

## UTILIZATION OF ANTI-HEELING SYSTEMS ON VESSELS AND CHOSEN MALFUNCTIONS DURING THEIR EXPLOITATION

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### **Abstract**

*Heeling is unsafe for ship, its machineries and people on board. It is known the main reasons of vessel's heeling such strong winds, hard and speedy turns, uneven cargo loading. The most dangerous for vessel should be the shift of cargo at sea due to faults during port cargo loading. During cargo operations, the vessel's heel may change and ought to be under control.*

*Some offshore vessels, pipe-lay, crane, heavy lift, container or ro-ro vessels ought to have the anti-heeling systems to prevent too high heels during port or offshore operations. They are needful for the vessel and cargo safety.*

*It was presented chosen examples of such systems showing the solutions, elements of anti-heeling (A-H) systems, method of vessel's heel visualization, ways of utilization etc. The proper utilization of A-H systems is the base of correct, save time and safe operations to minimize the risk of vessel's tilting or capsizing.*

*It was mentioned some problems during operation and some malfunctions of A-H systems creating the risk of vessel's accidents. Some examples of famous and serious vessel's accidents were shown.*

*It was discussed what may be done for improving these systems during the cargo operation especially in open sea particularly necessary for offshore vessels.*

**Keywords:** *heeling, anti-heeling compensation, vessel, malfunction, anti-heeling system*

### **1. Introduction**

When the ship tilts on port or starboard side and does not return to its upright position, it is known as heeling of the vessel. Heeling is unsafe for ship, its machineries and people on board. The main reasons of ship's heeling are strong winds, especially during the change of vessel's heading through the wind line, hard and speedy turns and uneven cargo loading. The most common cause is uneven cargo loading and unloading which may be compensated through the ballast system.

The anti-heeling system is designed and used for the continuous compensation of the vessel's heel during all kinds of loading operations in port as well during offshore operations. The limited heel is required so the anti-heeling systems ought to compensate the vessel's heel inside the limits [2, 4, 7, 9].

It is achieved by pumping ballast water (or other fluids) between the heeling tanks using reversible pumps or valves system changing the flow direction. The centrifugal pumps are more often used due to their capacity. Butterfly valves are standard parts and are activated pneumatically or hydraulically (remote controlled). Pipelines connected the heeling tanks ought to have as high as possible diameter due to pump capacity, more often from 50 mm up to 1500 mm (2"-60"). Clear visualization is presented in Fig. 1.

Special heel controls are needed for sailing vessels and cruise liners (due to wind compensation) and icebreakers (due to ice impact) [10].

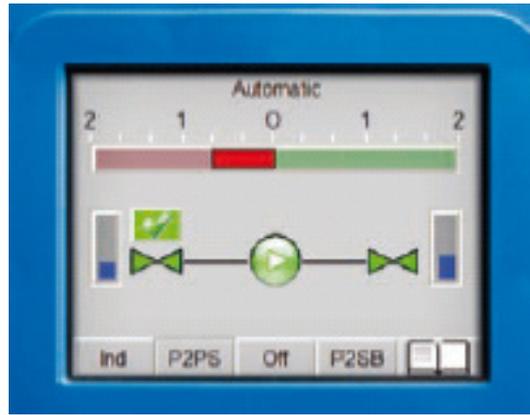


Fig. 1. Visualization of heel (in degree – heel about 1/3 degree on portside)

## 2. Utilization of heel compensation

A heel compensation has some characteristic features (advantages):

- allows safer and rapid cargo loading and unloading,
- shortens harbour time and saves port dues,
- reduces damage to ramp, rolling cargo, containers, etc.,
- ensures safety of the ship and crew.

There are two widely used anti-heeling (A-H) system on board ships:

- pneumatic system – this system comprises of air purging arrangement and regulating valve system to force the air on the top of ballast tank. The air is forced on one tank and purged from the other, making the water rapidly flow from pressurized to purged tank. This transfer of water is used to upright the vessel in quick time,
- water pump system – the pump system consists of electrical motor driven water pump, which can be a reversible or non-reversible pump, connected with remote controlled valves that can direct ballast water flow in between the tanks.

An idea of A-H system with water pump is presented in the Fig. 2.

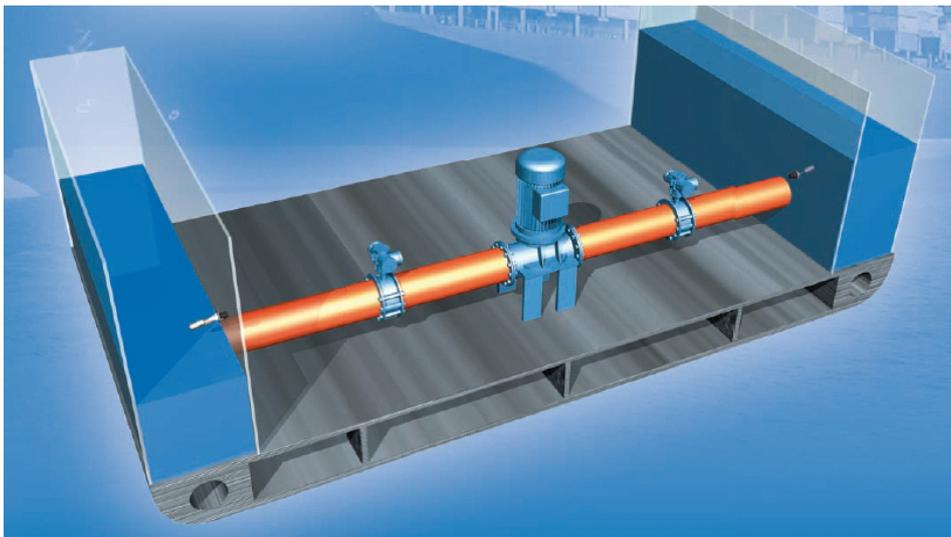


Fig. 2. Idea of anti-heeling system of Hoppe Marine [3]

The main components of A-H system are (Fig. 3) [1, 8, 11, 12]:

- pump starter panel and control panel,
- heeling pump driven by electric motor,

- variable frequency drive (VFD) with flow controller,
- control valves,
- level switches for pump dry-running protection,
- level sensors for tank content indication,
- inclinometer for static heel measurement,
- inertial measuring unit for dynamic heel measurement (optional).

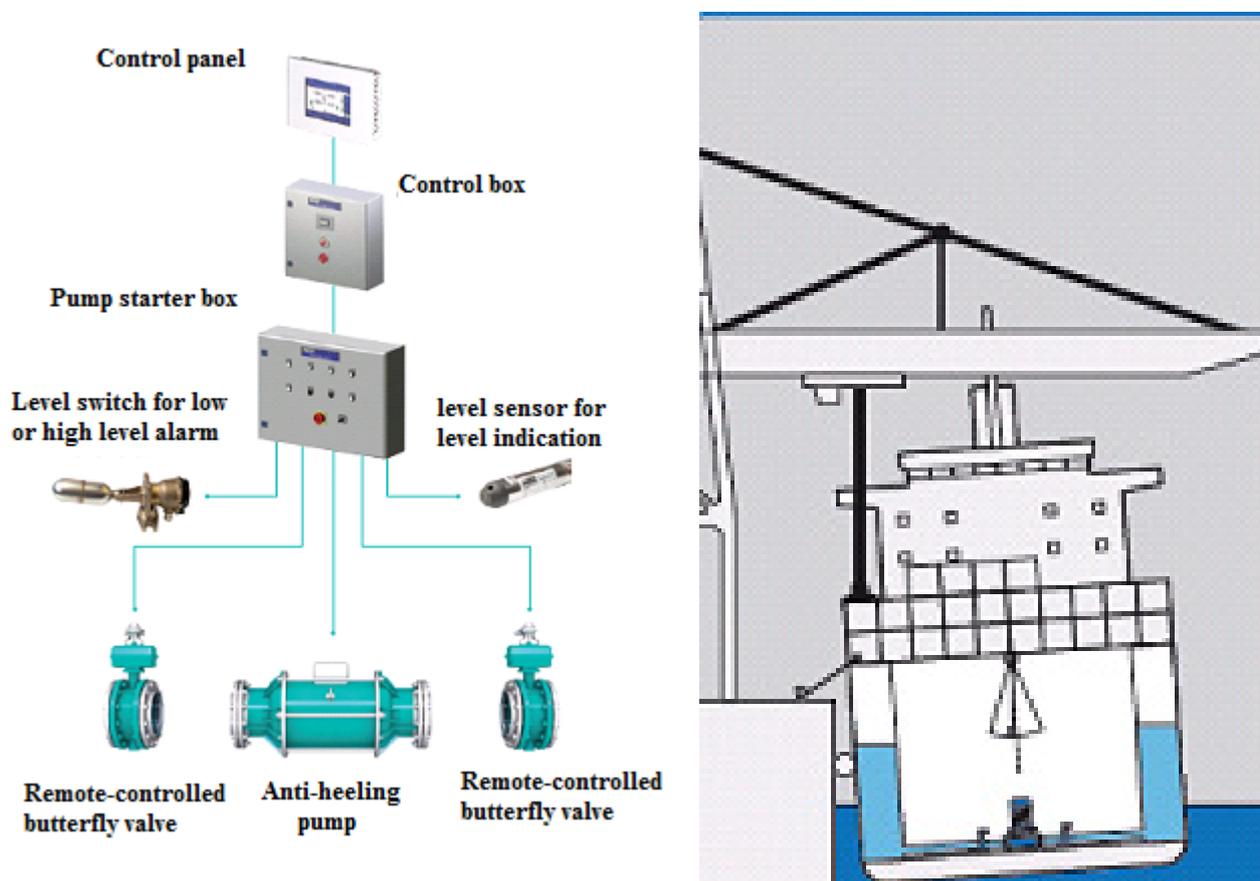


Fig. 3. Main components (left side) of anti-heeling system (right side) [1]

For some vessels (lift crane, offshore) it is needed an advanced anti-heeling system with a special load moment control. The destabilizing moments of heavy crane operations are recorded and used for automatically determine the required stabilizing moments [3]. Here it is needed frequency controlled reversible pumps ensure immediate flow control reaction. In the case of offshore heel operations, the inertial measuring unit (named MOSIM of Hoppe proposition) is used for accurately determine the vessel's motion. It eliminates the heeling effect to such level so the crane operations are possible even at sea.

An example of a vessel needed such A-H system is presented in Fig. 4. It may be seen what kind of problem ought to be solved. The mass of two cranes in side position and the load up to 350 tons each gives such a heeling moment too danger for safe operations. For the safety of vessel's operation, the heel ought to be compensate through the anti-heeling system.

Sometimes in the A-H system, it is a necessary to use additionally the stability test system [3, 5, 6]. Having data from tank content and draught measuring systems it is possible to carry out and verify the actual vessel's stability, providing valuable safety and cargo optimizing information.

In a case of icebreaker operations, the A-H systems are often used to heel the vessel regularly from port to starboard so that the vessel is not stuck in ice. It requires fast reaction times and large heel moments. So for higher capacities the pneumatic A-H system may be used having often the

name as blower A-H system. In a more complex version the Anti-Heeling System uses four anti-heeling tanks with powerful blowers and measures heeling and trim angles, e.g. by Hoppe's precision motion measuring system HOSIM [3], to keep the vessel in a pre-defined upright floating condition, while the on-board crane lifts heavy items.

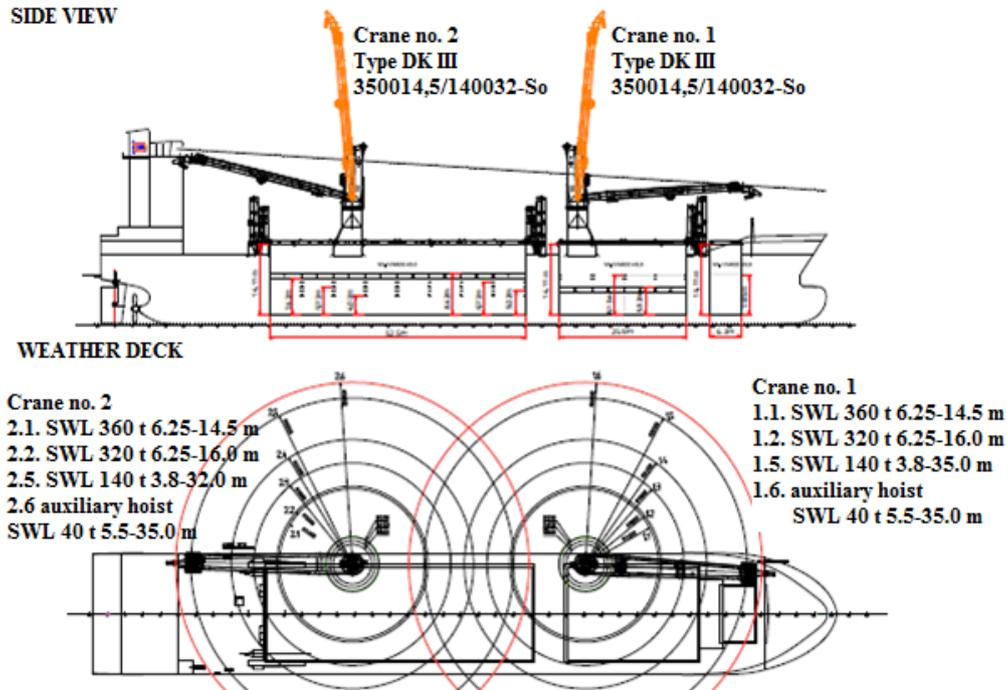


Fig. 4. Two cranes of SWL 350 tons each on m/s AAL Bangkok (built 2012) [13]

### 3. Other possibilities of heel compensation

During heavy lift operations in ports, the A-H systems are not to be sufficient to counteract the forces and moments from cargo masses. The added and supportive solution is a using of a stability pontoon. For example for m/s *Atlantic Dawn* (presented on Fig. 5) the large cargo cranes each have a maximum SWL (safe working load) of 150 tons at 16 meters and a SWL of 38 tons at a maximum outreach of 28 meters. Both cranes can also operate in tandem to facilitate the moving of large project loads. In such situations, the use of a “stability pontoon” is required, due to the relatively small beam (required for higher speed hull shape). This pontoon, with the dimensions: 11.0 times 5.50 times 3.40 meters, is normally stored flush in the cargo deck, next to the funnel. When deployed, it is put overboard with the aft cargo crane and hooked into the side of the vessel. The pontoon is then partially filled with seawater by gravity, thus providing a stable buoyancy component to counteract the lifting forces. There are the large volume dedicated heeling tanks also. They are provided in the sides, especially on port side (the vessel crane is starboard side). For optimal use of these heeling tanks, an Azcue transfer pump, with a capacity of 600 cubic meters per hour, is fitted in a special pump room halfway along the piping duct. The total bilge/ballast pump capacity is complimented with two bilge/ballast and two “general service” pumps, located in the forward pump room.

### 4. Operational problems of heel compensation systems

Heel compensation systems need the crew supervision. Proper work of A-H systems increases the vessel's safety but from the other side in a case of improper work they may be the reasons of dangerous situations for the vessel and people. There are many cases of emergencies, failures up to accidents due to out of control work of A-H systems.



Fig. 5. The Atlantic Dawn with external anti-heeling device [18]

On October 06<sup>th</sup>, 2015 (Tuesday) the passenger/ro-ro cargo ship m/s *Stena Gothica* (built 1982) called on the port of Frederikhavn (Denmark) with a severe list to port side (Fig. 6). The vessel is on regular route: two trips per day between Gothenburg and Fredrikhavn. As she passed under the Älvsborgs Bridge at around 08:00, a heavy list was occurred. There were on-board 39 passengers, 35 persons of crew, 35 trucks etc. [16]. The vessel proceeded towards Majnabbe Quay and berthed at around 08.45 hrs. The investigation shows that the reason of listing was a technical fault.

Next example – March 08<sup>th</sup>, 2007 the m/s *Repubblica di Genova* (built 1988) owned by Grimaldi Lines. Early morning that day during loading operations a containership capsized in the port of Antwerp. Antwerp port authorities reported all crew evacuated in time and there were no casualties. The vessel was lying in the Verrebroekdok and was loaded with containers and cars, about 100 containers and cars had fallen overboard (cargo capacity is 3,400 cars and 1,316 TEU). The 216-meter long vessel slowly rolled onto its starboard side in a dead end dock. After when the ship began taking on water the captain ordered the crew to evacuate [14, 15].

Around the capsized vessel, a security zone of 800 meter has stayed in force. No environmental damage was reported. Again, the technical error in A-H system was the main reason of vessel's capsizing.

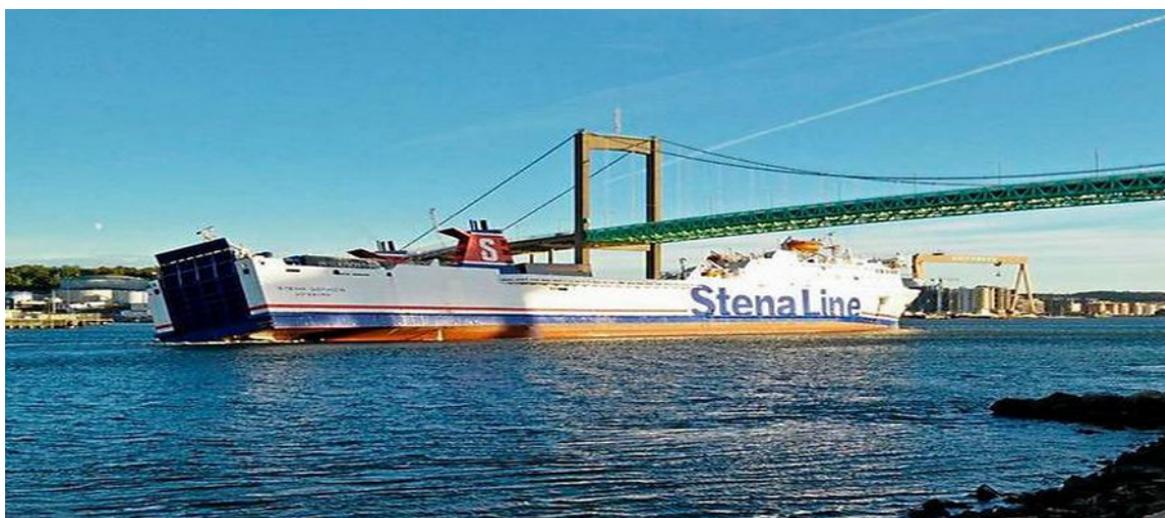


Fig. 6. *Stena Gothica* problems with anti-heeling system [17]



Fig. 7. *Repubblica di Genova* capsizing [International Marine Consultancy]

On July 23<sup>rd</sup> 2006, the *Cougar Ace* (built 1993) sailed out from Hiroshima to Vancouver with a cargo of 4703 brand-new Mazda cars and 109 small commercial trucks (value \$ 103 million). At sea near the Aleutians crew had started the exchange of ballast water (due to requirements of American Coastguard regulations) to avoid fouling local marine environments with non-native species. The seas were relatively calm and the weather almost balmy by Arctic standards. The water from the starboard ballast tanks was drained without being refilled simultaneously with fresh seawater. Therefore, the top-heavy ship keeled over almost instantly and onto its port side. The vessel's flip (Fig. 8) were damaged cargo. It is interesting that the worst injury was a steward's broken leg. All crew waited 23 hours until the helicopters lifted them to a safe place [17].

The indirect reason was inappropriate water ballast operation and with reduced transversal stability resulting in a vessel to flip aside. A mechanical failure between ballast and anti-heeling system was the direct reason of accident.

The *Cougar Ace* near sunk in the Gulf of Alaska. On July 31<sup>st</sup>, 2006 during salvage operations a disaster struck. One man fell 80 feet along the ship's stern, hitting his head on a bollard on his way down and landing on a winch. He died about an hour after being evacuated to a Coast Guard cutter. At the end, the vessel had been saved to port Unalaska on August 11<sup>th</sup>.

The ship-owner's investigations show that the reasons of accidents were technical errors in ballast and anti-heeling systems.

## 5. How to prevent dangerous situations?

The A-H systems allow transferring a heavy lift cargo more safely with lower expenditure of labour. The procedures of using the A-H systems seem to be very clear, simple and easy to execute by any person of crew. If it had happened dangerous accidents and disasters it would be the causes of such situations. It is known that human and organization faults are in 70-90% the reasons of incidents on vessels taking effect in failures and damages. Although prepared procedures the events have still occurred. The problems with vessel static and dynamic stability ought to be well known through the master (captain) and chief officer minimally in a level according to STCW 78/95/2010 requirements. If sometimes the system of crew training leads to human faults it is

a necessary to prepare additional protection. If during the operations with anti-heeling system the vessel heel reaches for example  $10^\circ$  it will be activated an alarm of too high level, if reaches  $15^\circ$  (depends on master order) it will be stopped all operations on a vessel (to prevent dangerous situations and in the end the vessel flip or capsizing).



*Fig. 8. The Cougar Ace flip [18]*

## **6. Final remarks**

The A-H systems used in vessel's 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 use of the offshore vessels. The proper use such systems need to fulfil the safety procedures to avoid human errors. This is the main reason of many accidents in my opinion, especially in mentioned above. Checking of proper work all elements of ballast and anti-heeling systems before starting the operations ought to be the first. The A-H systems stay more and more popular in still more types of vessels.

The A-H systems are important for improving the safety of work, crew's life, effectiveness of work, reduce disposal costs and environmental liability.

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