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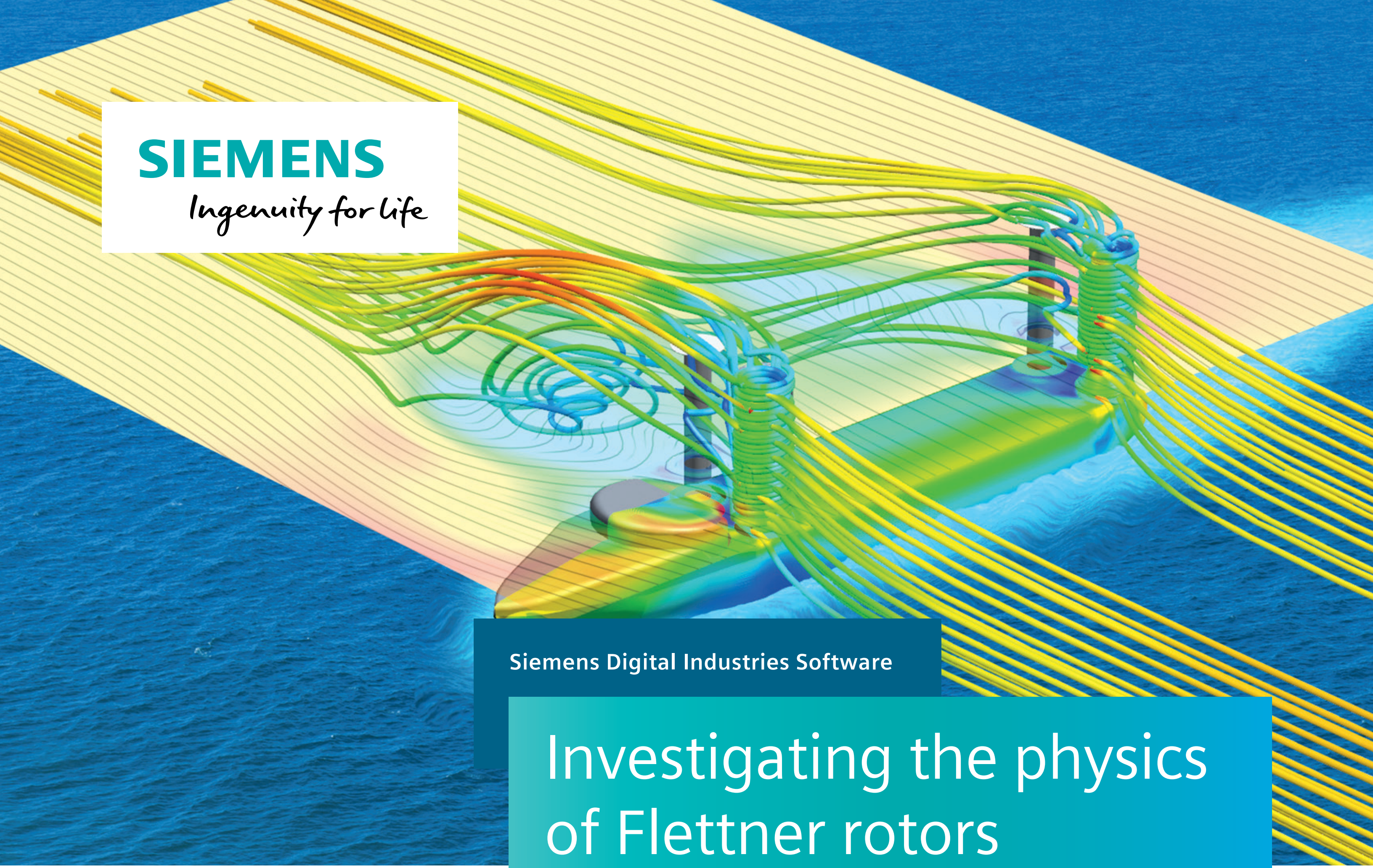

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Investigating the physics of Flettner rotors

Simcenter FLOEFD aids understanding of rotor sails

Executive summary

Rotor ships are propelled, at least in part, by large powered vertical rotors, sometimes known as Flettner rotors or rotor sails. These ships are designed to use the Magnus effect for propulsion – when wind meets the spinning rotor, the air flow accelerates on one side of the rotor sail and decelerates on the opposite side. The change in the speed of air flow results in a pressure difference that creates a lift force perpendicular to the wind flow direction. Investigation using Simcenter™ FLOEFD™ software helps understand the physics behind the phenomenon.

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Background

About 15 years ago, I became aware of the Flettner rotor in a book about forgotten inventions. German aviation engineer and inventor Anton Flettner invented a rotor ship, equipped with the rotors named after him. The rotors use the Magnus effect (named for the experimental scientist Heinrich Gustav Magnus). Two rotor ships were built in the 1920s: one, the Buckau (renamed Baden-Baden), even sailed from Germany to America and back.

The second ship, the Barbara, was equipped with two diesel engines and three rotors and has been used as a commercial freighter in the Mediterranean. With wind force 5, it ran at 13.5 knots (kn) operating with diesel engines (powering the ship propeller) and rotors simultaneously. Running with the diesel engines only, it ran at 10 kn. Using the rotors only, without diesel engines, it was almost as fast at 9.5 kn. This means the rotors were able to achieve almost the same ship velocity as the diesel engines. In the single rotor operating condition, the Barbara gained almost the same speed as the single diesel engine operating condition. The economic crisis, cheap oil and increasing performance of diesel engines, with which these kind of sails could no longer compete, unfortunately sealed the end of this technology in the 1930s[1].

A few years ago, as a young application engineer, I tried to reproduce this effect, but I did not succeed in successfully simulating the Magnus effect. Some time later, a colleague drew my attention to this technology again, because it has again been fulfilled and applied in today's shipping industry[2,3]. In the meantime, rotating capabilities were developed for Simcenter FLOEFD, prompting me to pick up this example again.

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Simulating the Magnus force

The Magnus force, which is the main influencing factor, can be simulated in Simcenter FLOEFD. Figure 1a shows a rotating cylinder.

A rotating, round object in an airstream experiences a force transverse to the flow direction. This is illustrated in Figure 1a by the blue low pressure area above the cylinder.

The modern application of the Flettner rotor offers one main advantage. A rotating cylinder produces a force transversely to the air flow direction through the Magnus effect of suction and compression forces. The forces of the rotors are generated by the rotation and act transversely to the wind direction. Hence, they do not generate any savings in situations where the resulting wind direction is directly from the front or from behind, comparable to sailing "in irons" or "running with the wind." The greatest advantages can thus be achieved when the wind comes from the side. The speed of the rotor must be adapted to the wind speed. At higher wind speeds, the rotor speed is also increased so that high drive energy is also to be provided for the rotors at high wind energy. Modern measuring and control systems enable efficient adjustment of the speed and direction of rotation and therefore make this technology interesting again in terms of fuel savings.

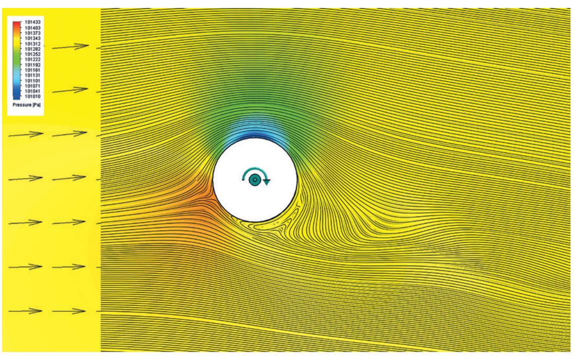

Figure 1a: Rotating cylinder

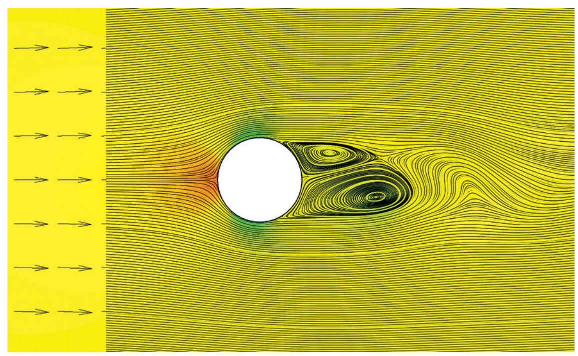

Figure 1b: Stationary cylinder

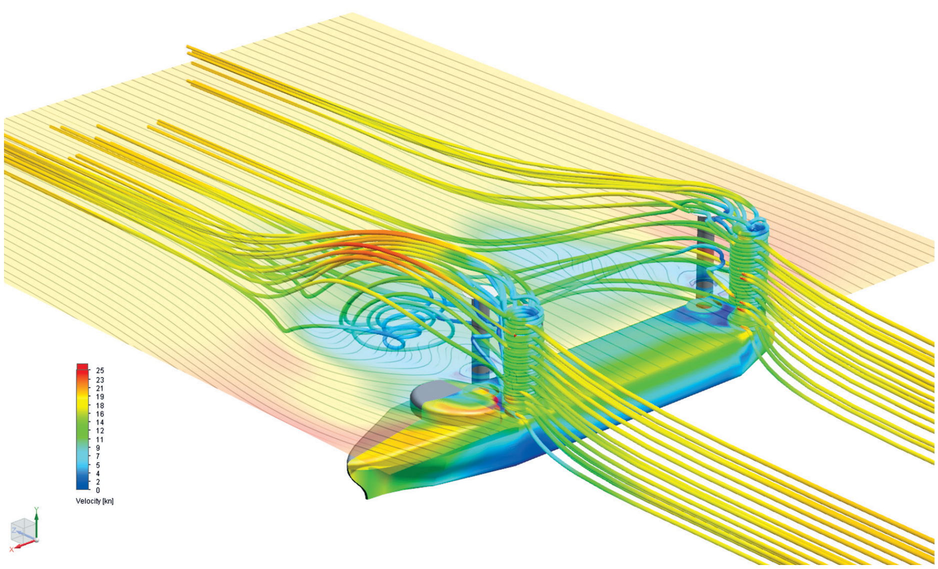

Figure 2: Vessel simulation with Simcenter FLOEFD

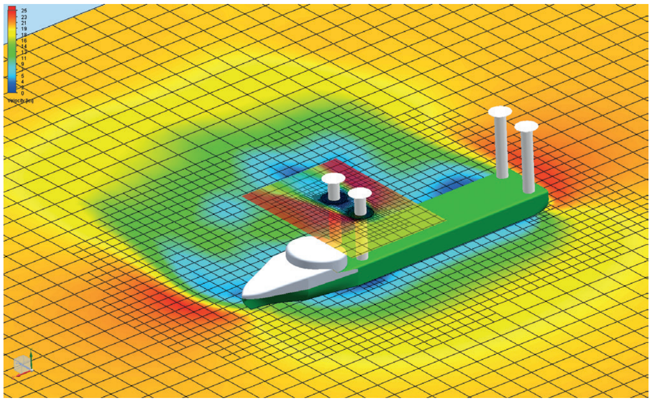

Figure 3: Vessel simulation with Simcenter FLOEFD

For the simulation, a simplified example of a vessel equipped with the four shown rotors was used and the forces of the air flow only were considered. The water forces were neglected for this comparison. The ambient velocity for the simulation is the resultant wind speed and the forward movement of the ship.

The goal was to reproduce the influence of the Magnus effect and to visualize it. Even if only qualitative results can be shown, the effect can be illustrated visually. This example is based on a generic, simplified model of a vessel, so no real drag coefficients were applied.

Figure 4 shows the vessel example and the resulting air velocity directions for the study. The air speed is 20 kn, from several directions between 20° and 160°. The height of the rotors is 20m with a diameter of 4m. The rotating speed of the rotors is 100 RPM for the four rotors. A parametric study was applied in Simcenter FLOEFD.

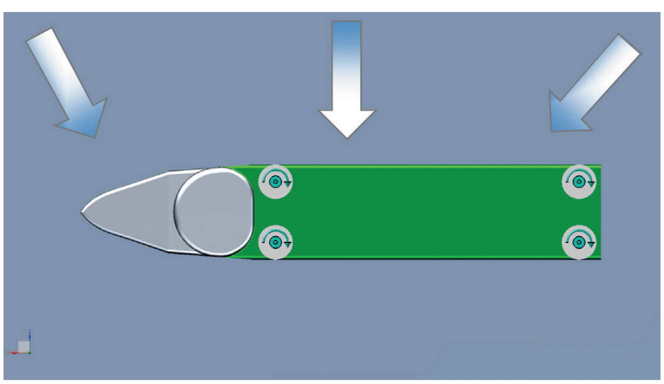

Figure 4: Vessel example with resulting air directions

Figure 5 shows a qualitative comparison of the vessel example. As the diagram shows, the resulting drag force on the ship's body is less on rotating rotors. Less drag force means lower fuel consumption, which saves money and protects the environment.

As expected, the highest reduction in the drag force is achieved at approximately 90°. It is not exactly at 90° due to the influence of the vessel's shape, which also corresponds to the available public information[4].

Of course, it is also necessary to consider the weight of the vehicle, the maintenance, the control technology, the possibly lost freight capacity and other factors to evaluate the savings. According to public operators' information, the fuel savings are estimated to be about 25 percent due to the use of Flettner rotors. Considering the high utilization rates in the shipping industry, it is certainly an attractive and environmentally friendly measure. Similar approaches in the future will likely be applied for ferries and cruise liners.

Further approaches to fuel economy can be found on the Internet, including container ships with sails or the Vindskip hybrid merchant vessel[5]. There are many opportunities for further Simcenter FLOEFD studies.

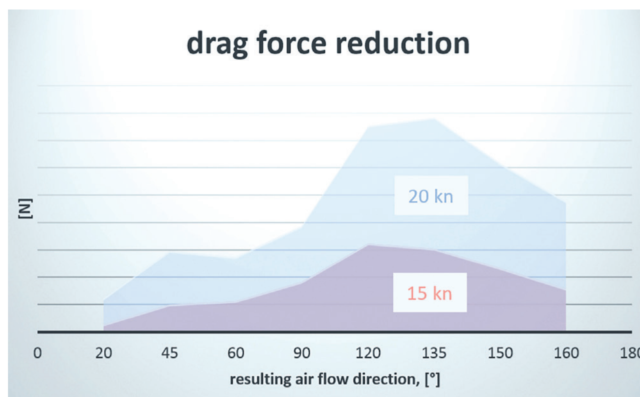

Figure 5: Drag force reduction

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