The Bubble Dynamics and Pressure Field Generated by a Seismic Airgun

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Declarations

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Statement of Co-authorship

Chapters 3 – 5 of this thesis have been written as scientific papers. All numerical simulation, experimental design, data analysis and manuscript preparation were the primary responsibility of the candidate; however, work was performed in collaboration with supervisors. Details of these contributions are outlined below:

Chapter 3

Modelling of Seismic Airgun Bubble Dynamics and Pressure Field using the Gilmore Equation with Additional Damping Factors
Irene Penesis and Paul Brandner contributed discussions on the numerical modelling and manuscript preparation.
Contribution Percentage: Candidate 70%, I. Penesis 20%, P.A. Brandner 10%

Chapter 4

The Pressure Field Generated by a Seismic Airgun
Paul Brandner and Irene Penesis contributed to experiment design, data interpretation and manuscript preparation.
Contribution Percentage: Candidate 70%, P.A. Brandner 20%, I. Penesis 10%

Chapter 5

Bubble Dynamics of a Seismic Airgun
Paul Brandner and Irene Penesis contributed to experiment design, data interpretation and manuscript preparation.
Contribution Percentage: Candidate 70%, P.A. Brandner 20%, I. Penesis 10%

We the undersigned agree with the above stated "proportion of work undertaken" for each of the above published (or submitted) peer-reviewed manuscripts contributing to this thesis

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Abstract

The bubble dynamics of a seismic airgun are investigated in relation to their use for shock testing naval vessels. A model-scale airgun is used to investigate the dynamics of a bubble generated at different standoffs from a steel plate and a free surface in an open top tank. The airgun is fired at 50 and 100 bar initial pressures. Field pressure, wall pressure and acceleration are measured, and the bubble is imaged using low- and high-speed photography. The behaviour of the bubble is described and the bubble growth is determined from shadowgraph photography and compared with the simultaneous pressure field signal. Four distinct bubbles are evident at the first bubble maximum as a result of the initial four jets of air. The Rayleigh–Taylor Instability is identified as playing a role in the bubble break up. The bubble and reverberant frequencies are identified using Wavelet and Fast Fourier transforms. The interaction of the bubble with the free surface is similar compared with other bubbles; however, the bubble is unaffected by the nearby wall for the standoffs tested. Only the initial shock generated by the airgun significantly impacts the wall, which moves in phase with the bubble pulsations. As a result of the movement, little pressure is felt at the wall from the pressure pulses generated by the bubble collapses. Despite the four port arrangement, the pressure signature of this airgun is not directional.

An analytical model of the bubble dynamics is developed based on the Gilmore equation. Additional terms for modelling the presence of the airgun body, mass throttling, effective viscosity and heat diffusion are included and Gilmore's model for the radiated pressure wave is used to predict the pressure field generated by the bubble. The results of this model compare favourably with the model-scale airgun data, with the exception of the initial shock and first maximum bubble velocity, which are over-predicted. Full-scale airgun pressure field measurements are predicted well by the model.

Smoothed Particle Hydrodynamics is investigated as a numerical method for modelling a pulsing seismic airgun bubble. Limitations are found in the available computational time and power, and in the ability to accurately model the gas-water interface. Some improvements are identified to enable modelling the bubble pulsation due to the pressure differential across the bubble surface.

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