Methods to prevent capsizing during turning of ships

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Abstract. Capsizing of vessels happens when there is inadequate Transverse stability. Such cases can be prevented by online measurement of the metacentric Height (GM). Measurement of GM can be done by a short inclining experiment before departure or by measuring constantly the rolling Period during the voyage. Both measurements are already part of OGMS system.

Theory. During the last few years, several cases of vessel Capsizing during turning were reported. Investigations of those cases revealed that such incidents were the result of reduced and inadequate Transverse Stability. To avoid such cases, online measurement of stability parameters is essential. In this article we will describe an Online Stability Measurement system (Online GM Monitoring System, OGMS) that is in operation for about 20 years on about 100 PCTC's and large container ships.

It should be pointed out that "Online Stability Measurement" systems do not replace the Loading Instruments (or Loading Computers) that are mandatory on large vessels. Loading Instruments are essential in order to plan the stowage and tank condition of the vessel and calculate the expected stability of each condition, especially before departure.

However, Loading Instruments have one big flow: Data inaccuracy. While liquids in tanks (ballast, fuel, cargo etc.) can be ascertained with high degree of accuracy (either automatically or manually), cargo data (containers, cars etc.) is, in many cases, inadequate or wrong. Errors can be pointed to shipper's wrong declaration of weight, wrong input by ship's officer and more. Consequently, wrong input can lead to wrong results that can lead to catastrophic events. Hence, the importance of "Online Stability Measurement" is not to replace the Loading instrument but rather to ascertain that it gives the correct status of ship's stability condition.

Stability of vessels can be measured online in two ways that will be described below:

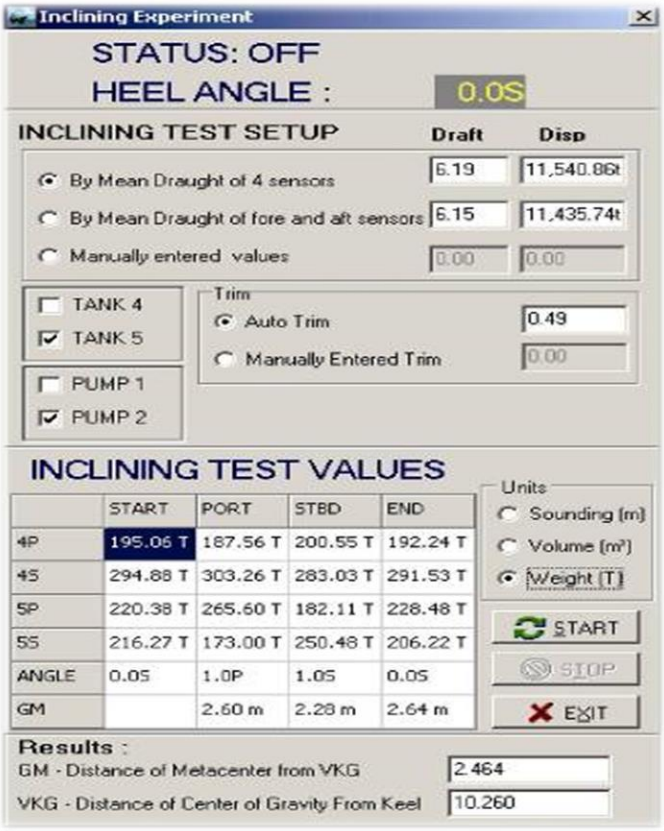
1. A pre-sailing "Inclining Experiment" that measures the transvers stability by moving a known weight across the ship.
2. Measurement of the Rolling Period of the vessel during the voyage.

1. Inclining Experiment before sailing.

Inclining experiment measures the Metacentric Height of the vessel (GM), by transfer of certain weight across the vessel and measurement of the corresponding heeling angle α. A Weight Moment M is created by moving a weight of W tons a distance of D meters, M=W*D, and this moment will heel the vessel to an angle α given by $\tan(\alpha)=M/(\Delta*GM)$ where Δ is the displacement of the vessel. Obviously the Metacentric Height (GM) can be extracted from this formula to give the simple relation $GM = M/(\Delta * \tan(\alpha))$.

The OGMS system of Totem Plus can carry out a short inclining experiment just before sailing, and provide the resulted GM that should be compatible with the Loading Instrument

prediction. Large differences between the two indicate that something is wrong and should be carefully checked. The measurement is done by controlling relevant valves and pumps, and transfer of certain amount of ballast water across the vessel. The relevant tanks can be any pair of ballast tanks (ideally the Anti-heeling tanks, if exist). The measured Heeling Angle for a known weight transferred and actual Displacement (measured by Draft sensors) will allow GM determination. See below an example of the User interface of the OGMS (fig. 1) on a certain vessel:



The OGMS user have in general several options, before stating:

- Decide on the tanks to be used (if more than one pair).
- Number of Pumps to be employed (if more than one pump available).
- Parameter to calculate displacement (Draft sensors or manual entry).

Once OGMS is ordered to start, it performs the following steps:

- Perform ballast transfer on designated tanks to bring the vessel to a heel of 1° to Portside.
- Perform ballast transfer on designated tanks to bring the vessel to a heel of 1° to Starboard.
- Perform ballast transfer on designated tanks to bring the vessel back to zero heel.

Actual weight in each tank and actual heeling angle are measured and recorded before and after each step. Calculation of GM are performed individually for each transfer and the average GM value is presented to the user.

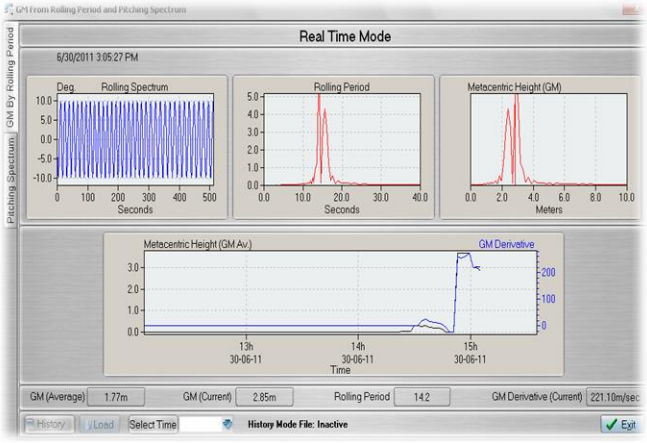
Inclining experiment by the OGMS can take about 20 minutes, depending on the actual GM. It is highly recommended to carry it out before every departure and record the evidence. User should compare the resulted GM with the Loading instrument predictions and act accordingly.

2. Measurement of the Rolling Period of the vessel during the voyage.

Capsizing of vessels due to loss of stability during the voyage can have catastrophic consequences (example: Cougar Ace, 2006). Such loss of Stability can be the result of improper ballast distribution, consumption of fuel and fresh water, damage to tanks etc. Losing of cargo can will affect the stability to the other direction, and may result in over-stability, violent rolling and possible resonance. Consequently, constant measurement of stability online is essential during the voyage as well.

Monitoring the stability of the vessel by measurement of the Rolling Period is a known technique, used by Seasoned mariners long before computers were placed onboard. Rolling period of ships (T) is related to the Metacentric Height (GM) by the simplified relation **$GM = (f * B / T)^2$**, where **B** is the breadth of the vessel and **f** is a coefficient determined by the Radius of Inertia of the vessel. The coefficient **f** will change slightly with the amount of cargo on the vessel, but is generally taken as 0.8 of the breadth of the ship. GM and B in this formula are given in meters.

However, it should be noted that the simplified formula above is good for still water and does not take into account the interference with waves (constructive or destructive) and consequently a single roll may defer significantly from the still water value. Hence OGMS takes the average value of the rolling period over a long time (500 Sec) and automatically calculates the GM and, not less important, the first derivative of the GM that signifies that GM was changed and the operator should be alerted and acknowledge the situation.



Case Study. The major problem with online measurement of GM is the crew reluctance to spend the 20 minutes or so required for the Inclining Experiment. In one fleet it was solved by direct instruction from the management to record the test on the departure forms and report it to the management office every departure. On other fleets, not always the procedure is followed as there is no regulation that requires vessels to do so.
One major event that could have been prevented is the capsize of the PCTC Golden Ray, Sept 8th 2019 at the port of Brunswick, GA. This vessel had a functioning OGMS but failed to operate it before sailing, as can be seen in the NTSB report and the Maritime Mutual Risk Bulletin No. 52 (https://maritime-mutual.com/risk-bulletins/car-carrier-golden-ray-capsize-and-the-billion-dollar-stability-lesson/). Excerpt from above article says:

GM check process, independent of Modes 2 and 3, which calculated the GM by automatically pumping ballast to heel the vessel 1º to each side and then measuring the weight of the ballast transferred.

NOTE: Mode 3 was based on the physical 'inclining experiment' methodology used to establish a vessel's GM. As such, it negated the impact of any Mode 1 cargo/fuel/ballast weight entry errors made by the stability computer operator.

*NTSB RECOMMENDATIONS TO PREVENT RECURRENCE : Verification of the C/O's LOADCOM Mode 1 manual stability calculation could have been accomplished by use of both the **Mode 2 and Mode 3 functions**. **This was not done** and appears to have been a recurrent failing.*

Conclusion. Capsizing can be prevented if the crew will be aware that there is a risk of reduced stability, regardless to the results of the Loading Instrument. Such awareness can be obtained by online measurement of stability, as described by the two methods above (Inclining Experiment and Rolling Period). Such system (Totem Plus OGMS) is already in the market and can be used. Regulators are called to make such systems and their use mandatory in order to save lives and property at sea.

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