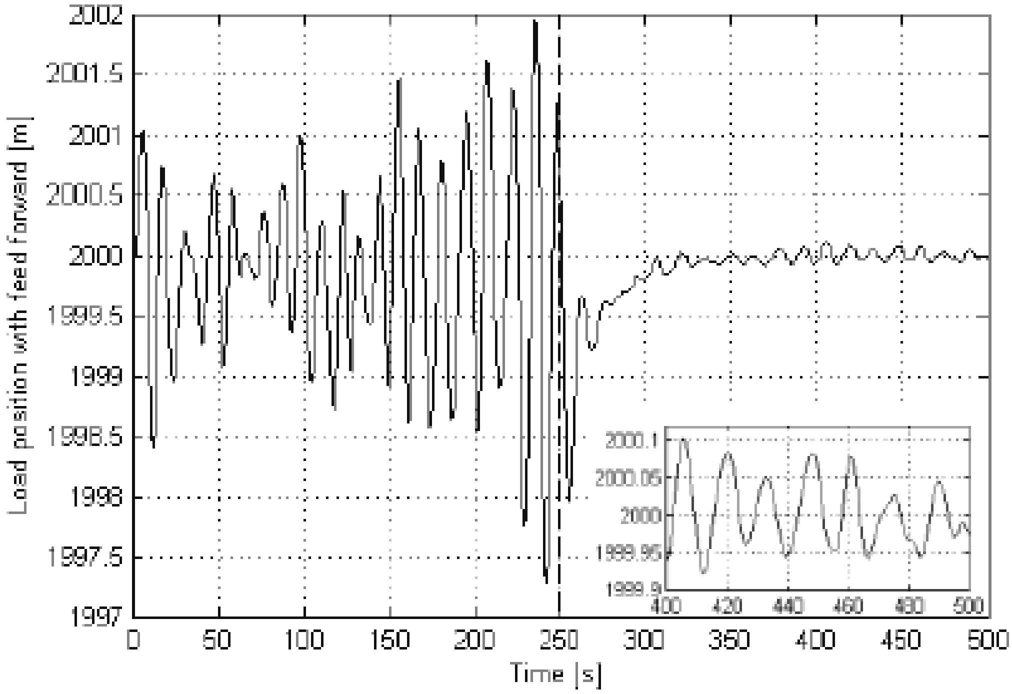


*Fig. 4. Simulation results without and with active heave compensation [11]*

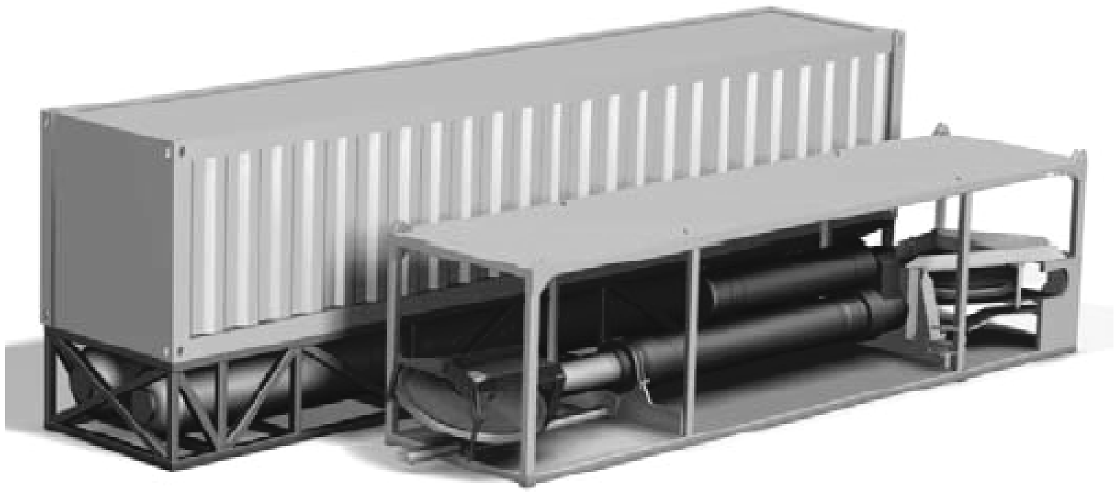

*Fig. 5. AHC and PHC system in a single cylinder for winch with power pack in a container [6]*

The modular AHC system incorporates following operational modes [2, 6, 11]:

- Active Heave Compensated mode – for lowering and landing (H&L),
- Empty Hook mode – for re- and disconnecting in deep water,
- Shock Absorber mode – at surface load handling,
- Tension mode – for landing in shallow water (ART, CTM),
- Manual mode – for testing commissioning and reeving,
- Normal mode – for no heave compensation.

The AHC systems are complicated. For example, the Liebherr AHC winch is driven by 16 hydraulic motors – eight motors on the left and eight-motors on the right hand side [9]. The advantage of Liebherr winches is automatic memorizing of vessel's motion and self-acting calibration of the Heavetronic® system within 20 minutes [9]. Chosen parameters of Liebherr RAHC winches are presented in the Tab. 1.

Tab. 1. Active Heave Compensation with Secondary-Controlled Winch Drive in Power Classes [9]

| | | | | | |
|---|---|---|---|---|---|
| Winch capacity [kN] (10 kN = 1 t) | 50 | 500 | 1000 | 2500 | 5000 |
| Installed power [kW] | 55 | 480 | 950 | 2350 | 4700 |
| Maximum power of winch [kW] | 200 | 1800 | 3600 | 8800 | 17600 |
| No. of drive units | 2 | 6 | 12 | 14 | 28 |
| Capacity of drive units [$cm^3$] | 71 | 355 | 355 | 1000 | 1000 |

The main disadvantages of AHC are a big power demand and high rope wear, potential risk of blocking. To decrease the power demand, it was done a hybrid solution with an energy accumulator. The advantages of AHC are additional installation for compensation is minimal, good regulation with small fault, adapted regulation for compensation tank. When it has been required more accuracy in tension control, the active tension control should be used, as the pressure variation, inertia and friction give load variations during the passive heave compensation.

## 3. Utilization of passive heave compensation

A passive heave compensation has some characteristic features:
- provides simple heaving load limitation,
- adapting in any increase in load due to external influences by giving way or pulling in,
- system is similar to car absorbers.

The advantages of PHC systems are no power consumption for added equipment, easy to understand and maintain. The main element is hydraulic cylinder may be replaced by spring cylinder is connected to an accumulator. This type of system can be used for equipment with high resistance against motion, i.e. diving bells [3].

The disadvantages of PHC systems are: it requires load with very high resistance to the motion, requires adjustment for actual load and motion, due to its high friction, the system always has a greater positional hysteresis, the acceleration of loading is the worst to the AHC system and the range of motion is limited. Most PHC systems can be considered to be "fail safe" as they do not require an external source of energy to operate. Example links of the PHC are as follows: www.crnaemaster.no, www.safelink.no, www.controlflow.com.

The effect comparison between the passive and active heave compensation is presented in the Fig. 6.

It may be seen that the force variation in hoist wire is approximately 11.5% by using PHC and 2.5% by using AHC. Computing algorithms and the choice of control method are principal for the heave compensation system (HCS) performance. The suitable choice of all components is vital for the AHC and/or PHC performance quality.

An example of the application of passive heave compensation system is presented in the Fig. 7. This is typical PHC with the "shock absorber" system. It is a simple closed loop with a little requirement for an electrical/electronic control system.

All components of heave compensation should be properly sized and adequately connected. The vessel at the surface moves freely with the existing sea state, while the suspended load, representing considerable more mass, remains relatively still [4]. The weights and sizes of all components of heave compensation are obviously critical to achieving the proper heave control of the payload.

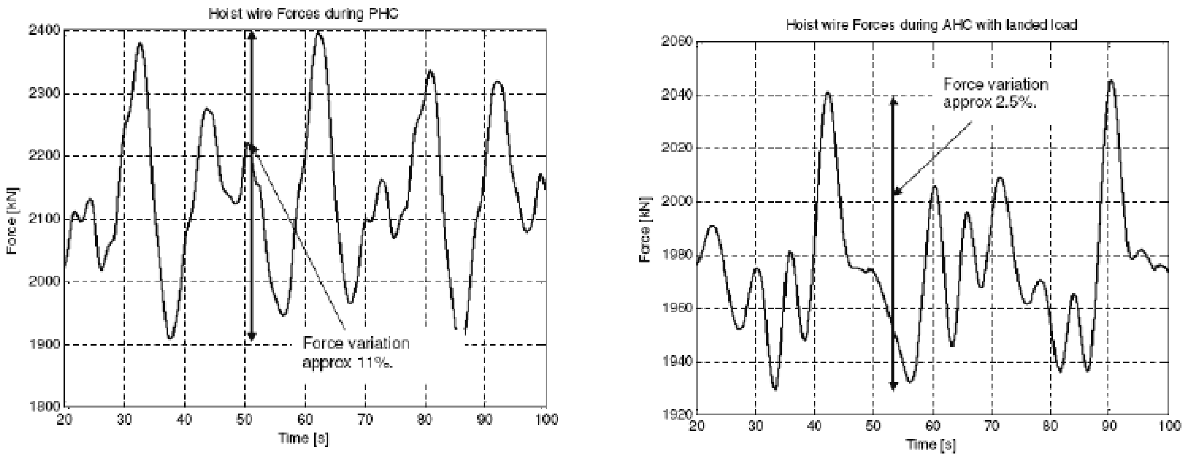


*Fig. 6. Comparison between the passive and active heave compensation for drill vessel SAIPEM3000 [8]*

*Fig. 7. An example of Passive Heave Compensation use during lifting operations [14]*

## 4. Final remarks

The PHC and AHC systems used in DP vessel equipment give a possibility of work independent to the weather conditions (of course to a limited maximal level). It allows for increasing the weather window and better makes use of the offshore vessel.

The heave compensators are the critical on-board instruments that reduce downhole motion on logging tools deployed from a moving platform or vessel, and minimize motion effect on downhole measurements.

The new development in subsea installation in years will continue to improve the profitability of many future offshore installations. The AHC and PHC using are important for improving the safety of work, crew life, effectiveness of work, reduce disposal costs and environmental liability.

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