WEEG NEWSLETTER April-May 2022

The newsletter is published monthly by the University of Southampton's Water and Environmental Engineering Group WEEG, and reports things of interest in this field worldwide, as well as ongoing undergraduate student and research work in WEEG itself.

We believe that water and energy are the most important topics worldwide for the next decades. Our work covers river and coastal engineering, water and wastewater and energy related to water.

Editorial: everybody knows that water does not just flow in rivers or sit in oceans, it can also be used to drive machinery such as hydropower converters. There are also some more unusual machines driven by water, which employ inertia rather than e.g. momentum or gravity forces - for example rockets or pumps. Let's look at some of them today.

Hydraulic Engineering International: *inertia driven hydraulic machines*

The water rocket: Ordinary rockets are driven by highly explosive liquid or solid fuels, leaving a trail of flame whilst ascending – or that's the general opinion. And, as so often the general opinion is not the whole truth. There are in fact rockets which are driven by steam, and some are actually driven by water.

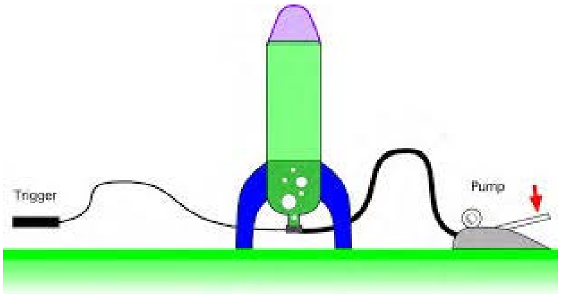

Fig. 1: Water rocket made from a PET bottle

Or, to be more accurate, by a combination of pressurised air and water. Meet the *Water Rocket*. This device consists of a container with a narrow outflow, a soda bottle for example, which is partially filled with water. A stopper is applied, and the air inside is pressurised with an air pump. Fins are fitted to the stopper end of the bottle, it is set vertically, and then the stopper is removed.

And now comes the interesting thing: the air pressure p_0 acts on the top of the bottle, and on the water surface at the bottom which causes the water to flow with a velocity v_0. When forced through the nozzle, which has a much smaller diameter than the bottle, the water must flow out with velocity $v_1 >> v_0$.

This creates an acceleration force F_a which counteracts the pressure of the air acting on the water surface, and is not connected to the bottle. So the air pressure now acts vertically at the top of the bottle; and if the force generated by the pressure is larger than the weight W of bottle and water, then the rocket takes off.

This is of course the principle of a rocket engine, and leads to a net upwards force acting on the bottle. And this force drives our rocket upwards.

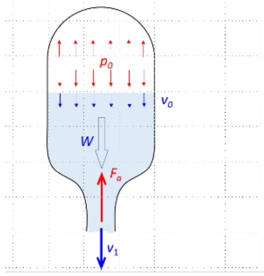

Fig. 2: Water rocket principle

Simple PET bottles can withstand a pressure of around 20 bar, and heights of around 100 m are possible. People are of course trying to improve this by strengthening the bottles with wire and heavy-duty tape, so that the pressure can be increased. Very serious enthusiasts build their own pressure containers from aluminium, with pressures up to 55 bar. At the moment, the world record for the maximum height reached by a water rocket stands at an astounding 961 m.

Fig. 3: Water rocket take-off

The principle is not new, however: squid have employed it to propel themselves forward for several million years.

The pulsator engine: Again, this is a machine which uses inertia forces in flowing water, only this time the force acts in the opposite direction. It is basically a pump which employs the flow generated by a small pressure difference, see Fig. 4. The flow in pipe 'D' is driven by the pressure created by reservoir 'A'. Pipe 'E' branches off 'D', and tap 'F' is installed at the pipe. Pipe 'D' ends in a check valve 'G', which leads into a pressure vessel ‘H’ from where pipe ‘I’ leads into a higher reservoir ‘K’.

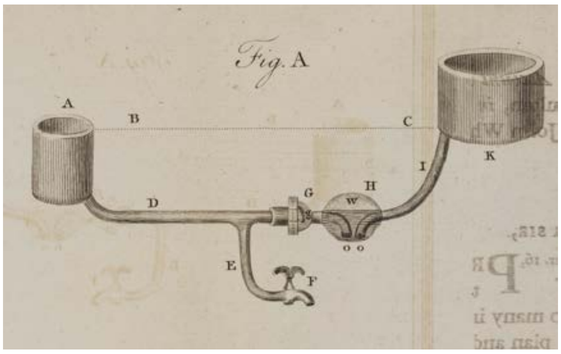

Fig. 4: The pulsator engine of 1772

For operation, the tap ‘F’ is opened. As soon as the flow through ‘E’ has reached its maximum velocity, the tap is shut, and the water in ‘D’ is decelerated. With a velocity v_0, and a tap closure time Δt, the acceleration becomes $a_0 = v_0 / \Delta t$. Force equals mass times acceleration, so the deceleration of the water mass in the pipe creates a pressure which drives the water first into the pressure vessel and from there up into the upper reservoir ‘2’. Hopefully, anyway. The pulsator engine is of course related to the hydraulic ram; however it does not employ the water hammer effect.

In principle it is a neat machine, with only one moving part, which can make use of small pressure differences. Or, and that’s what we are investigating, it can use slow flowing water e.g. in irrigation canals. Fig. 5 shows the idea: a long pipe with a slat-type shutter SG at the downstream end, is put into a canal.

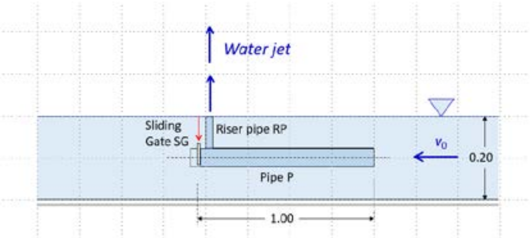

Fig. 5: Inertia pump for irrigation canal - principle

A riser is located at the end of the horizontal pipe. When the shutter closes suddenly, a pressure is generated which drives the water upwards into a higher reservoir from where it can be distributed. Then the shutter is opened again, the flow accelerates, and the cycle is repeated. Very simple, and it works for flow velocities as low as 1 m/s – a velocity which otherwise is very difficult to use to drive machinery.

Current research projects: *Hydraulic analysis and optimisation of algae raceway ponds*

Raceway ponds are shallow, oval-shaped ponds used to cultivate algae. These can be used e.g. as food supplements, or for pigments and cosmetics. Some types of algae also produce organic oils, so-called lipids, and there is a strong desire to use algae to produce biofuel. WEEG is currently co-operating with a London-based company to optimise the hydraulic performance of algal ponds, thereby minimising the operational energy demand.

Members of WEEG recently conducted a site visit to Brilliant Planet’s algal production plant in the Moroccan Sahara as part of the Innovate-UK funded project AGRI-SATT. The project aims at optimising the hydrodynamic design of raceway ponds that are used to cultivate marine microalgae. In this picture Dr Gustavo de Almeida and Dr Sergio Maldonado from WEEG are collecting velocity measurements, which will be used to gain a more detailed understanding of the flow and the efficiency of the paddlewheel propulsion system.

Fig. 6: The paddle wheel and algae raceway

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Jobs in water engineering:

This section gives you ideas of the type of work you can do when working in industry.

Civil and Environmental Engineering at Southampton University:

WEEG: our modules offer the chance to deepen your knowledge in water-related areas, and give better preparation for environmental engineering projects.

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Further information:

We have two Facebook pages, which provide a logbook of our laboratory activities:

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