Cavitation Hydrophobia

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Background

Today 90% of the world trade is carried by ships and the volume transported is continuously increasing(marisec.org). Boats are commonly used as a way of transportation because of their simplicity, efficiency, and capacity. Ships have a major influence on the environment. It is estimated that the shipping industry is responsible for 3% of the global CO2 emission – the equivalent of a major national economy(marisec.org). Large transportation boats are also a source of noise pollution. Noise pollution affects marine mammal reproduction and communication.

One source of noise is the complex phenomenon of cavitation (adsabs.harvard.edu.) In simplistic terms cavitation is water boiling due to the low pressure created at the back of the propeller. Cavitation creates noise but it also reduces the propeller efficiency and eventually wears out the propeller.

Cavitation is affected by the characteristics of the surface of the propeller. It has been proven that hydrophobic materials have the property of stabilizing small bubbles, and cavitation starts with small bubbles.

Purpose

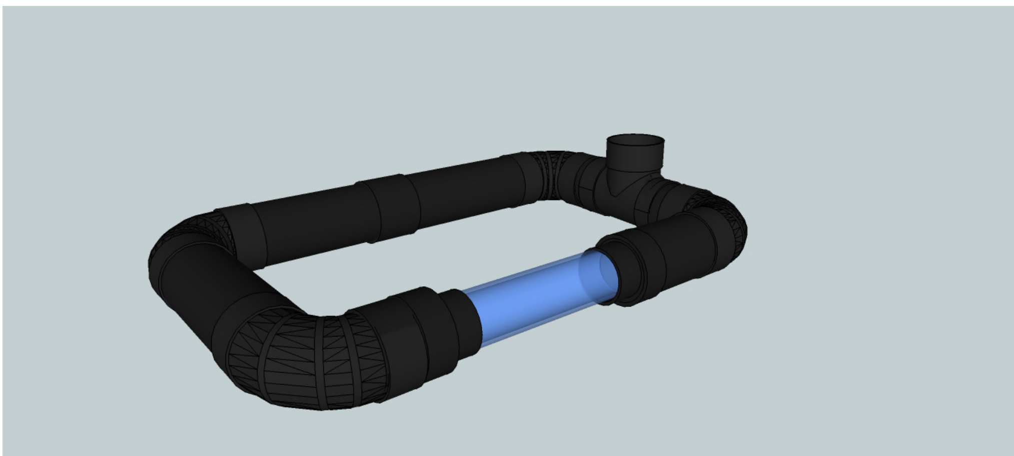
The purpose of the experience is to reduce ship CO2 emission and noise by reducing propeller cavitation.

Hypothesis

My hypothesis is that the use of hydrophobic coating on the propeller can reduce cavitation, thus reducing noise and improving efficiency.

Material and procedure

Cavitation tunnel material



- ABS pipes, bends, transitions
- Water heater with thermostat, thermometer
- Motor, shaft, stuffing box, propeller (2)
    - Test section : Plexiglas, ABS pipe (3")

Testing Equipment material

- Camera, Oscilloscope, Infrared emitter and detector, resistors, capacitors, scale

Procedure

1. Verify that the tunnel is horizontal

2. Fill the tunnel with pre-heated water

3. Tilt tunnel to eliminate bubbles in test section

4. Connect motor universal joints

5. Block all vent pipes and main inlet

6. Verify scale zero, turn on oscilloscope and rpm measurement circuit

7. Start main motor

8. Start secondary motor with remote control.

9. Set the torque value using control. For each torque, take picture of oscilloscope screen (with time base button), test section, and venturi pipes

10. Redo steps 1 to 9 with propeller coated with different materials

Results and observations

Creating cavitation conditions in a laboratory environment is difficult. Cavitation conditions are related to the value of the cavitation number. Cavitation occurs for low cavitation number values (lower than 1). Lowering the cavitation number is achieved by:

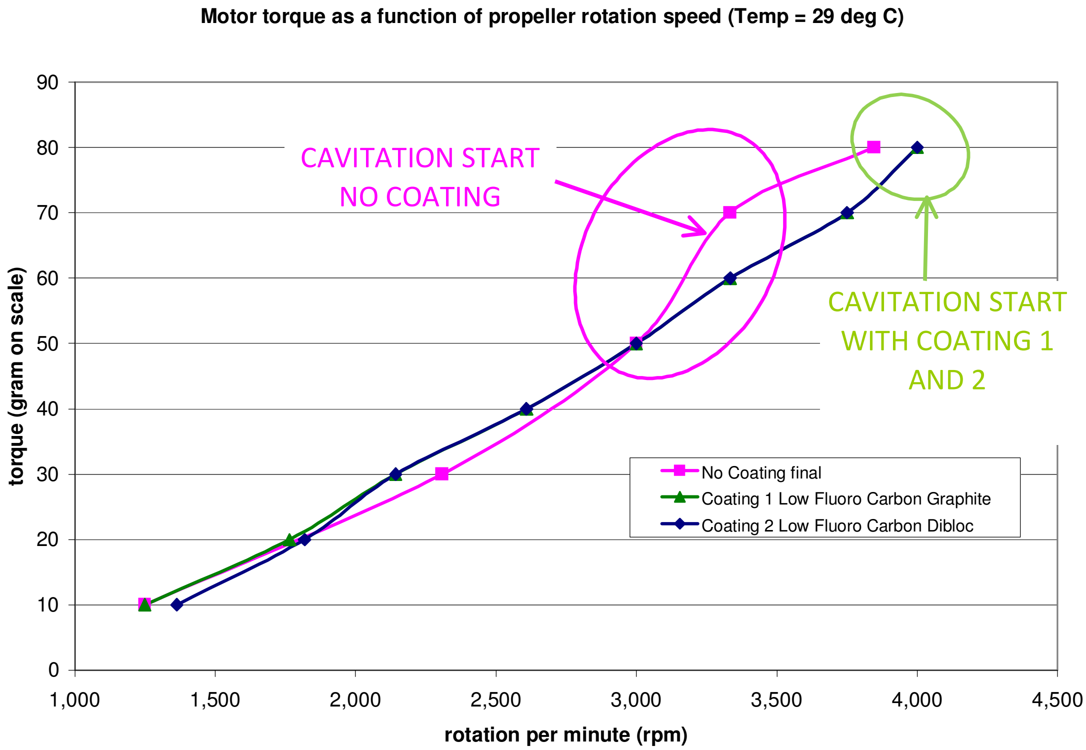
- Decreasing the difference between the water pressure and vapor pressure
- Increasing the value of the water speed

Increasing the water speed proved to be difficult in the original design, which consisted in a propeller immersed in an aquarium. The design required a very large shaft torque, which limited the propeller speed. The lack of natural water circulation also created a very turbulent and unstable flow.

The solution was to design a small version of the cavitation tunnels used to test large propellers. In the tunnel, the water is continuously circulated in a closed pipe ring by the mean of a propeller - simulating the boat speed. The propeller under study is placed at another location of the ring, and driven at a much higher rotation speed to create cavitation. A clear pipe is used to visualize the cavitation on the propeller.

Cavitation conditions were successfully created and controlled. Torque vs. motor speed curves were measured with two different coatings. Cavitation was visually observed above a certain RPM. The effect of temperature was verified by making tests at two different temperatures – everything else being equal. As predicted, cavitation occurred for lower RPM at higher temperature (lower cavitation number). Cavitation increased the torque required at a given RPM.

Measures with and without hydrophobic coatings were compared (the coatings used were two types of Low Fluorocarbon wax designed for cross country skiing): see figure below. The results show that cavitation with coating happens at a higher RPM. In other words, the coatings tend to prevent the phenomenon to occur.



Conclusion

The conclusion seems to be that hydrophobic coating would reduce cavitation and thereby reduce the torque needed at a given RPM. As a result it would increase propulsion efficiency – and reduce noise.

Next step would be to replace wax coating with grafted hydrophobic material.

This project has been an extraordinary opportunity to investigate concepts such as cavitation number, Reynolds number, Bernouilli law, Venturi effect to name a few. I also realized that the small tunnel developed can be used to validate large scale coatings, as surface effects unaffected by scale.

Acknowledgment

I would like to thank Mr Jacques for helping me conceive the project, Mr Posta for helping me with the metal work, Jordan Forsyth and David Albert-Lebrun for providing high performance wax, and my father for teaching me fluid mechanics and funding my project.

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