Bacterial Inactivation using Radial Ultrasonic Horns

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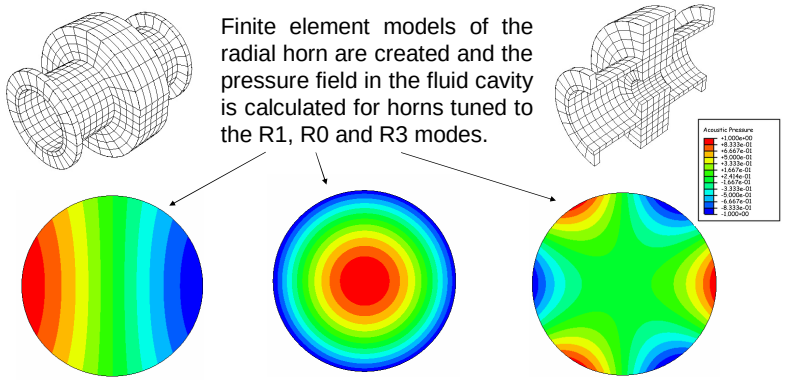
Introduction

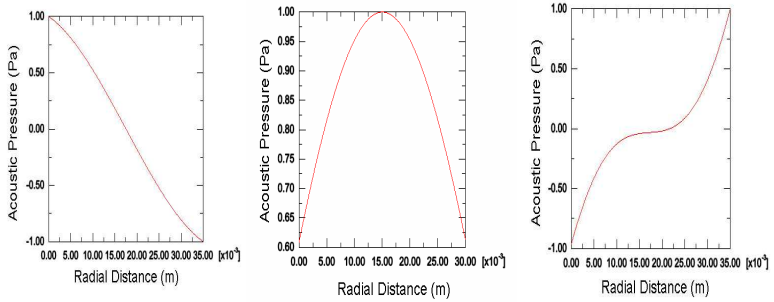
The authors have shown that a radial-mode ultrasonic horn is more effective for bacterial inactivation than a traditional longitudinal-mode probe device. The primary cause of cell death is through cavitation caused by the pressure field created in the fluid by ultrasonic vibration of the device. This study aims to create a model of the radial-mode ultrasonic horn and fluid cavity that can be used at the design stage to create a device that has the best cavitational field for the inactivation of bacterial organisms.

Finite element study of a radial horn



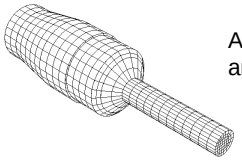
Finite element models of the radial horn are created and the pressure field in the fluid cavity is calculated for horns tuned to the R1, R0 and R3 modes.

For the R1 and R3 modes the pressure is highest at the anti-nodes. For the R0 mode the highest pressure is obtained in the centre of the fluid cavity.

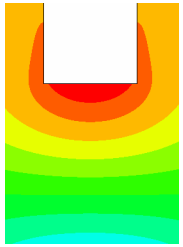


Plotting the pressure distribution across the fluid cavity clearly shows the concentrating effect of the R0 mode of vibration at the centre of the fluid cavity.

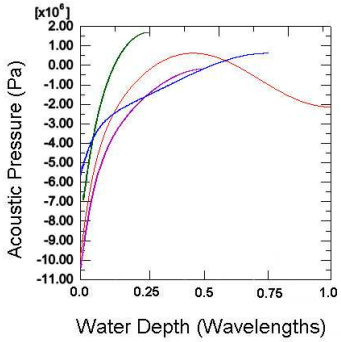
Finite element study of an ultrasonic probe horn



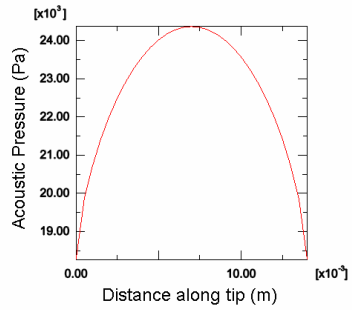
A finite element model was created of an ultrasonic probe device.



The pressure field created by the probe in the fluid volume is calculated. The highest pressure is close to the tip of the probe.



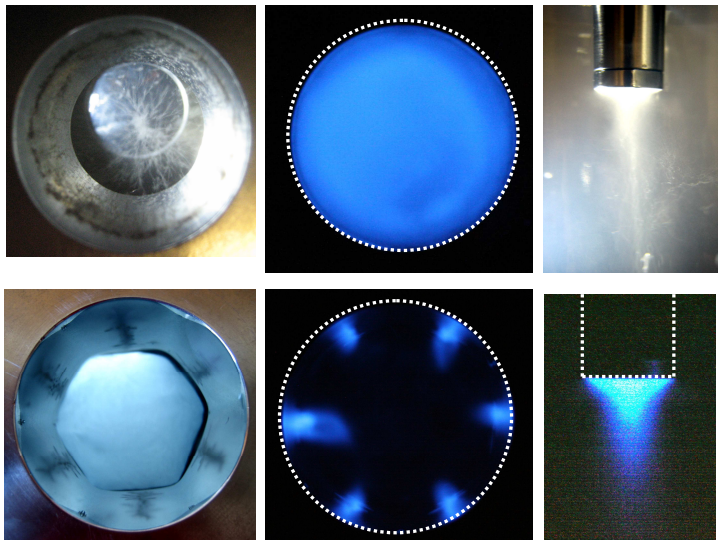
The graph shows how the pressure varies with the fluid cavity depth. At ½ and 1 wavelength depths the maximum pressure is much greater than at ¼ and ¾ wavelength depths due to standing waves being set up within the fluid.



The graph shows the pressure distribution across the tip of the probe.

Visualisation study

Visualisation studies were carried out using photographs of the bubble cloud and also by using Luminol to take advantage of the chemical reaction between this chemical and cavitation bubbles. For the R0 mode ultrasonic horn, cavitation occurs throughout the fluid although the photograph shows a strong central bubble field. The R3 horn cavitates at the anti-nodes as expected and the probe horn has a cone shaped cavitation field around the vibrating tip.



Bacterial inactivation comparison

From microbiological tests using E.Coli K12, the R0 mode radial horn has a significantly better inactivation rate than the probe device. Also, the R3 mode horn has a similar inactivation rate to the probe device.