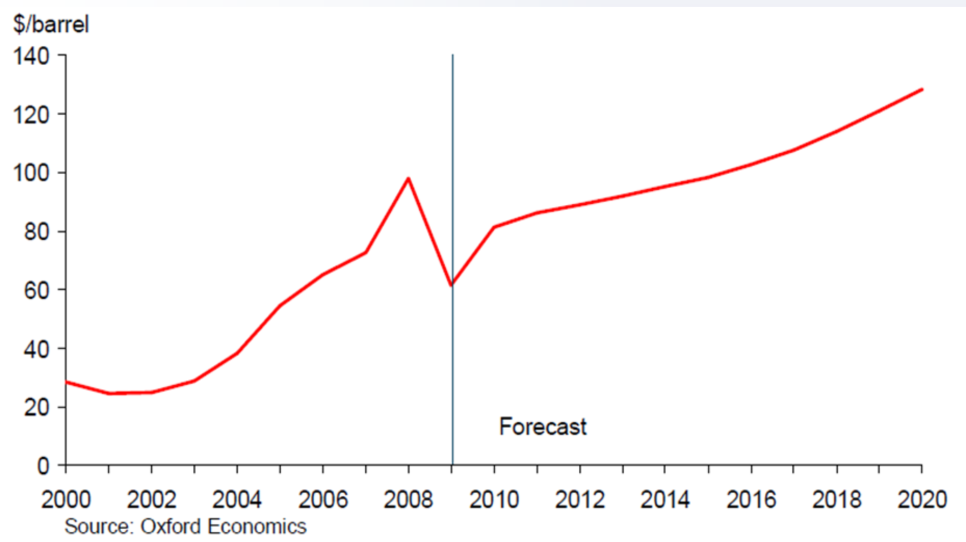
James Grimshaw
James.grimshaw@student.manchester.ac.uk
Meng Mechanical Engineering

Examining Flettner Rotors for Ship Propulsion using CFD

Introduction and Objectives

Due to increased oil prices and changes to the International Maritime Organisation (IMO) regulations new methods to increase the efficiency of cargo ships are now being investigated by shipping companies. There are many proposed methods, including redesigning the hull and the use of LNG as fuel. However, it is a method from the 1920's that is emerging as the most promising. Flettner rotors use the Magnus effect to create a propulsive force that can be used to provide some of the drive of a ship.

Oil Prices



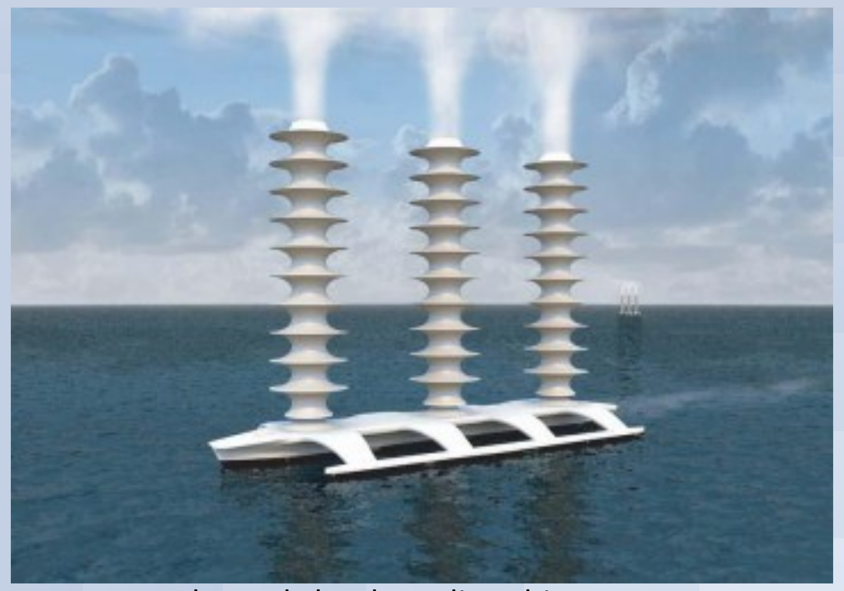
Forecasted oil prices

Changes to IMO regulations

Currently the shipping industry contributes to 3% of the world's human induced emissions, changes introduced by IMO are:

- Sulphur Oxide (SOx): Emissions in protected areas 1% until it becomes 0.1% in 2015
- Nitrogen Oxide (NOx): Tier III vessels limited to 3.4g/Kw in controlled areas and Tier II standards outside
- Carbon Dioxide (CO2): Efficiency of 400 tonne ships increased by 30% after 2024

- Autonomous cloud seeding ships are proposed as one method to overcome climate change.
- These ships are to be powered using Flettner rotors but due to their size there are concerns about the effect of the interaction between the low pressure field of one rotor and the high pressure field of another.
- There has been little research into the effects of the interaction between flow fields and the effects of cylinder separation distance (T/D).
- The aim of this project is to look into the effect of these distance ratios on the achievable lift from the Flettner rotors.



Planned cloud-seeding ships

Existing Flettner Project

Buckau 1920

Picture of Buckau

Total Sail Area (m^2)	883
Total Rotor Area (m^2)	87.4
Rotor Diameter (m)	2.8
Rotor Height (m)	15.6
Rotor Weight (to)	7
Max Rotor RPM (min^{-1})	135
E-motor Power (Kw)	2x11
Max Speed (Kts)	9.1

Designed by the German scientist Anton Flettner. In 1926 was renamed to the Baden Baden and successfully crossed the Atlantic.

Barbara 1926

Picture of Barbara

Total Rotor Area (m2)	204
Rotor Diameter (m)	4
Rotor Height (M)	17
Max Rotor RPM (min-1)	150
E-motor Power (Kw)	3x35
Max Speed (Kts)	13

Built for the German Navy, during its testing it was reported the Flettner rotors could increase the top speed by 2-3Kts with a fuel consumption of 1Kg/h.

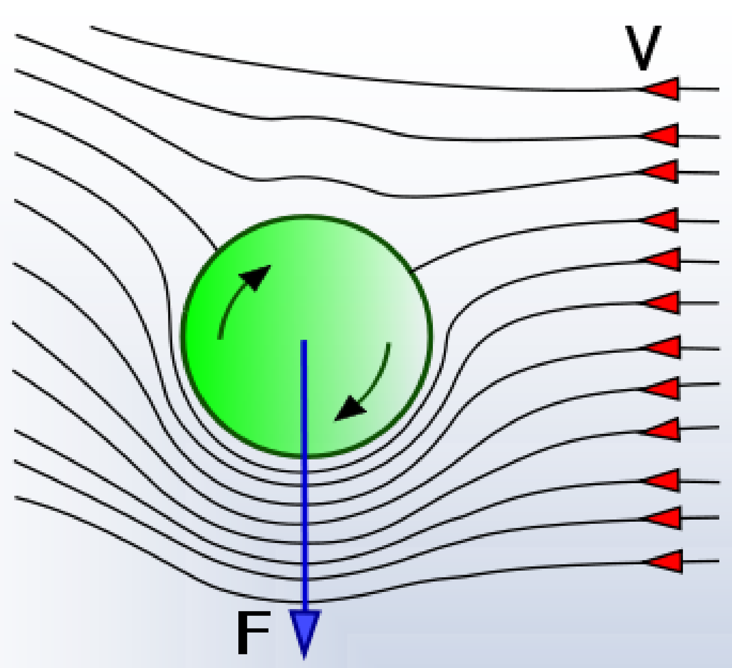
E-ship 1 2010

Picture of E-ship 1

The E-ship 1 uses a number of new technologies including Flettner rotors, whose power comes from a steam turbine using the exhaust gases from the conventional diesel motor which runs the propellers.

All the improvements make the E-ship 1 30-40% more efficient than a conventional cargo ship.

The Magnus Effect

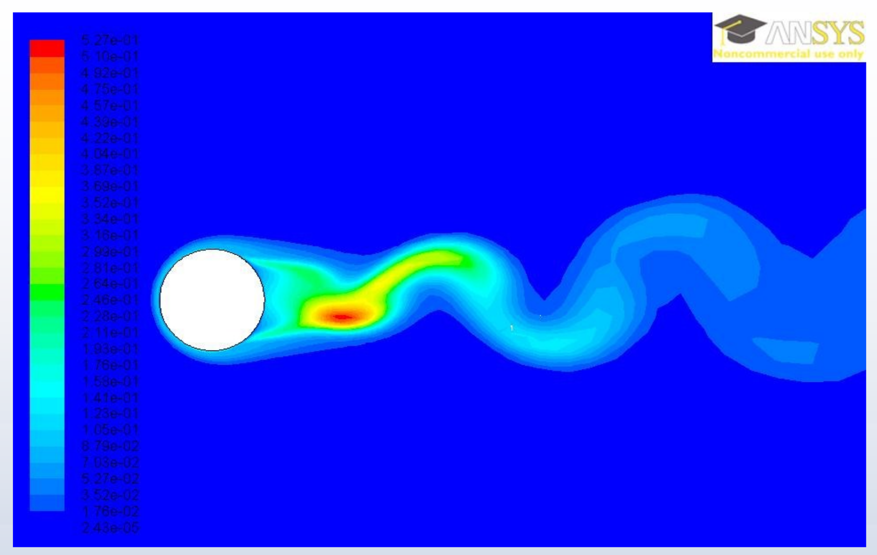


The Magnus Effect

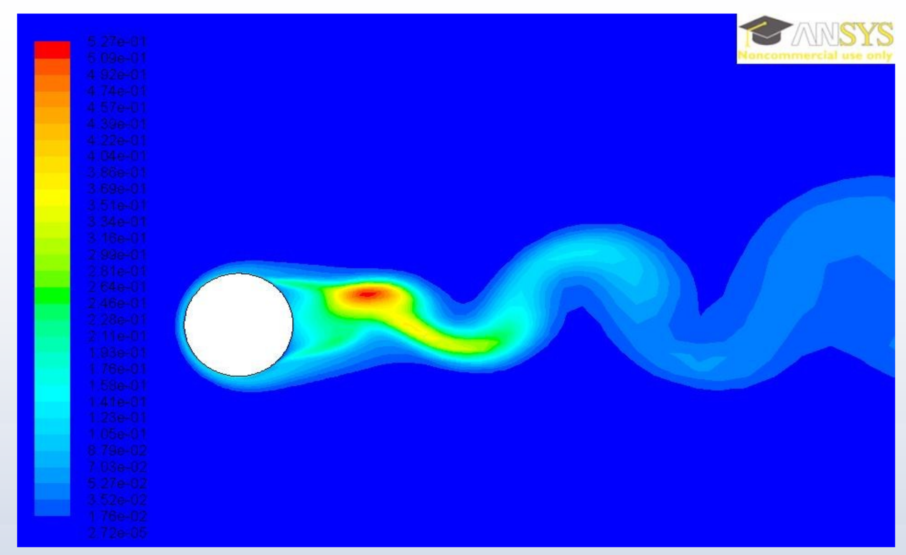
Flow passing over a rotating cylinder produces a force perpendicular to the flow. The force is created due to two local pressure fields at either side of the cylinder. The pressure fields come from the friction between the cylinder wall and the flow. In the case seen above there is a higher local pressure over the top of the cylinder and a local area of low pressure on the bottom of the cylinder.

Simulation Work

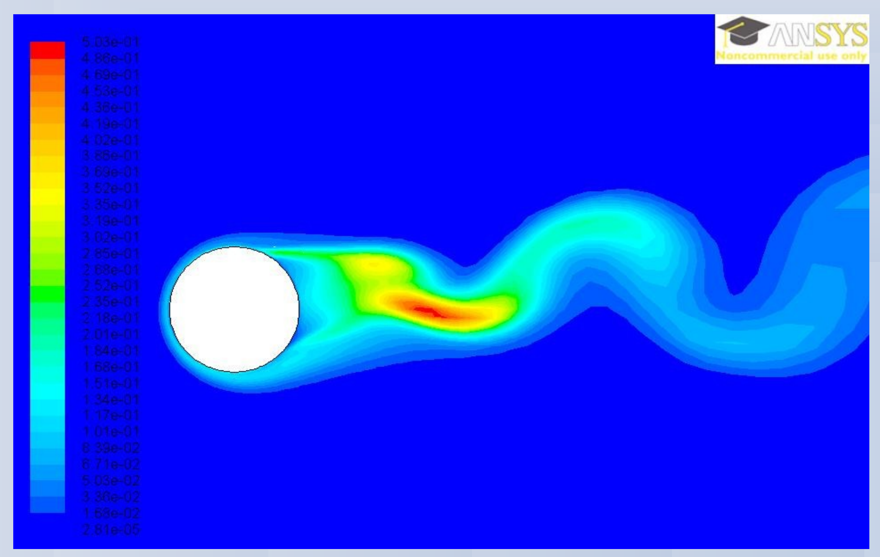
- The experimental work for this dissertation is to be completed using Ansys-Fluent.
- In order to save on computational costs a URANS solver has been chosen, employing the K-Ɛ Turbulence model and a Wall function.
- Inlet values of velocity, k and Ɛ were chosen to be representative of those that might be found in Flettner rotor environments
- To gain accurate results, second order discretization has been used, with PRESTO! for the pressure field.
- The time step was chosen to ensure the Courant number was typically less than 1, whilst a 100 or more time steps would cover the expected vortex shedding period.



Contours of Turbulent Kinetic Energy at α=0 Re=200,000



Contours of Turbulent Kinetic Energy at α=1 at Re=200,000



Contours of Turbulent kinetic Energy at α=2 Re=200,000

- In Karabelas (2010) it is stated that at Re=140,000 the vortex shedding is suppressed after a critical spin ratio of 1.3.
- As can be seen at a spin ratio of 2 vortex shedding is still present.

Future Work

Look closely at the simulation set up to find possible explanations as to why my results differ to Karabelas (2010).

Once the spin ratios have been applied, the geometry will have to be adapted to include a second cylinder so that the effect of the cylinder spacing can be analysed.

References: *S.J. Karabelas. Large Eddy Simulation of high-Reynolds number flow past a rotating cylinder. International Journal of Heat and Fluid Flow 31 (2010) 518–527*