Why do ships float?

The first instalment in Gard News' non-mariners' guide to ship construction and operation. With the growing specialisation of jobs within the marine insurance and international trade industries, today many people working with ships on a daily basis may not fully understand certain practical and technical aspects of the trade. This is often the case with the growing number of maritime executives without a technical background or previous sea-going experience. So, for all of you non-mariners out there, Gard News is starting a series of articles explaining some basic aspects of ship construction and operation. The first article of the series explains why ships float, which seems to be an obvious place to start.

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Density

In order to establish why ships float one needs to look at the principle of density. Everybody has an idea of what density is. Density describes how much something weighs relating to its size, or mass per unit volume. In technical terms, the density of a body is defined as the weight (mass) of the body in kilograms (kg) divided by its external volume in cubic metres (m^3). The formula for density is: density = weight/volume (kg/m^3).

Some examples of density for different fluids and materials are:

Fresh water: 1,000 kg/m^3

Salt water: around 1,025 kg/m^3

Certain oils: around 850 kg/m^3

Steel: 8,000 kg/m^3

Wood: around 700 kg/m^3

From the above, only oil and wood naturally float in water. This is because fluids and materials that float in water have densities that are less than the density of water. In other words, an object's buoyancy is determined by its density in relation to the density of the surrounding liquid.

When applying this principle to ships, it is natural to question how a ship that has a hull made of steel, which has a density eight times greater than that of water, can float. A steel bar would sink, so why don't ships?

Archimedes

In the third century BC, the Greek mathematician and philosopher Archimedes discovered the principle of buoyancy while relaxing in a bathing pool. When he entered the pool he noticed that water spilled over the sides and that he felt lighter. Archimedes realised that the amount of water that spilled was equal in volume to the space that his body occupied, and concluded that an object in a fluid experiences an upward force equal to the weight of the fluid displaced by the object.

Because the upward force equals the weight of the fluid displaced, an object must displace a greater weight of fluid than its own weight in order to float. That means that in order to float an object must have a lower density than the fluid. If the object's density is greater than that of the fluid, it will sink.

The density of ships

Although ships are made of materials that are much denser than water, the density of a ship itself is its total weight (including, cargo, bunkers, stores, crew, etc.) divided by the external volume of the hull. This means that the hull must have an external volume that is big enough to give the whole ship a density that is just less than that of the water in which it floats. Ships are therefore designed to achieve that. Much of the interior of a ship is air (compared with a bar of steel, which is solid), so the average density, taking into account the combination of the steel, other materials and the air, can become less than the average density of water.

When the metal hull of a ship is breached, water rushes in and replaces the air in the ship's hull. As a result, the total density of the ship changes and depending on the extent of the change, the ship may sink.

Freeboard

In the past, ships built and loaded in Europe would sometimes sink when they reached the tropics for the first time. Cargo would have been loaded in cold, salty waters, but then when the ship reached warmer, less salty seas, it would sink. This was because Archimedes' principle, described above, would not have been taken into account. When the ship was first loaded it would float because cold, salty water has a higher density than fresh water, which meant that less water had to be displaced to equal the mass of the ship. Once the ship entered warmer, less salty waters, more water had to be displaced to maintain equilibrium. The ship would drop lower in the water - and if it dropped to below the water line (the line where the hull of a ship meets the water surface) it would sink.

This problem was overcome in the 1870s by Samuel Plimsoll, who marked ships with what became known as the Plimsoll Line, a marking positioned amidships, which indicates the draft of a ship and the limit to which a ship may be loaded for specific water types and temperatures.

A safety margin between the deck and the water line was made mandatory by the 1930 Loadline Convention (now replaced by the 1966 Loadline Convention, as amended). This safety margin is created by increasing the external volume of the hull so the deck line rises well above the water line. This safety margin is known as freeboard.

Where a freeboard is incorporated, the density of a ship becomes the total weight of the ship divided by the external under water volume of the hull (including the shell plating, propeller and rudder).

Displacement tonnage

A ship's displacement is the volume of water it displaces when it is floating, and is measured in cubic metres (m3), while its displacement tonnage is the weight of the water that it displaces when it is floating with its fuel tanks full and all stores on board, and is measured in metric tons (MT, equivalent to 1,000 Kg). The displacement tonnage is the actual weight of the ship, since a floating object displaces its own weight in water.

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