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Symmetry and Symmetry Breaking in Boats, Its Propulsion Methods and Navigation Techniques

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Abstract. Destroying common symmetries existing in our life is often very hard and almost impossible to attempt it, since it seems to be an offence to the natural principle. Contrarily, however, symmetry breaking introduces sometimes enormous practical advantages. Some examples, about boat are discussed. Common characteristic in these cases is the fact that ideas of employing asymmetry were not created by particular person(s) but were born based on daily experiences of ancient people over a long time scale.

1. Introduction

Good symmetry in every day life often gives us a feeling of “normal”, “natural” and “not strange”, which has a passive effect, even if it is not exciting. On the other hand, destroying good symmetry often gives us a feeling of “relaxing” and “familiar”. Sometimes, the regularity and perfect symmetry works very actively and gives a sense of “authentic”, “orthodoxy” and “an obligation”, as if breaking symmetry should be a matter of damaging common sense or being against the nature and God’s will.

However, destroying such taboo could introduce a great advantage which has not been expected. Here are shown several examples that happened in the history of boats, along with their propulsion modes and behavior in navigation.

2. Symmetry in Boat Propulsion: Rowing

The commonest, the simplest and the most primitive way of propulsion of boats or any floating object would be the rowing in normal way. This is of an old origin, probably about the same époque of beginning of the human being. Any child, even a monkey or a dog, floating on the water normally does a similar action.

The rowing by an oar can be shown symbolically in Fig. 1.

The rowing is to push the oar in the water towards exactly in the opposite direction of the propulsion, keeping the oar plate perpendicular to its motion. Anyone, without doubt, may imagine and even believe that this is the most natural and efficient way of rowing a boat. It sounds natural and almost obvious, even if not logically concluded or experimentally

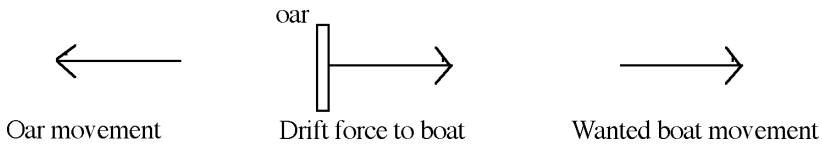

Fig. 1. The normal rowing that with a good symmetry.

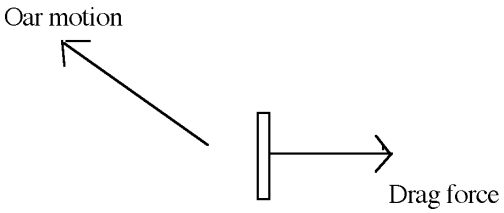

Fig. 2. An example of the broken symmetry of rowing.

demonstrated. Therefore, this way of rowing is not a special invention or discovery but a common action for any people in the world, just as the creation of a boat itself (or even as the swimming). The rowing is perfectly symmetric both in position and in movement. Can the reader imagine who would row in asymmetric way? For example, the simplest possible way (the only possibility way of destroying the symmetry) is to change the direction oar movement (Fig. 2). Turning the oar angle from that perpendicular to the boat movement is exactly identical.

Before discussing on this possibility, let us look, at another old mode of boat propulsion, that is the wind sailing.

3. Symmetric and Symmetry Breaking Sailing Down in the Wind

From ancient time the best wind for sailing is considered to be the wind blowing from behind your boat. This condition is called to sail before the wind (running is the modern sport technical term), vent arier (French), aver vento in poppa (Italian), otte ni ho kakete (Japanese), etc. In fact such phrases are also used commonly to express a favorable condition or a good luck. However, as is well-known, it is not necessarily the best condition of sailing, i.e. *not the fastest* or safest but creates a delicate situation. Since it could strongly depend on the type of sail, we have to limit to sail types that enable 2D plane projection. Let us consider for example a common type of boat and sail, i.e. the sloop.

General aspect: The relation between the boat movement direction relative to the wind and the speed of the boat is generally shown in Fig. 3.

Typical characteristics shown in this experiential result are listed below:

(1) There is an impossible angle zone against the wind. It has been a big problem from the ancient time to make this zone smaller and to allow sailing up to the wind direction.

(2) The curve just out of, the forbidden zone, depends delicately and strongly on the types of boat and sail. This property has been also an essential problem historically, with

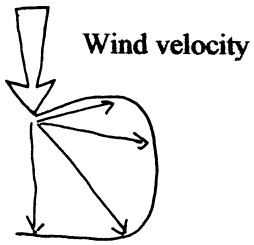

Fig. 3. Boat speed as a function of the boat movement direction relative the wind (not the direction of boat itself).

demand to go toward the windward that was almost impossible. It is noted that the maximum speed is at an angle far from the wind direction.

4. Advantage of the Symmetry Breaking Down Wind Sailing: Bon Plein

Our present interest is the advantage of the navigation with a wide angle far from the wind direction, in other words, a fairly large asymmetric sailing is better, since that lead to, faster and more efficient sailing. *Why does this happen*?

Firstly, in the symmetric sailing since relative velocity of the boat and the air is very small, the pushing power of the wind is poor. Secondly, the air coming perpendicular to the sail create a lot of vortices, and looses its energy.

On the other hand, the sail inclined from the wind direction can avoid this effects and the air flow along the sail becomes much smoother and effective (Fig. 4).

This way of sailing is commonly called *bon plein* (well inflated in French) due to the shape of the sail, as is explained in a popular text book of navigation "*Cours de navigation des Glenans*".

There is another advantage for off-symmetric sailing. The wind is not constant both in strength and direction, and waves also disturb the boat. For the symmetric sailing, these effect make a main sail flip to the other side, i.e. an unwanted jibing. This is very dangerous and also decelerate the boat.

5. Symmetry Breaking Rowing is Possible, Then?

The above notion suggests a possibility that the *off symmetric* movement of the oar as shown in Fig. 2 *could also have a larger drag*. Is it true? If it be true, the strange *asymmetric* rowing as in Fig. 2 should be more efficient than the symmetric (Fig. 1). It is worth noting that a simple experiment in an artificial canal in University of Trieste is now taking place.

Let us imagine that the oar is inclined roughly 45 degrees in the case of transversal rowing (see Fig. 5)*.

*It is easy to understand that the up-side oblique rowing movement (or left side of the boat motion) in Fig. 2 is exactly same as down-side (or right side) oblique rowing. Therefore two ways of completely different rowing in Fig. 5 relative to the boat are same relative to water and makes the same effect to the boat.

Fig. 4. Flow around the oar of the symmetric case and not symmetric.

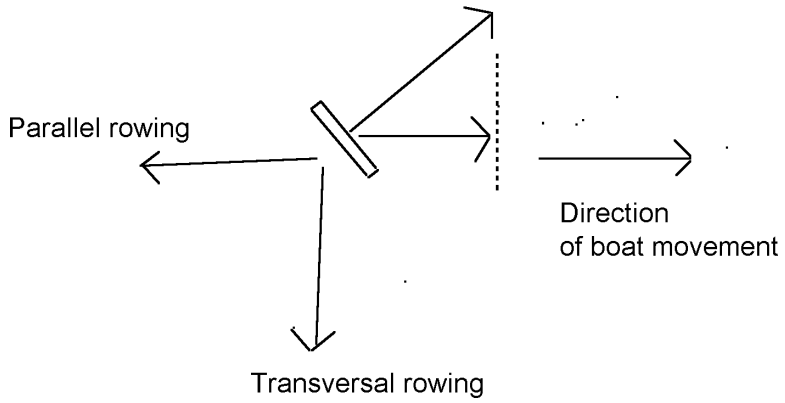

Fig. 5. The effect or the drag strength of both very distinct oblique rowings should be exactly the same.

Then the drag and its component in the boat movement is exactly the same in the cases of both backward and lateral rowings. Both of these rowings *could* be more efficient than the usual and trivial symmetric rowing as Fig. 1. This possibly better efficiency, however, is *almost negligible* comparing to the fact mentioned below, which would lead us to a revolutionary conclusion.

6. Many Advantages of the Symmetry Breaking Way of Rowing

The symmetric longitudinal rowing obliges to pull up the oar out of the water surface after one stroke of the rowing and then to bring it back to the initial position. On the other hand, in the other way, say *transversal rowing*, one does not need to bring back the oar to the initial position, but to push the oar keeping in the water just only rotating the oar in the opposite inclination. This transversal rowing has an enormous advantage of saving work.

This rowing has a new symmetry, since in every stroke the oar changes inclination as

completely symmetrically relative to the boat direction. This fact does not only assure an labor economy, but also simplify the oar movement and in consequence enable an improvement of oar type so as to suppress turbulence. Further improvements are possible, such as

1) to increase the oar size, 10 times, 30 times, even 50 times or more, and row slowly,
2) to change the longitudinal shape of the oar, to give bending,
3) to change cross section from a flat plate to that of wings of airplane,

The advantages do not end here, the modification of oar type mentioned above makes possible a effective part of the oar much deeper in the water. This can reduce the relatively less efficient part near the water surface (where waves and turbulence are easily created).

7. The History of Transversal Rowing

Has such an efficient boat propulsion method ever existed? The answer is, very surprisingly, yes! It is not invented by a technician or a scientist but by ancient people based on daily experiences.

It is certain that it already existed in ancient China and exists still now. The word *wasen-kogi* exists in Japan and was introduced probably from China of Tang Dynasty in 7-th century, later more evidently in 11-th century.

The English word '*scull*' is unknown origin (probably very old). It is very similar to the Japanese '*wasen-kogi*'. The rower faces to the side of the boat.

In North Atlantic coast in France, there is a word '*godille*' (verb '*godiller*'). Again the origins of this word and method are obscure, so long as referring to the dictionary. It is very easy to learn to row in this way even a big boat of length 20m. This is the strong contrast to the normal symmetric rowing and even to other transversal rowing modes.

Such rowing exists also in Lake Titicaca in Bolivia among the local indigenous people living on floating islands on the lake.

In North Italy, Venetian lagoon, exists a similar method '*voga*' (verb '*vogare*'). It appeared in 13-th century coming probably from Far East (China or South Pacific islands?).

Since this transversal rowing is not a trivial idea and even against natural human sense, the method is considered not to have been created independently at many places in the world. It is natural to suspect that it was born in a region somewhere in Pacific or Indian Ocean, islands or along their coasts in ancient time, among some people, and then propagated along coasts.

8. Progress of Rowing Lead to a Revolution "Screw"

In many centuries Venetian people lived practically on the water. Pieces of land also have been made by themselves piling up stones etc. They are naturally much more sensitive to new techniques about boats than any others. When Venetian people accepted this new technique, the Venetian Republic was the most advanced country of the world in culture, science, literature, music, theater, play, etc.

This popular rowing method voga uses *forcola* to support a oar with three or four steps working as a gear change of automobile and also for a back march essential in narrow canal. At the support the oar is not fixed tightly, so that continuous gear change and the most

effective application of human effort becomes possible as in CVT. Since the voga deviates boat a bit left direction due to the right board rowing (probably caused by the old keep-left rule vigorous in narrow canals), they invented a unique asymmetric boat bending towards right side board, i.e. the well-known gondola. Note that the invention of screw seems to have happened in this region. Probably this was a military top secret during the epoque of the transition from Venetian Republic to Austro-Hungarian Empire. But, this marvelous invention needed a realization of engine to make it into practice. Obviously, the inventor is not known, probably boat-oar carpenters, and it needed almost one century of time for popular application of screw to boats.

It should be noted that the invention of screw seems to be a modification of vogare gondola to a new mechanism (rotation) by people of Venetian lagoon, not by Austro-Hangarian, typical inland people.