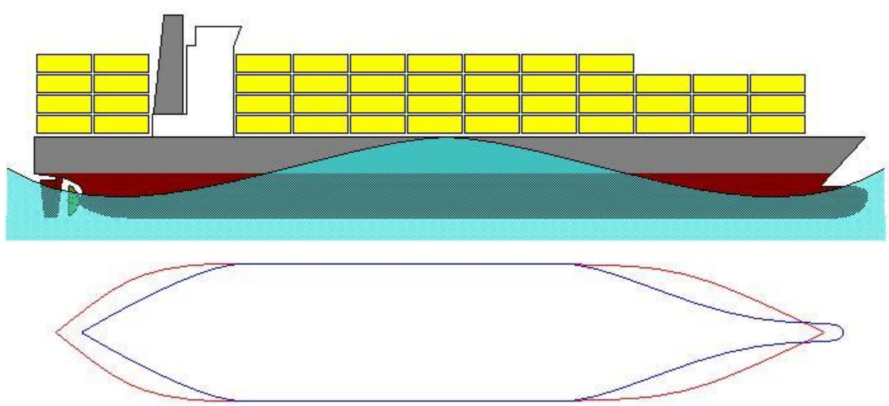
Parametric roll or Resonance Parametric roll

A few years ago the MV Asian Emperor, a pure car carrier, arrived at the port of Halifax with a shipment of cars, tractors and agricultural machines having sustained extensive damage. The probable causes of the damage were faulty securing and shifting of cargo due to ample rolling during the sea passage.

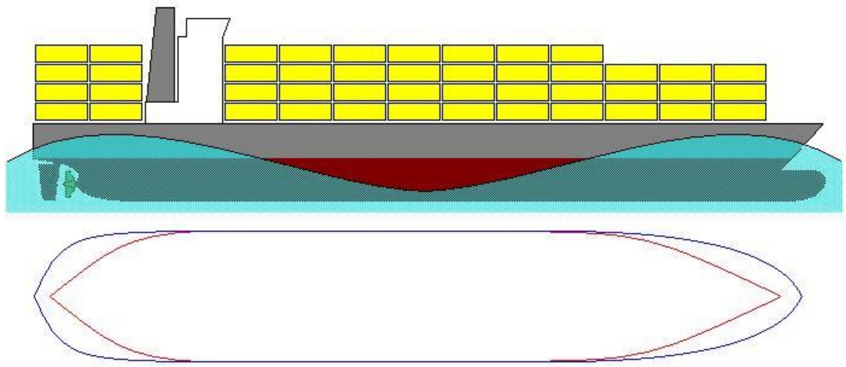
In the information presented to the public someone mentioned parametric rolling as a probable or contributing factor. When we refer to transversal stability very rarely parametric rolling comes to mind. However if we are sailing on a Ro-ro ship or a container ship, or some types of fishing vessels -all with full forms in the middle section but finer in the fore and aft end with large flares, that is, a ship with reduced block coefficient, water plane or fineness coefficient and midship section coefficient - this event is a possibility, which could even result in capsizing.

The possible scenario would be this: navigating seas with heavy swell and wavelengths (distance between consecutive crests) similar to the length of the ship, waves coming from dead ahead in order to weather the storm, the speed reduced to avoid vibrations and slamming shocks.

When the wave crest reaches the midship section, the waterplane area is minimal: the troughs are at the fore and aft end which due to the hull geometry have very small submerged volume. As result from this reduced water plane area the values of metacentric height (GM) and righting arms (GZ) are reduced too.



When the trough reaches the midship section, the area of the water plane is maximum, even more so than it would be in calm waters: the midship section is fuller even in low waterplanes, while the crests are at fore and aft end above water level which due to the hull geometry and bow flares have a much larger submerged volume. As result of this increased water plane area, the values of metacentric height (GM) and righting arms (GZ) are increased too.



In the above diagrams we can compare the water plane area for calm or mean seas (red) and the water plane area for swell seas or effective water plane (blue).

It is this succession of large and reduced values of stability what causes uncontrolled oscillations or balances until the vessel stabilizes at high angles of rolling or capsizes.

But how does this happen?

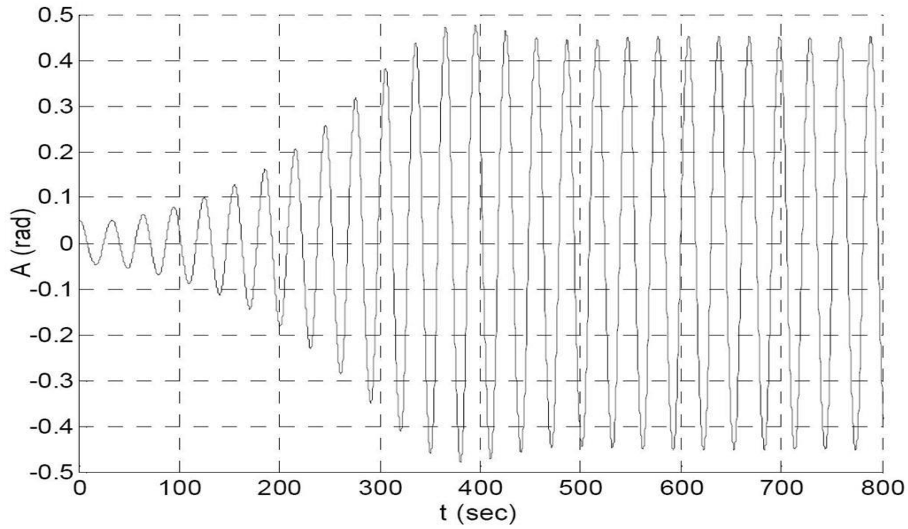
Let’s suppose the trough of the waves reaches the midship section while the crests are at the fore and aft ends. According to what was above described, the stability is maximum and the righting arm is maximum too, so when the ship inclines (rolls) she will react swiftly to the opposite side.

As this happens, the ship keeps moving forward. When the crest reaches the midship section and the troughs are at the fore and aft ends, the stability parameters go from maximum to minimum and her response to that inclination to the opposite side will be minimal, so the inclination will be undamped.

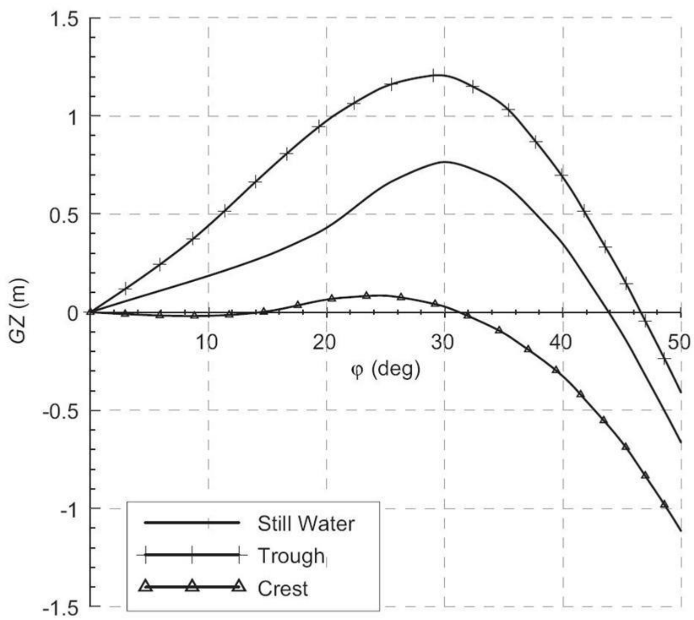
By the time the next trough reaches the midship section the ship is heavily inclined and the stability will increase to a maximum with a maximum angle of inclination; therefore, the value of righting moment will be maximum too and she will oscillate or roll to the opposite side very rapidly causing an even larger inclination.

The process will repeat itself until the oscillations of balances stabilize or the ship capsizes.

Normally, when a force or phenomenon causes the ship to incline, the effect of righting moments will return the ship to the position of equilibrium (upright) through successive decreasing oscillations (damped). In the event of parametric rolling the oscillations will be growing to a certain value.



The Static Stability curve shows the substantial difference between the values of righting arm (GZ) at different inclinations for calm or still waters, for trough at midship section (max values of GZ) and crest at midship section (reduced values of GZ).



The above doesn't mean that any swell seas encountered from dead ahead will result in resonance parametric rolling. A number of conditions have to be met: the direction of the seas from dead ahead, the wavelength similar or equivalent to the length of the ship, the hull geometry to be of the type explained above to cause alternate maximum and minimum water plane area, the height of the wave beyond a threshold value for the vessel (the crest reaching the bow flares and after fuller forms) and last but not least, the frequency of balancing to be half of the frequency of the waves.

Preventing this phenomenon can be difficult, as the resonance (and by resonance it should be read two systems where the vibrations of one causes the other to oscillate at specific frequencies) begins to develop before the increase of the angles of inclination or heel can be noticeable. Some ships have resonance diagrams on board which are calculated by complex mathematical models, others have fin stabilizers or communicating tanks (U tanks).

In the absence of such devices, the speed should be increased as this augment the damping effect of oscillations.

An event such as this and angle of loll (negative initial stability) can be misleading and have grave or fatal consequences.