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Sub.: Contribution to the paper by the Triantafyllou brothers
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translated from Scientific American (March 1995) 40/48.

Working on the principles of propulsion for thirty five years I jumped of course onto the article by the Triantaffylou brothers with great interest. But to my disappointment the paper repeats mostly things, which have been described before by other authors much more carefully and in greater detail, also in the Scientific American; Spektrum der Wissenschaft (September 1984) 84/97.

My impression, to stay with the editorial paradigm of the Scientific American, was largely based on the German translation of the paper of which I first got hold. In the original version of the paper, which I saw only later, I found some points more carefully phrased.

But already in its first paragraph the paper sets the scene, giving the impression that technical solutions are far inferior to natural, maybe due to our lack of understanding the principles of nature. This impression is certainly wrong as will be outlined shortly. In order to keep this discussion to a reasonable length it is restricted to the aspect of propulsive efficiency. The aspects of rapid acceleration and narrow turning circles are not concidered.

To start with the most fundamental things: Naval architects select large diameters for their propellers even if there are no losses due to rotation of the wake as e. g. in the case of contra-rotating propellers. The reason is that with increasing diameter the loading of the propeller decreases and propulsive efficiency increases correspondingly.

In the case of propellers for deeply submerged vehicles the loading of the propellers is generally so low that the losses due to rotation in the jet are of minor importance. These losses can best be avoided by the design of hull and rudder as stators. Additional stators would increase the frictional losses!

This very simple idea lead to a very successful development between the world wars, patented as Star-Contra-Configuration, which was widely introduced in the commercial fleet and was expected to become standard in ship design; R. Wagner: STG 30 (1929) 195/256. STG is the acronym for Schiffbautechnische Gesellschaft, the German Society of Naval Architects and Marine Engineers.

Wagner refers to his first presentation of the idea at the annual meeting of the STG in 1905 and the research by E. Foerster and W. Kucharski among others. According to usage at his time he is speaking of 'contra-propellers', although only stators are being considered. This concept has been re-invented after the second world war, pre- and/or post-swirl configurations having been subject of much funded research. But nobody does evidently care to read what our grand-fathers already knew about the subject.

Contra-rotating propellers proper, in modern terminology, are being used at torpedoes for the compensation of torques, i. e. to prevent rotation. The reduction of rotational losses is a by-product. In order to simplify the design stators are being considered as well. In nature the propulsion of penguins, i. e. the vortex streets they shed very nearly approach those of large contra-rotating propulsors. Hulls and propulsors are perfect and perfectly matched. That is how nature (God) does it, knowing its (His/Her) momentum principle. Relevant among others is the research of R. Banasch, now at the Technical University Berlin (TUB).

The concept of vortex streets consisting of interlaced vortex rings, attributed to R. Blickhan (1992) in the German translation of the original paper, is known to German naval architects at least since 1950, when Dickmann published his beautiful little paper on ship propulsion by intermittently operating propulsors in Schiff und Hafen 2 (1950) 252/269. But already Föttinger knew most of this and taught it to German naval architects right after the first world war; STG 19 (1918) 385/472. More recent is the related research by Hertel and his followers at the TUB under the heading Technology and (und) Biology (TUB/TUB), which is still going on.

By the way, it was Föttinger who invented the hydromechanic clutch installed in every American car, while it is still not so popular in Europe. As an electrical engineer in his early career he invented the electrical analogue and only the low technical standard of the electrical industry at that time forced him to switch to the hydrodynamic pendant and let the much more advanced pump industry build it. Large systems, not only very large hydrodynamic clutches, but multiple stage hydrodynamic reduction gears, have been built for ships in the early days.

The disadvantage of intermittent propulsor operation are the higher losses as compared to steady operation. The reason are the concentrated vortices shed. More efficient are steadily operating propulsors shedding uniformly distributed vorticity, vortex cylinders. The technical solution approaching ideal propulsion is the ducted propeller with an actuator consisting of rotor and stator. Due to the frictional losses at the duct this solution is superior to open propellers only at sufficient loading. This line of thought is followed at many places world-wide, at MIT as well; J. E. Kerwin et al. Transactions Society of Naval Archtitects an Marine Engineers (SNAME) 102 (1994) 23/56.

As every other propeller design is now wake adapted, ducted propellers can be perfectly adapted to the wake of the hull, i. e. recovering energy not only from different sources, e. g. some other vehicle moving somewhere ahead, but the vehicle's own losses. This was known to naval architects since R. E. Froude presented his famous paper: A Description of a Method of Investigation of Screw Propeller Efficency. Institution of Naval Architects (INA) 24 (1883) 231/255, now Royal Institution.

Sailors have always taken advantage of the trade winds and everybody knows that geese and swans are taking advantage of the vortices shed by their predecessors, while dolphins are frequently just taking advantage of the ships' waves to achieve their fabulous performance. And of course sailors take advantage of the vortices shed by their competitors' sails.

Sailing in ones own wake, as the naval architects do and the authors mention, is of course tricky. Everybody has to go through the mental exercise himself, that the creation of extra wake, to be utilized with advantage, does not pay. The increase in the configuration factor of merit is by far out-weighed by the additional power needed.

A change of paradigm in the theory of ship propulsion based on an innovative concept of hull-propeller interaction permits a wake adapted design approach treating all interactions between hull, duct, and actuator implicitly without approximations; Schmiechen, M.: Design and Evaluation of Propellers as Pumps. Centenary of the Krylov Ship Research Institute, St. Petersburg, 1994.

Such an approach and the corresponding evaluation methodology are necessary for advanced hull integrated propulsor concepts; Schmiechen, M.: 2nd INTERACTION BERLIN '91; Proceedings of the 2nd International Workshop on the Rational Theory of Ship Hull-Propeller Interaction and its Applications. Mitteilungen der VWS, Heft 57, 1991.

It was one of the authors, who deliberately decided that the presentation of these advanced ideas based on a sound theory of knowledge might not be suitable for members of the Society of Naval Architects and Marine Engineers at New York in 1991. His verdict was, that the theory of knowledge might be required for the physical sciences, but certainly not for the engineering sciences!

The comparison of the efficiency of some fish propulsion with that of some badly designed propeller in the paper is totally misleading. Due to the fact that the propulsive efficiency of any propeller depends on the loading a valid comparison of different propellers at different operational conditions, assuming nearly the same design conditions, can only be based on the pump efficiencies of the propellers.

When we want simple propulsors we will certainly not copy whole fishes, but better check with nature and the patent literature on propulsion. The simplest propulsion mechanism we find in nature is the systole and diastole of medusas. In technical terms a piston oscillating in a cylinder open in thrust direction does the job, including high accelerations, which I wanted to exclude from my discussion. Due to the different flow patterns at suction and ejection, i. e. due to the nose effect saving us from being poisoned by our own exhaust, the sytems work very effectively, but clearly not with the highest possible efficiencies.

The field of propulsion has always been the playground of inventors. And evidently every inquisitive mind has to re-invent the fish tail on his way to maturity. It's like the measles. The naive drive to out-smart the experts by finding nature's still secret, superior principles of propulsion will be greatly encouraged by the present paper. The new do-it-yourself paradigm in science promoted by MIT is spreading like mushrooms.

And everybody will want to be at least as innnovative as MIT and to take advantage of that wave. I foresee the hordes of researchers sitting down and writing proposals. How far away are we from the age of reason and the reasonable use of our intellectual and financial resources?

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