Century-old technology set to save $BILLIONS in fuel costs!

The Flettner Rotating "Sail" and the Magnus Force

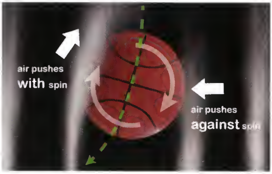
by **Ross Tester**

Some time in the not-too-distant future, you may see large ships with strange-looking spinning towers mounted on their decks. They'll be using the same laws of physics that keeps planes in the air and golf balls travelling further . . . and saving lots of fuel in the process.

The 400m-long Emma Maersk, launched in 2006, is one of the largest container ship in the world, capable of carrying 15,200 shipping containers at a steady 25.5 knots (47km/h).

Actually, the "largest" title is *currently* held by the MSC Oscar, capable of carrying 19,224 containers. Even bigger vessels are currently under construction.

But the Emma Maersk held this title for some time. So it's not surprising that she also has one of the world's largest reciprocating engines.

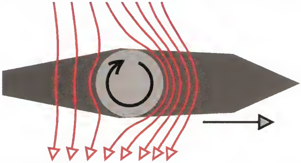


The Magnus Force (aka Magnus Effect) as it applies to a spinning ball, making the ball deviate from its expected path – left, right and even up and down. Perhaps "Bend it like Beckham" should actually have been "Bend it like Magnus".

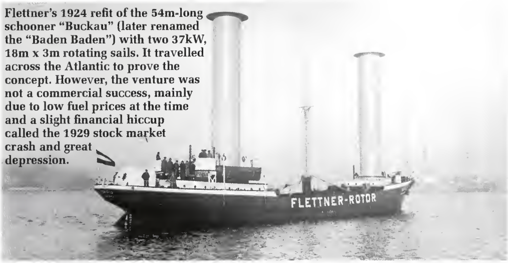
The 14-cylinder, turbocharged two-stroke diesel behemoth is five storeys tall and weighs 2300 tonnes. It puts out 84.4MW (114,800 hp) – up to 90MW when the motor's waste heat recovery system is taken into account.

This mammoth engine is also claimed to be one of, if not the most efficient engines ever built. Even so, under way, it consumes approx 16 ***tonnes*** of bunker fuel per hour or 380 tonnes per day.

If you could save just 10% of this fuel, that would be a saving of 38 tonnes of fuel each day – or, given a



On a spinning but "fixed" object such as a Flettner Sail, those same forces apply – but in this case are transferred to the hull of the ship, making it move in the direction shown. It's not huge – but it's worthwhile!



Flettner's 1924 refit of the 54m-long schooner "Buckau" (later renamed the "Baden Baden") with two 37kW, 18m x 3m rotating sails. It travelled across the Atlantic to prove the concept. However, the venture was not a commercial success, mainly due to low fuel prices at the time and a slight financial hiccup called the 1929 stock market crash and great depression.

typical 250-day-per-year "at sea" schedule, nearly 10,000 tonnes per annum. At a minimum cost of AU$400 per tonne (and up to almost AU$750 per tonne in some ports), that would be a fuel saving of at least AU$4 million per annum.

Now *that* would be more than enough to make any ship owner smile!

Incidentally, those cost figures apply to the lowest-grade "IFO380" bunker fuel available (ie, highest sulphur content @ 3.5%).

If the ship is forced to use "MGO" grade bunker fuel (1.5% sulphur) or even "L SMGO" (0.1% sulphur), as is now required in many ports around the world to minimise pollution, you can almost double the costs and the savings.

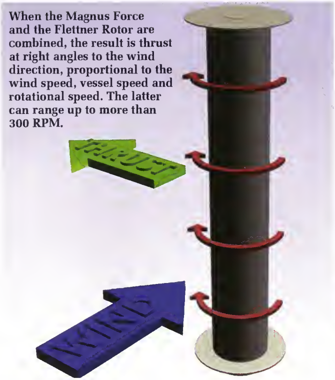
What is bunker fuel?

Bunker fuel is actually a generic term given to *any* fuel stored in a ship's bunkers, or fuel storage areas, to power its engines. But most people (ship operators included) understand the term to mean the heavy, residual oil left over after gasoline, diesel and other light hydrocarbons are extracted from crude oil during the refining process.

While some vessels are now being built to use compressed natural gas (CNG) and other fuels, most deep-sea cargo ships, tankers etc typically burn bunker fuel. As noted above, there are various grades of bunker fuel available.

Less pollution, too

It has been said that in one year, a single large container ship can emit pollutants equivalent to fifty million cars (*The Guardian, April 23, 2009*). Or conversely, 15 of the world's largest ships emit as much sulphur oxides (SO_X) as ALL of the planet's 760 million cars!



When the Magnus Force and the Flettner Rotor are combined, the result is thrust at right angles to the wind direction, proportional to the wind speed, vessel speed and rotational speed. The latter can range up to more than 300 RPM.

With governments around the world getting tougher on "big polluters", it's in the ship operator's interests to play ball.

For this reason, many ships switch from IFO380 bunker fuel to MGO or even L SMGO fuel as they enter ports or sail close inshore. At sea, it's usually a case of "out of sight, out of mind."

The world's 90,000 vessels emit some 20 million tons of SO_X each year – one large ship can account for more than 5000 tonnes on its own.

Naturally, ship's captains and engineers take all steps possible to minimise fuel use anyway – they usually don't run the engines at maximum speed, for example – but we are talking about a means of saving huge amounts of fuel while maintaining vital schedules.

Hence the interest in the Flettner Rotating Sail. Savings of 7-10% have already been demonstrated and some proponents are claiming theoretical savings of up to 30% (though Norsepower, the main players in the game, claim up to 20%). Try plugging even 20% savings into the figures


The three-rotor ship "Barbara" in Barcelona harbour, 1927. It suffered the ignominy of being sold and having its three rotors removed, converting to standard propulsion! https://commons.wikimedia.org/w/index.php?curid=48364872

The four 27m x 4m Flettner Sails on the E-Ship 1, a 13,000t RoLo cargo ship that made its first voyage with cargo in August 2010. The ship is owned by the third-largest wind turbine manufacturer, Germany's Enercon GmbH and is used to transport wind turbine components. Maximum rotor speed appears to be in the order of 310 RPM, though this depends on both ship speed and wind direction/speed. (Courtesy Enercon GmbH).

above and the dollars become even more dramatic.

The Magnus Force

While the owners of the Emma Maersk are not (currently!) considering refitting that ship, they are currently planning to refit one of their large ocean-going tankers with the revolutionary Flettner Rotating Sail propulsion method.

The tanker in question is 240 metres long and by next year will be fitted with two electrically-driven rotating columns (or "spinning sails"). It is the interaction of these rotating columns with the prevailing winds which provide the propulsion.

It's called the "Magnus Force": wind passing the spinning rotor creates an air flow which accelerates on one side, creating a lower pressure, while it decelerates on the opposite side, creating a higher pressure.

In a similar way that a moving aircraft wing provides lift due to higher pressure underneath, the Magnus Force rotating sail provides a force at right angles to the wind direction. Because the rotating sail is fixed to the deck of the ship, this force provides thrust, which is used to take some of the load off the ship's engine(s).

Like a sailing ship, the course of the ship needs to be adjusted for wind direction but unlike a sailing ship, a Magnus rotor ship can sail very much closer into the wind – or "close hauled" – as close as 15° versus about 30°- 45° minimum for sailing ships.

Where did the name "Magnus Force" come from? A German physicist, Heinrich Magnus who described the effect in 1852, when he was analysing the path of cannonballs.

Curiously, Isaac Newton described the same thing almost 200 years earlier (in 1672) after witnessing tennis balls' flight at Cambridge. Newton also theorised the reason... and was 100% correct. 70 years later (1742) a British mathematician, Benjamin Roberts, explained deviations in the trajectories of musket balls using the same forces. His work led to the "rifling" of barrells to make them spin.

If you're a sportsman using any form of ball, you will almost certainly use the Magnus Force – probably without knowing it – to control the flight of the ball.

You can make it longer (eg, a golf ball with backspin flying further than it should . . . or the opposite, when you slice or hook the ball making it go where you don't want it to!), making it dip before your opponent believes it should (eg,

One of big features of the Flettner Rotor is that, unlike a "sailing" boat, no additional crew are required to run it. Here's the control panel which is on the bridge, alongside other instruments. It even has a "big red button" to stop the rotating sails in an emergency!

A Norsepower artist's impression of the Maersk Magnus, an existing tanker currently being retro-fitted with a pair of Norse Power Flettner rotors. 7-10% fuel savings have been demonstrated; some proponents claim much more – 20% according to Norsepower and others as high as 30%! The roll-on roll-off ferry "Estraden" (see photo on p12) is already fitted with Flettner rotors and is achieving 6%+ fuel savings.

a tennis ball with underspin) or even making it deviate from its probable course (eg, a baseball curving away).

Now at least you know who to curse when you're looking for your ball in the rough!

The Flettner Sail

The spinning sail concept is not new – it is usually regarded as the invention, almost 100 years ago, by a German engineer, Anton Flettner.

(We note that Norsepower's website claims it was actually invented by a Finnish engineer, Sigurd Savonius [more famous for the Savonius Turbine] and later developed by Flettner. But that is the only reference which disagrees with popular knowledge). See siliconchip.com.au/l/aacs

In 1924, Flettner refitted a schooner named the Buckau with two rotating cylinders about 15m high and 3m in diameter, driven by 37kW electric motors. Its maiden voyage was in February 1925 across the North Sea from Danzig (Germany) to Scotland.

It was claimed at the time that the rotors did not give the slightest cause for concern in even the stormiest weather. In 1926 the ship, now renamed Baden-Baden, sailed across the Atlantic via South America, arriving in New York on 9th May.

Another rotor ship, the Barbara, served as a freighter in the Mediterranean between 1926 and 1929.

Despite Flettner's attempts to show shipping companies and even yachtsmen the undoubted advantages of his designs, the Flettner rotor ships were not a commercial success, beaten by (a) the very low cost of fuel, and (b) the stock market crash and depression of 1929.

Indeed, after the Barbara was handed back to its owner (the German Navy) in 1931, they onsold it to a new owner who dismantled its three rotors and used only its engines!

Fast-forward nearly a century

Despite the lack of appeal for early 20th century shipowners for the rea-


In this view, the *Estraden* is docked at the ro-ro terminal in Teesport, UK. The Flettner sails (one forward, one aft) are kept spinning, albeit at a much slower speed, providing the ship with some stability while vehicles driving on or off. At sea, the speed is significantly increased. We've seen figures of 300+ RPM although this has been difficult to verify.

Another artist's impression, the LNG-powered *Viking Grace*, which is owned by Finland's Viking Line and operates between the Finnish port of Turku and Stockholm in Sweden. It is already one of the most environmentally friendly ferries in operation but the installation of a single rotor sail will further reduce fuel burn and emissions, saving an estimated 300 tonnes of LNG consumption each year. The Norsepower rotor sail will be retrofitted during the second quarter of 2018 when one medium-sized unit, 24m in height and 4m in diameter, will be installed. The system will be fully automated so that when the wind is strong enough to deliver fuel savings, the rotor starts spinning automatically.

sons already given, with the price of fuel now hovering at or near record levels, shipowners are once again looking at the Flettner Rotor as a means of saving money.

The German wind-turbine manufacturer Enercon launched a new rotor vessel, *E Ship 1*, in 2008. It entered service in August 2010 and is still in service seven years later, ferrying wind turbines and other equipment, primarily to wind farms being constructed in ocean areas. See siliconchip.com.au/l/aacq

In 2014, the roll-on, roll-off freighter *Estraden* was retro-fitted with two Norsepower Rotors.

The sea trials onboard M/V Estraden, verified by NAPA and supported by VTT Technical Research Centre of Finland, confirm fuel savings of 2.6% using a single small Rotor Sail on the vessel's route in the North Sea.

Later tests show a reduction in fuel consumption of 6.1%.

The Estraden's Rotor Sails are effective 80% of sailing time, giving 460kW average propulsion boost and 1.5MW peaking for 10% of time.

Norsepower forecasts savings of 20% for vessels with multiple, large rotors travelling on favourable wind routes. See siliconchip.com.au/l/aacr

The Flensburg University (Germany) has made a rotor-driven catamaran called *Uni-Cat* – there's a video of a catamaran on the Nile River at siliconchip.com.au/l/aaco

There's also another video explaining the Flettner sail advantages on a coastal freighter at siliconchip.com.au/l/aacp along with several other interesting videos on various aspects of Flettner and the Magnus force.

You'll find a huge number of other refences to the Magnus force and Flettner Rotary Sail on the net.

Rotor ship components

Norsepower Rotor Sails are available in three sizes with heights of 18, 24 or 30 metres and diameters of 3, 4 and 5 metres respectively.

The optimal number and size of Rotor Sails are based on the size, speed and operating profile of the target vessel.

The essential parts of the Rotor Sail system are:

- The Rotor Sails themselves, which deliver the forward thrust. Depending on space available and operational requirements, there can be anywhere from one to four (or even six) rotors.
- A suitable mounting location on the ship's deck. Cranes and cargo handling equipment do not normally create excessive turbulence but they must not interfere with rotor sail operation (and vice versa).
- A control panel (usually mounted on the bridge), which gives the crew full control of the operation and performance of the Rotor Sails.
- Wind & GPS sensors, which provide the automation system with real-time wind speed and direction information as well as ship speed and course data to optimise the performance of the Rotor Sails.
- An electrical power supply from the ship's low voltage network to each Rotor Sail. (Remember that low voltage is defined as up to 1000VAC or 1500V DC).

Conclusion

So will it happen? Will we see ferries, container ships and supertankers on the high seas with these spinning columns providing fuel savings and cutting exhaust pollution?

With the successful trials of Flettner Rotors undertaken in Europe (especially) in recent years, it is highly likely that the answer will be yes!

There is other technology out there, much of it involving the wind – giant kites and conventional sails are also being trialled right now.

Or it could perhaps be an as-yet unknown breakthrough which the world's shipping will latch onto.

But one thing is for sure: with ever-rising fuel prices and "green" pressure, something will change! SC

Acknowledgement: much of the information and photographs in this feature courtesy of Norsepower Oy Ltd. For more information, visit their website: www.norsepower.com