A NOVEL METHOD FOR TWO-DIMENSIONAL PHYSICAL MODELLING OF A VESSEL'S RUDDER WAKE USING FLOWING SOAP FILMS.

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FLOWING SOAP FILMS - AN OUTLINE

Flowing soap films have been used in recent years as an apparatus to study natural phenomena encountered within fluid dynamics, such as the movement of flexible bodies within a flow field [1].

The apparatus consists of a water/soap solution which is suspended between two threads and allowed to flow from a raised position. This creates a thin sheet of flowing liquid into which static or moving bodies can be placed. This thin film may be considered to be two dimensional as it is typically $10^5 - 10^6$ wider than it is thick [2].

The water/soap solution results in a thin water layer covered by a soap surfactant. When photographed under a monochromatic light source, the movement of the surfactant on the film can be clearly visualised. Here the classic example of a cylindrical object in laminar flow is shown. [Fig 1]

Fig 1

AIMS OF THE RESEARCH

The primary aim of the research was to investigate the applicability of flowing soap films to the field of Naval Architecture for use as a tool for the qualitative assessment of hullforms.

The following questions were investigated:

- Can the wake from a ship be adequately modelled using flowing soap films?
- How does twin rudder positioning/spacing affect this modelled wake?
- Can the wires supporting the flowing soap film be used to model a system boundary, such as the sea surface or bottom?
- Can the forces acting on bodies inserted into the soap flow be readily measured?

HIGH SPEED PHOTOGRAPHY

To see the high speed photography captured during this project and represented by the figures on this poster, scan here:

EXPERIMENTAL METHODS

Two different experimental setups were constructed in order to explore the research questions. A vertical flowing soap frame and an inclined flowing soap frame.

The vertical frame was used primarily to image the flow field around a test body.

Various 3D printed test forms could be inserted into the vertical soap film and the resulting flow fields examined.

3D printed bodies representing waterline sections of the standard KCS hullform bow, stern and twin rudder arrangements were placed into the vertical soap flow and photographed using Photron high speed cameras under a monochromatic light source to produce the images on, and included with, this poster.

To interpret the images produced the flow field contours are examined; slow speed regions exhibit few contours while laminar regions show smooth and regular contours. Turbulent regions can be clearly seen as the contours compress together showing a rapidly changing velocity gradient within the flow field. [3]

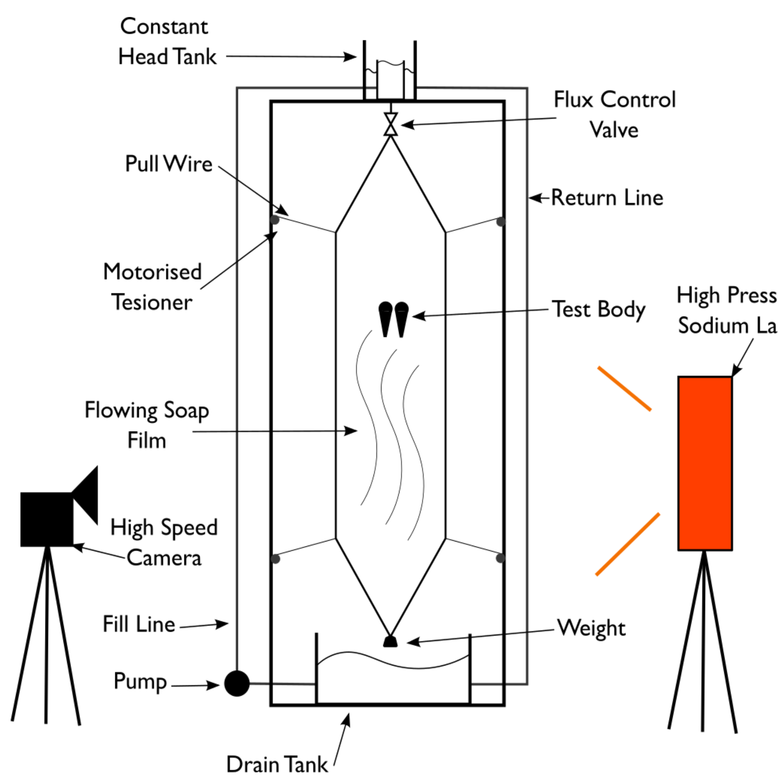

Fig 2 – Vertical Flow Frame Setup

For better similarity with the full scale an inclined flow frame was also constructed. The lower flow speed of this setup (~0.3m/s) better lends itself to Froude similarity with the full scale.

As before 3D printed bodies were inserted into the now inclined flow, attached to a flexible spring steel rod. Tracking points were added the bodies for use with a Qualisys Motion Tracking Camera System. This allows for recording of the body's motion in the flow and for the forces involved to be calculated.

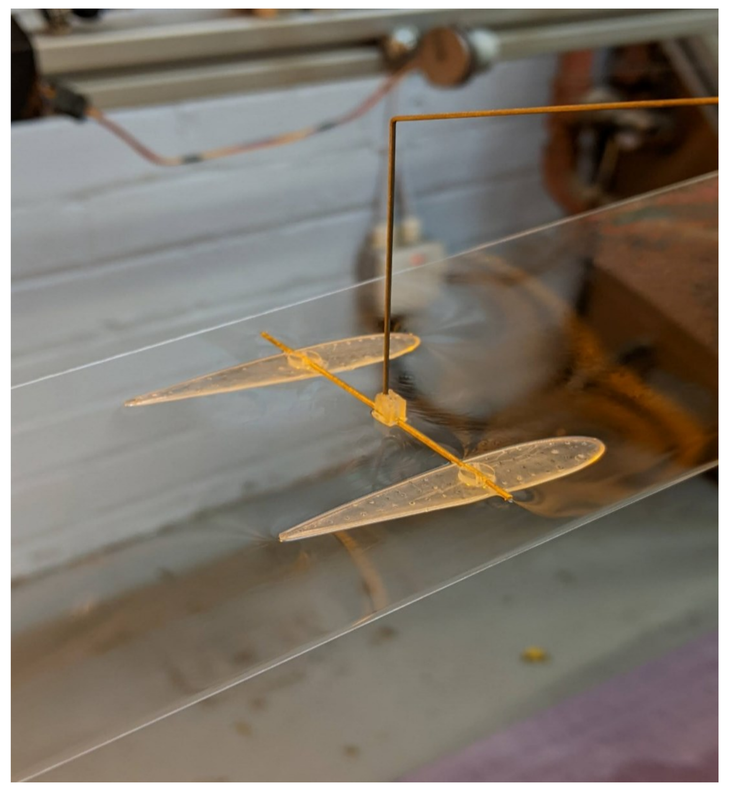

Fig 3 – Twin Rudder Arrangement in an Inclined Flowing Soap Film.

OUTCOMES OF THE RESEARCH

Flowing Soap Films are a visually striking and engaging method of physically modeling a complex flow.

For naval architects they may prove a useful tool for examining the wake shedding at the stern of a vessel and for examining the 'nominal wake' of a hullform. With the aid of rapid prototyping technologies, such as resin 3D printing, it may be possible to physically test several forms within a short time frame.

For the questions investigated during this research project the following answers were gained:

- The nominal wake of a hullform at various 2D sections can be modelled and examined using this method.
- The spacing and positioning of the rudder certainly affects this wake, although the scale of the models needed for this method prevents further investigation of using this method.
- The wires supporting the flowing film cannot be used to model a surface boundary; slow speed regions propagate along the wires due their geometry and throttling effects induce vibrations into the structure.
- The forces acting on a body in the film can be determined using the positional recording method used here, although further processing of the data gathered is required to fully assess the accuracy of these measurements.

Evidently some further work is needed to refine the procedures described and to further investigate the accuracy of any data recorded.

Fig 4 – KCS Stern Wake

Fig 5 – Twin Rudder Wake

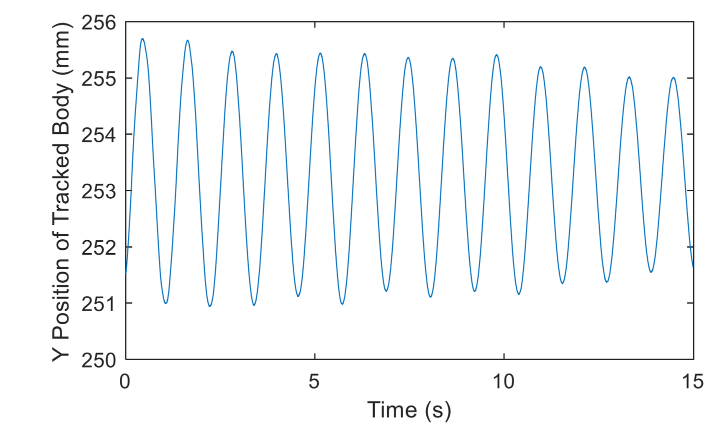

Fig 6 – Plot of Measured Displacement

Fig 7 – KCS Bow Flow Field

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