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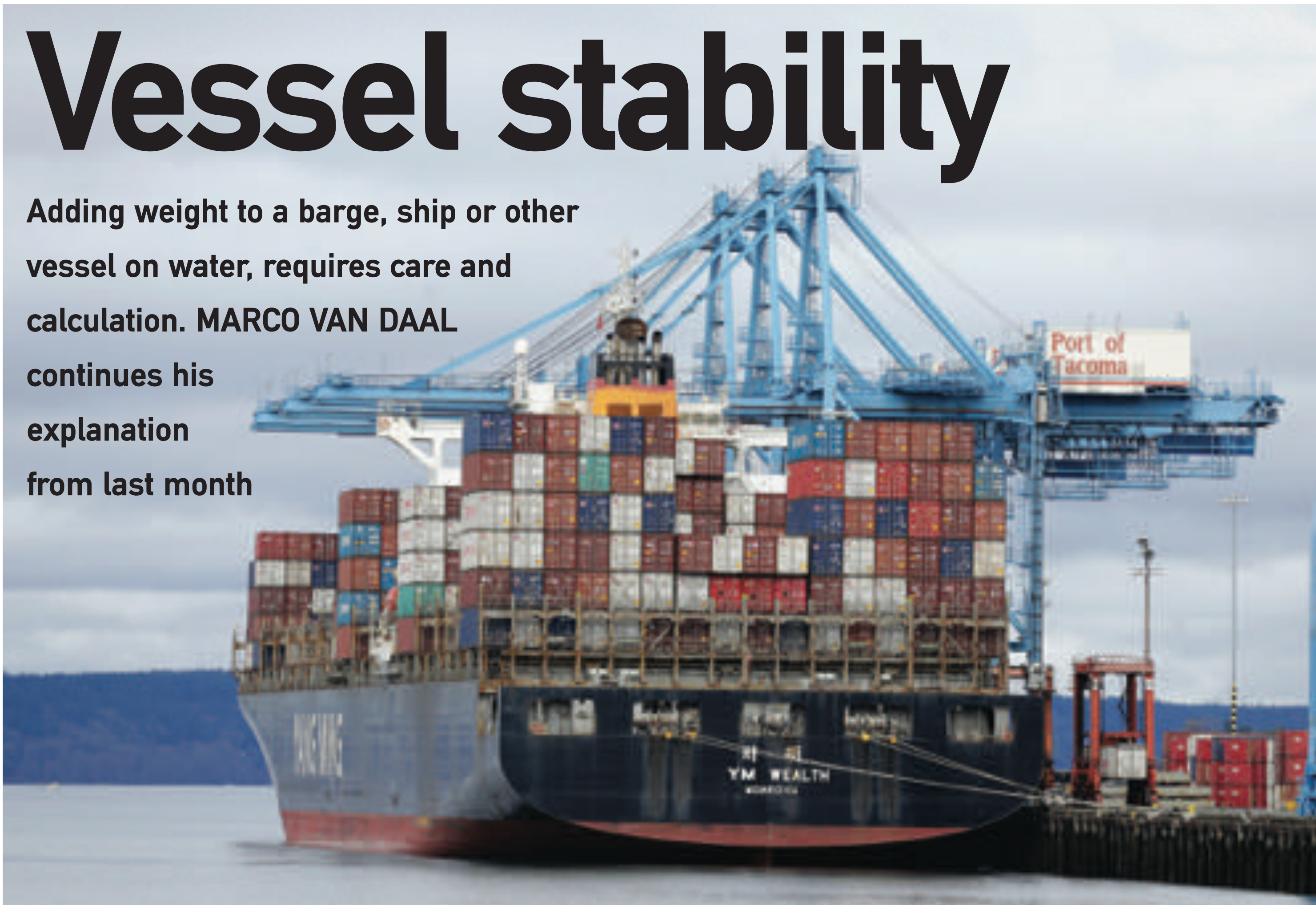
Vessel stability

Adding weight to a barge, ship or other vessel on water, requires care and calculation. MARCO VAN DAAL continues his explanation from last month



A container ship operated by Yang Ming Marine Transport Corp. sits docked at the Port of Tacoma in Washington, USA

With the nautical terms and the buoyancy theory under our belt it is time to move on to the next topic, vessel stability. When adding weight to a vessel, ship or barge, the ultimate goal is to maintain a stable situation (without capsizing) throughout the loading activity as well as during the entire voyage. Added weight can be cargo, fuel, fresh water, ballast water, crew with luggage, supplies, etc.

Additional weight on a vessel will cause it to further submerse (Archimedes law). The vessel will find a new equilibrium where the new buoyancy force (upward) equals the new gravitational force (downward). So far there is nothing new. It starts to become more complex when the buoyancy force and the gravitational force no longer line up and the vessel leans to one side or to one end under the influence of external forces or weight being positioned off-centre on the vessel. See Figure 1.

The question here is how the vessel is being kept from capsizing. Why does the vessel not behave the same as the tree trunk as shown in Figure 2? As the boy makes an attempt to climb on the tree trunk, it will keep rotating in the water, making it difficult (if not impossible) to get on top of it. What makes these two floating objects behave differently? The answer lies in the shape of the object.

Before we go deeper into this, we have to clarify a number of hydrostatic terms

FIGURE 2

ABOUT THE AUTHOR

Marco van Daal has been in the heavy lift and transport industry since 1993. He started at Mammoet Transport from the Netherlands and later with Fagioli PSC from Italy, both leading companies in the industry. His 20-year plus experience extends to five continents and more than 55 countries. It resulted in a book *The Art of Heavy Transport*, available at: www.khl-infostore.com/books Van Daal has a real passion for sharing knowledge and experience and holds seminars around the world.

FIGURE 1

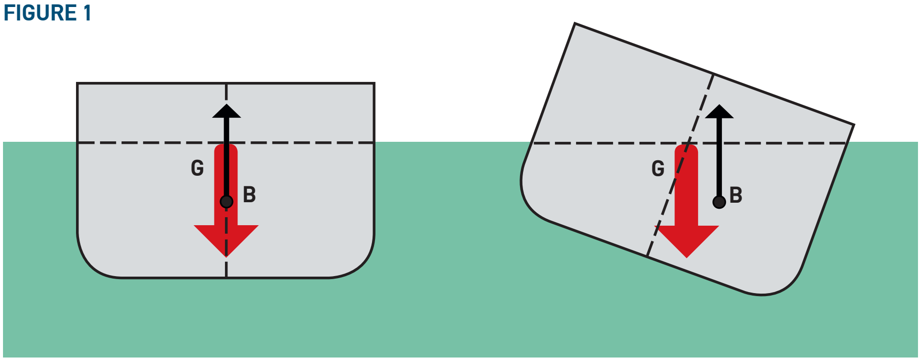


FIGURE 3

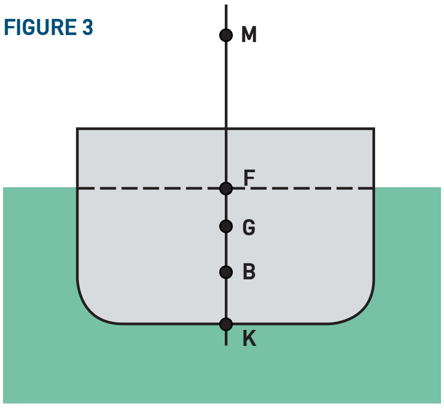
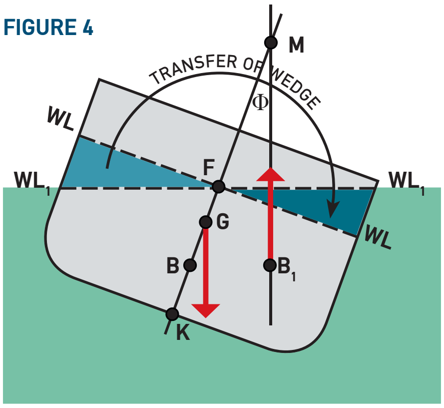


FIGURE 4



that we did not cover in the last article. Figure 3 shows each of these terms on a nautical vessel.

G or CoG stands for centre of gravity
B or CoB stands for centre of buoyancy
F or CoF stands for centre of flotation
M stands for metacentre.

The difficulty with each of these terms is that although they are all locations on the vessel they cannot be seen or measured. They can only be calculated, some only mathematically, some also graphically.

Let's start with the centre of gravity (CoG) as we have covered this in an earlier article. The CoG is actually the combined CoG of the vessel and everything (all added weight) on board. Figure 3 shows the CoG below the waterline, this is just an example, it can be above the waterline as well if the cargo weight is large compared to the vessel weight.

The centre of buoyancy (CoB) is the upward force caused by the weight of the displaced fluid (fresh water or seawater). This is Archimedes Law that we saw two articles ago. The CoB acts on the centroid of the shape of the displaced volume. The CoB is therefore always below the waterline. For many vessels this is an extremely complex calculation to perform due to the shape of the vessel. For that reason there are hydrostatic particulars. These hydrostatic particulars are a table (or a spreadsheet) with CoB values for every draft of the vessel.

The centre of flotation (CoF) is neither below the waterline nor above - it is always at the waterline. The CoF is the point about which the barge moves (rotates or pivots) under the influence of external forces such as the load or cargo, wind or waves. Roll (side to side) movements and pitch (end to end or bow to stern) movements are both about the CoF.

Common point

It is imperative that the CoG, the CoB and CoF are all calculated from the same point. A common reference point is often the point where the horizontal keel line intersects with the vertical bowline.

To explain the location of the metacentre review of Figure 4 is required. Figure 4 shows the same vessel as Figure 3 but is now slightly heeled (leaning to one side) due to an external force such as wind or waves. In this case the heel is not caused by an offset of the cargo as you can see that the CoG (shown as G) is located on the centre line of the vessel. Because of this heel, the shape of the submersed part of the vessel has changed and since the CoB is defined as the centroid of the shape of the displaced volume, the location of the CoB has changed as well. It moved from B to B'.

Note: Heel is a situation whereby a vessel leans to one side. Another term for side-to-side lean of a vessel is list. Both terms are commonly used interchangeably which, in general, does not cause any problems. There is, however, a difference between both terms. Internal forces of cargo and ballasting cause list. External forces such as waves and wind cause heel.

Figure 4 shows the same situation as the situation on the right in Figure 1 and we are back to the question, how is the vessel being kept from capsizing. Here is where the metacentre comes into play.

In Figure 4 we can draw two lines that will indicate where this metacentre is located. The first line we draw by extending the CoB (or B) to CoG (or G) line above the vessel. The second line is a vertical line through B' intersecting with the first line. The intersection point is called the metacentre.

Because the CoG is below the metacentre, the gravitational force acting on the CoG and the buoyancy force acting on the CoB form a moment. See the two red arrows in Figure 4. This moment is called the "righting moment". It prevents the vessel from capsizing. In case of heel caused by external forces, the righting moment brings the vessel back to equilibrium without heel. In case of trim caused by internal forces, the righting moment prevents the barge from capsizing but does not bring it back to a situation without trim.

In Figure 4 the CoG is raised above the metacentre. This moves gravitational force to the right of the buoyancy force. The two forces still form a moment but this is no longer a righting moment as is worsens the list or heel situation. The vessel will capsize as stability is lost.

It can, therefore, be stated that a vessel shows a stable behaviour as long as the CoG is located below the metacentre. Generally a buffer of 1.0 to 1.5 metres is used that the CoG needs to remain below the metacentre.

So why does the tree trunk rotate when the boy attempts to climb on it? The answer lies in the shape of the object. The tree trunk has a (near) perfect round shape. When it slightly rotates, the shape of the submersed part of the trunk has not changed and, therefore, the CoB has not moved either. As long as the CoB is on the same vertical line with the CoG there is no righting moment to correct or stop the rotation.

Loading cargo

When loading cargo on a vessel, it is obvious that not all can be placed on the centre line. Some will have to be placed off-centre and this causes a list. Even though the righting moment prevents the vessel from capsizing, it is not a desirable situation to set sail when the vessel shows a list. It has an effect on fuel consumption as well as on the wellbeing of the crew. Ballast water is used to compensate the list to (near) zero.

When performing a roll-on operation (shore to barge) we make use of the same principles. Generally, the aim is to roll onto the barge where the CoG of the cargo lines up with the centre line of the barge. This minimises the ballasting to compensate the list. With a roll-on we also have to keep the trim of the barge under control as well as the draft. The trim is important as it is ideal to drive onto a barge that neither has an inclined nor a declined deck. When driving onto a barge with a long vehicle (20 plus axles), keeping the barge with minimum trim is important to avoid a situation where the vehicles run out of cylinder stroke or suspension travel.

The draft is important to maintain as this allows a smooth transition from shore to barge. As the first axles enter the barge it will submerse and this has to be compensated, either by an incoming tide or by de-ballasting. In addition, the opposite end of the barge also has to be ballasted down to maintain a (near) zero trim. The CoF can determine how this can be achieved with minimal effort.

Next month's article will focus on roll-on operations in both tidal as well as non-tidal conditions. ■