

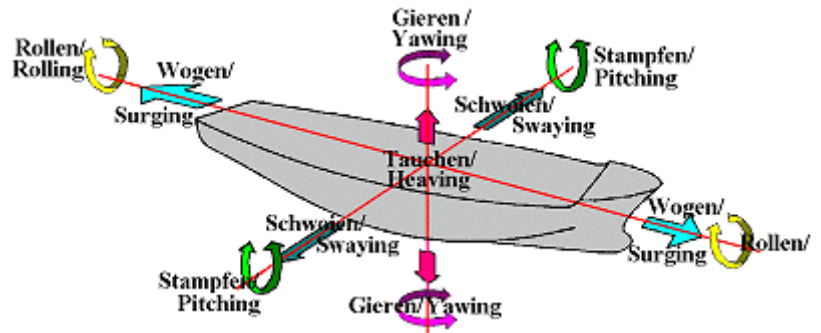
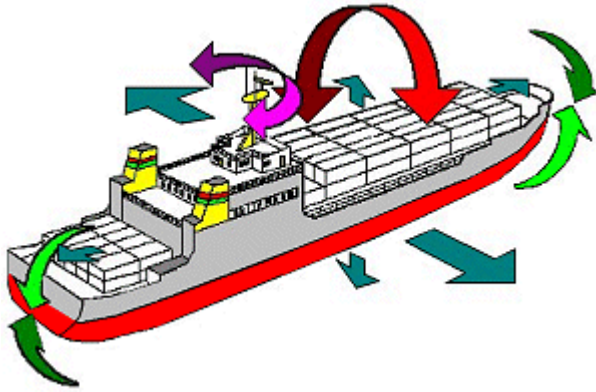
MECHANICAL STRESSES IN MARITIME TRANSPORT

Section 1 "General conditions" in the [CTU packing guidelines](#) clearly states, for example in point 1.1: *Voyages are made in a variety of weather conditions which are likely to exert a combination of forces upon the ship and its cargo over a prolonged period. Such forces may arise from pitching, rolling, heaving, surging, yawing or swaying or a combination of any two or more.*

Point 1.2 continues:

Packing and securing of cargo into/onto a CTU should be carried out with this in mind. It should never be assumed that the weather will be calm and the sea smooth or that securing methods used for land transport will always be adequate at sea.

The acceleration values to be anticipated in maritime transport depend on the shape of the surface or sub-surface vessel, its beam, the position of the center of gravity and center of buoyancy and similar parameters which determine the behavior of ships at sea

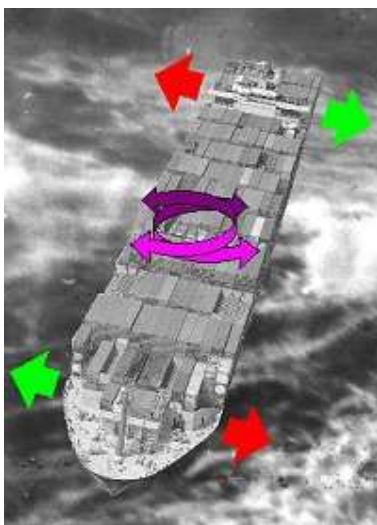


Ship movement at sea

SUMMARY OF SHIP MOVEMENT

All kinds of ship movement may be divided into three types of linear motion and three types of rotational motion.

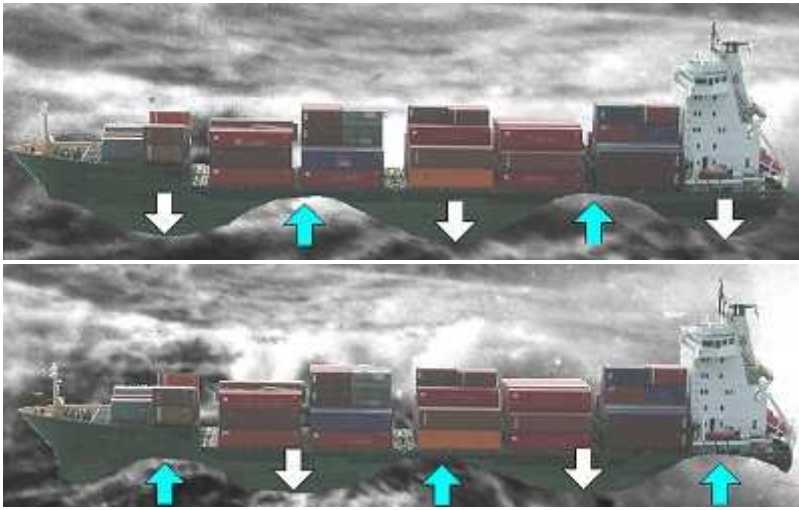
Linear motion	Rotational motion
Surging is motion along the longitudinal axis.	Rolling is motion around the longitudinal axis.
Swaying is motion along the transverse axis.	Pitching is motion around the transverse axis.
Heaving is motion along the vertical axis.	Yawing is motion around the vertical axis.



It can in general be stated that the outwardly directed centrifugal accelerations brought about by any rotational motion are not significant. This accordingly applies to yawing, [pitching](#) and [rolling](#).

Yawing involves rotation of the ship around its vertical axis. This occurs due to the impossibility of steering a ship on an absolutely straight course. Depending upon sea conditions and rudder deflection, the ship will swing around its projected course. Yawing is not a cause of shipping damage

Yawing is motion around the ship's vertical axis

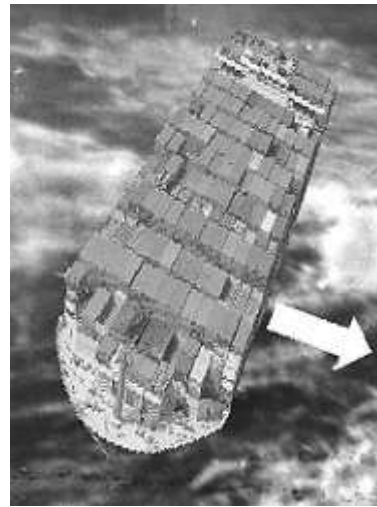


Heaving involves upward and downward acceleration of ships along their vertical axis. Only in an absolute calm are upward and downward motion at equilibrium and the ship floats at rest. Buoyancy varies as a ship travels through wave crests and troughs. If the wave troughs predominate, buoyancy falls and the ship "sinks" (top picture), while if the wave crests predominate, the ship "rises" (bottom picture). Such constant oscillation has a marked effect on the containers and their contents

Heaving is motion along the ship's vertical axis



Surging is motion along the ship's longitudinal axis



Swaying is motion along the ship's transverse axis

In **SURGING** and **SWAYING**, the sea's motion accelerates and decelerates the ship forward and backward and side to side. Depending upon the lie of the vessel, these movements may occur in all possible axes, not merely, for example, horizontally. If a vessel's fore-body is on one side of a wave crest and the after-body on the other side, the hull may be subjected to considerable torsion forces



Pitching is the movement of a ship around its transverse axis

In **PITCHING** a ship is lifted at the bow and lowered at the stern and vice versa. Pitching angles vary with the length of vessel. In relatively short vessels they are 5° - 8° and sometimes more, while in very long vessels they are usually less than 5° . In a container ship 300 m in length with a pitching angle of 3° , a container stowed in the bay closest to the bow or stern at a distance of approx. 140 m from the pitching axis will cover a distance of 29 m within a pitching cycle, being raised 7.33 m upwards from the horizontal before descending 14.66 m downwards and finally being raised 7.33 m again and then restarting the process. During upward motion, stack pressures rise, while they fall during downward motion.



Rolling is the movement of a ship around its longitudinal axis, the rolling angle in this case being 10°.

ROLLING involves side-to-side movement of the vessel. The rolling period is defined as the time taken for a full rolling oscillation from the horizontal to the left, back to horizontal then to the right and then back to horizontal. In vessels with a high righting capacity, i.e. stiff ships, rolling periods of ten seconds and below are entirely usual. Rolling angle is measured relative to the horizontal. Just in moderate seas, even very large vessels roll to an angle of 10°.



Rolling angles of 30° are not unusual in heavy weather.



Rolling angle of 45°

On rare occasions, rolling angles may reach 45° and above. It is easy to imagine what that means for inadequately secured container cargoes.

ROLLING and **PITCHING** of a vessel generate upward and downward acceleration forces directed tangentially to the direction of rotation, the values of which increase with distance from the rolling or pitching axis and are inversely proportional to the square of the rolling or pitching periods. At an identical distance from the axis, if the rolling or pitching period is halved, acceleration forces are quadrupled, while if the rolling or pitching period is doubled, acceleration forces are quartered. Rolling or pitching angles generate down-slope forces. Steeper tilting, as occurs during rolling, promote cargo slippage. As already mentioned, the outwardly acting centrifugal accelerations generated by rotational motion are of no significance in rolling and pitching.

Overall, containers and packages may be exposed to such accelerations for very long periods when at sea. Moreover, the oscillations may be superimposed one on the other and be intensified



Slamming describes the hydrodynamic impacts undergone by a ship

SLAMMING is the term used to describe the hydrodynamic impacts which a ship encounters due to the up and down motion of the hull, entry into wave crests and the consequent abrupt immersion of the ship into the sea



Free surfaces on board always increase the risk of capsize.