

Parametric Roll

The phenomenon

Large roll angle quickly generated in head/stern or near head/stern sea conditions. Period is about half the natural roll period, occurs in phase with large pitch angle. There are two pitch cycles for each roll cycle and maximum roll always occurs when the ship is pitched down. Quite unexpectedly, the roll angle can increase from a few degrees to over 30 degrees in only a few cycles. On container ships, the violent motions could introduce extreme loads on containers and their securing systems, resulting failures and lost of containers overboard. The following video shows the onset of Parametric rolling of a model container ship in a towing tank.



Model test of C11 Class (APL China) experiencing parametric roll in long crested head seas

In real-life, these ships have sustained one of the largest casualties in history with hundreds of containers damaged or lost overboard as shown in the figures.



The cause

Today's Post-Panamax container ship designs feature wide beam and large bow flares in order to carry more containers on deck while still minimize the resistance with the stream lined underwater hull. As wave travels down along the hull, the stability (as indicated by GM) varies as the wave crests travel along the hull. When the bow is down due to moderate pitching couple with slight roll, the large flare suddenly immersed in the wave crest. The restoring buoyancy force plus the wave excitation force would "push" the ship to the other side. Similar action will happen on the other side as the bow pitch down in the next cycle. This coupled, synchronous motions could lead to large roll angles with sort period in few cycles even with moderately high waves.

Unpredictable

Due to the unexpected nature of the motion as compared with synchronous roll in following or beam seas on smaller and finer ships, parametric roll is quite dangerous. Unfortunately, it is a phenomenon can be duplicated in controlled model test environment and with time-domain computer simulations, but unpredictable in real seas when multiple seas and swells coming from different directions. From the research studies carried out so far, the following have been observed:

1. Parametric roll occurs when natural roll period is between 1.8 to 2.1 times the encounter period (normally associated with the pitching period)
2. Larger flare the more likely is the parametric roll angle and wider range of resonance.
3. It requires a group of waves above a threshold or critical height for parametric roll to be initiated and sustained. The threshold depends on size and shape of the hull.

The frequency domain linear ship motion prediction tools cannot predict such occurrence and it is impractical to run the computer intensive time-domain simulations for all types of wave conditions and varying ship loading conditions.

What can you do about it ?

First stay calm. When detecting the short roll period close to the pitching period, it is a warning of the parametric roll inception. Change heading to beam seas is the fastest way of getting rid of it. Then slowly come back to the original heading if necessary.

Nature has its way of taking care of things. For ship's loading condition with high GMs, i.e. shorter natural roll period say around 10 second, the waves that could cause the pitching period around 5 seconds are usually not very high and therefore unlikely to initiate parametric rolling in head/stern seas. However, the synchronous roll may occur in beam seas. So the way to reduce the roll is by heading into the sea.

For ship's loading conditions with low GMs, i.e. long natural roll periods, parametric roll in head/stern seas of moderately high seastate is likely. But synchronous roll in beam seas is unlikely.

It is hoped that with future R&D, we will be able to correlate the parametric roll with predictive events such as large relative bow motions and bow submergence (indicating flare immersion), thereby alert the master in the route planning stage or change loading conditions (GMs) before departure.

For further information, please contact :

Henry Chen, Ph.D.
Ocean Systems Inc.
2701 Monarch Street, Suite 210
Alameda, CA 94501 USA
Tel: 510 337-0812
Fax: 510 337-0120
Email: osi@ocean-systems.com
Web: www.ocean-systems.com