ASYMMETRIC SOLIDS MOVE FASTER IN WATER WHEN THE BLUNTER END LEADS

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Abstract

Two identical but asymmetric solid bodies are pushed by the same force through water with opposite configurations. When the front end is more blunt and the back more pointed, that body moves more quickly than the other one does and wins the race every time by a considerable margin. This result runs counter to the intuition of many technical and non-technical people. A qualitative explanation is offered in terms of reaction forces of the water on the solids, which is based on Newton's third law (action equals reaction).

Key Words: blunt fronts are quicker

1. Introduction

Most non-technical and technical people alike, and of all ages, think that a solid moves easier through water when the front end is definitely pointed, and the back end is usually less pointed, or apparently its shape doesn't matter so much. For example, the majority of boats and ships have been made with pointed bows (and flatter sterns) for thousands of years. How this notion originated and got so firmly locked into people's minds is hard to determine now. Nature certainly did not come up with that solution. Just the opposite in fact. Many creatures that spend considerable time moving through water have evolved a body plan that has a blunt front and a pointed back. A fish has maximum thickness much closer to its mouth than to its tail. What follows is an attempt to better understand this potentially confusing situation: people vs. nature.

In summary, a general concept in fluid dynamics, for flow past a solid body, is illustrated by a particular experiment. Newton's third law, action equals reaction, is the general concept applied here, but it has been used very little if at all in the fluid mechanics publications of the past [1].

For the particular solid body adopted in the experiment a circularly symmetric buoyant hard wood was selected that was shaped like two cones back to back with equal bases but altitudes that are significantly different; called a cone/cone for simplicity. Where the bases join the surface ridge was smoothed to avoid eddy shedding, and a small hole was drilled down the long axis. Two identical cone/cones were made in order to have a race between them with opposite configurations going first through the water.

Although it was easier originally to explain the reaction force concept within a two dimensional context [1], the experimental application presented next is fully three dimensional.

2. Flow Plan

In the deep end of a swimming pool, in 250 cm of water, two taut thin plastic lines were set up vertically and 10 cm apart. Along these lines the two cone/cones were to rise up to the surface from a standing start at the bottom, driven only by buoyancy.

Each cone/cone is 20 cm long with a maximum width of 5 cm located 3.5 cm from one end and 16.5 cm from the other end. They were made from mesquite wood and they weigh the same in air. The aspect ratio of the two altitudes of the cones in a cone/cone is based on that obtained from the photograph of a fish taken from above and published in a magazine [1].

Sliding of the cone/cones along taut lines is necessary because otherwise when the one with the more pointed front rises up unrestrained, it is unstable and will flip around 180 degrees. That by itself is a signal that there may be something not optimum with that configuration for easy movement through a fluid.

Friction is not of the greatest importance in this project because, for one thing, the surface area of a cone/cone is the same whichever way it moves through the water, as long as it has the same speed relative to still water. Also since both ends are pointed no eddies are expected to be shed from either one, which would have had the effect of increasing the frictional drag one way more than the other if one end were not pointed but spherical, for example.

Since the buoyancy force is exactly the same for both cone/cones, when fully submerged in water (according to Archimedes), the differentiating factor between them is the distribution of the reaction forces, which is what the trial runs were designed to illustrate.

3. Result

There is only one result: when the blunter end of a cone/cone goes first through the water, it beats the cone/cone with the more pointed end in the front every time. It does not matter which line the blunt ended cone/cone takes; it does not matter which cone/cone it is. And the race is not even close. The first cone/cone to break the surface does so by more than four lengths, where one length is 20 cm, as can be seen in a video taken of one of the trials.

One additional point to be made is prompted by the observations: since the cone/cone with the more pointed front moves slower through the water, it will experience somewhat less friction than the other cone/cone does, because the friction force depends on the relative velocity between the fluid and the solid (actually on the square of the relative velocity). And still it came in second! What can be inferred then, since the buoyancy force is the same magnitude and direction for both cone/cones, there is a third force of the same order of magnitude as the other two which acts in the same direction as the buoyancy force on the blunter front cone/cone and in the opposite direction as the buoyancy force on the more pointed front cone/cone. That third force has been called the reaction force [1], described in more detail next.

4. Explanation

With respect to the solid surface of the cone/cone rising through the water, the laminar flow increases in speed to a maximum at the thickest part of the body and then decreases again to the same starting value at the back end. Thus, next to the solid surface the fluid first accelerates and then decelerates. It takes a force to cause acceleration and deceleration which the solid body makes happen. Action equals reaction (Newton’s third law) produces equal but opposite forces of the fluid back on the body, called reaction forces. At the front end the reaction force points in the same direction as the buoyancy force. At the back end the reaction force points in the opposite direction as the buoyancy force. If the body is symmetric front to back, there will be no net reaction force on the body. For a cone/cone with a more pointed back and a less pointed front, there will be a net reaction force aiding the buoyancy force. Just the opposite will be true for a body with a more pointed front and a less pointed back: the net reaction force will oppose the buoyancy force.

A qualitative explanation has now been given for the main result of the experiment: a solid body with a more pointed back and a less pointed front will go through water more quickly than the other way around when the force pushing it is the same. Unfortunately, the experiment and its explanation cannot be made quantitative at this time due mainly to the lack of detailed information about the friction force. Also unfortunate is the fact that the explanation goes against a large body of intuition that has been building up over a period of many years.

5. Discussion

All trial runs of the cone/cones ended the same way, but some variations in details occurred from run to run. Probably the reason can be tied to the rather crude method of releasing them at exactly the same time from the bottom of the pool. A long pole with a cross piece at one end pushed the cone/cones down the taut lines, and the cross piece had two grooves in which the lines fitted loosely.

On one trial the cone/cone with the blunter front got off to a slower than usual start for some reason. Then it accelerated and passed up the other cone/cone and so reached the surface first. At no time was the cone/cone with the more pointed front ever observed to accelerate upward.

One relatively minor improvement for a future experiment is the following. Mesquite is a hard wood, but it rises very quickly through the water, which is especially true for the blunter fronted cone/cone. In order to slow down the trial runs to make watching them easier, a denser hard wood is suggested. Iron wood is known to sink in water, so some wood between mesquite and iron wood could be appropriate. Alternatively, time can be slowed down by means of a video whatever type of wood is chosen.

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Reference

[1] Kenyon, K. E. (2006) Reaction forces of fluid flows on solid boundaries. Phys. Essays, 19, p.507.