ULTRASOUND IMAGING AND THE RING VORTEX PHANTOM: AN INITIAL EXPERIENCE

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Introduction

The ring vortex complex flow phantom is a prototype device designed to challenge quantitative flow imaging technologies. The device employs the ring vortex as its reference flow, producing complex yet well-characterized flows over a range of generating conditions. Ring vortices are generated by propelling a slug of fluid through a circular orifice into an ambient fluid volume. An axisymmetric toroidal circulating core forms around the orifice before detaching and propagating across the tank at a steady translational velocity. These vortices have demonstrated high predictability, stability and reproducibility to within 10%. This study explored the performance of established clinical ultrasound techniques (B-mode and PW Doppler) in the context of the flow phantom.

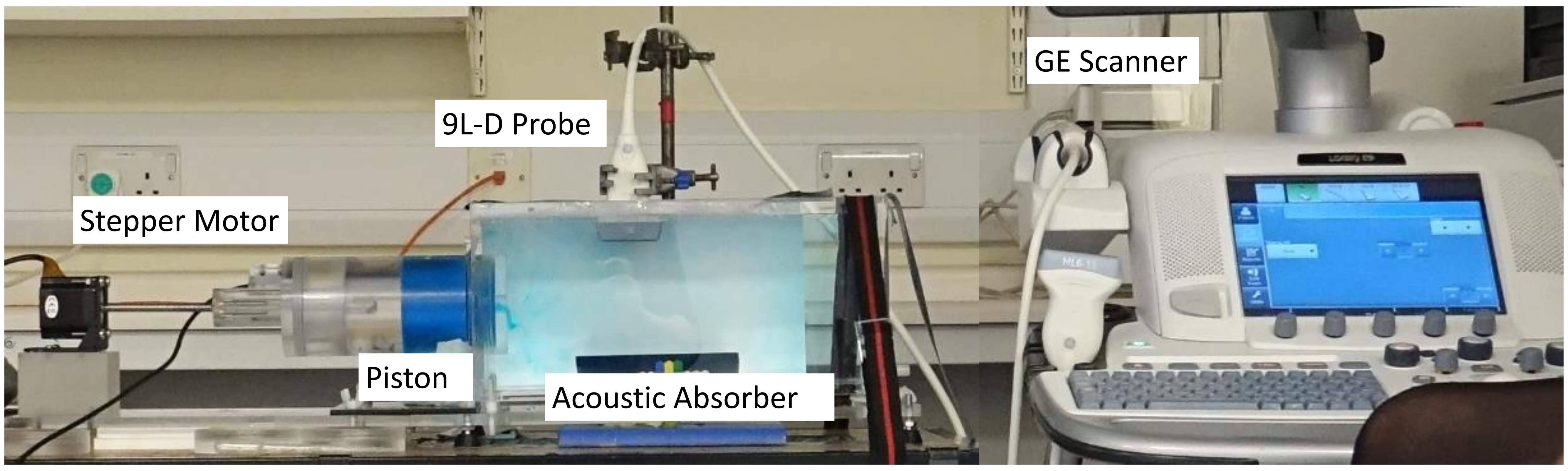

Figure 1: Annotated experimental setup of the ring vortex phantom and Ultrasound scanner

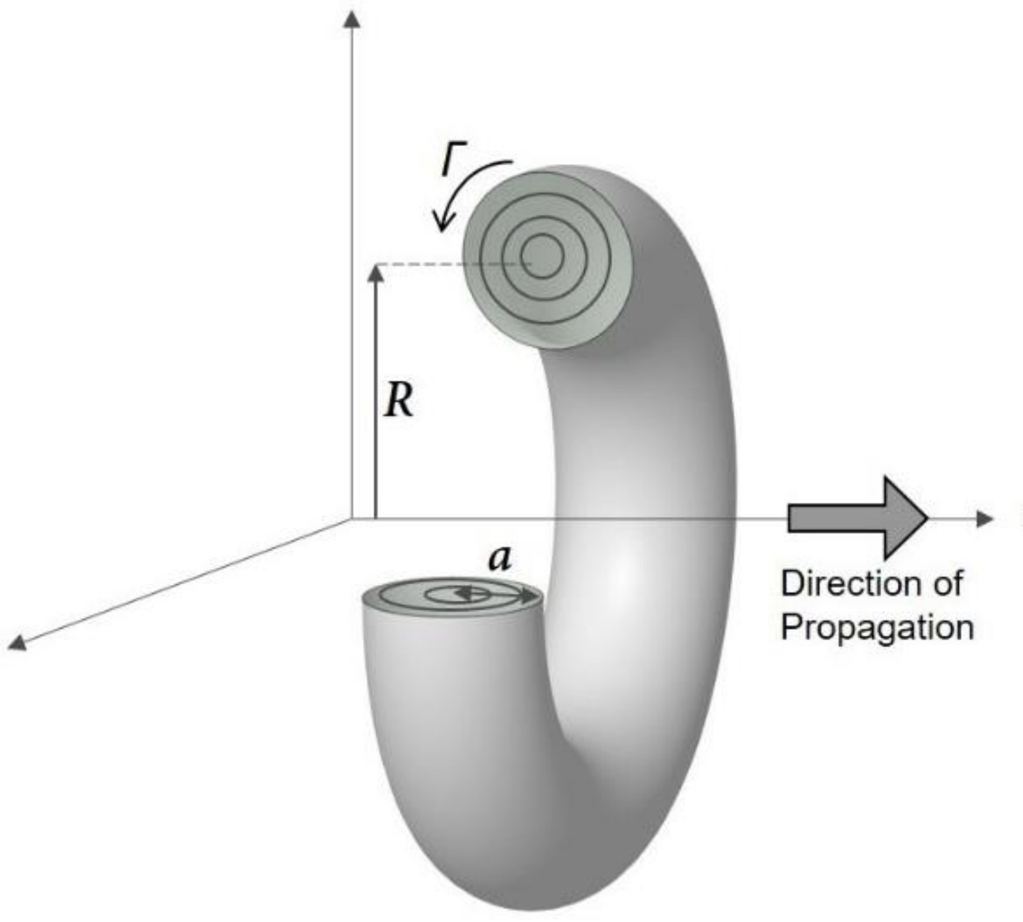

Figure 2: Schematic of the Ring Vortex

Methods

A selection of ring vortices were generated over 5 generating conditions, with translational ring speed ranging from 5cm/s-40cm/s. The flow was seeded with neutrally buoyant 10µm diameter nylon particles to ensure sufficient visualization through scattering, and ten vortices of each condition were generated and analyzed.

The vortices were visualized using a GE LOGIQ E9 scanner with 9L-D probe. Firstly, B-Mode images were taken of the rings in a cine loop, imaging the rings as they travelled. The rings' translational speeds were calculated through measurement of the inter-frame displacement and compared to real-time camera recordings.

Secondly, PW Doppler was used to interrogate the intra-ring micro-flow velocities, using a 1mm gate positioned down the ring's cross-section in 1mm increments. Five measurements were taken for each position with maximum values averaged. These were then compared to Laser-PIV datasets.

B-Mode Results – Bulk Measurements

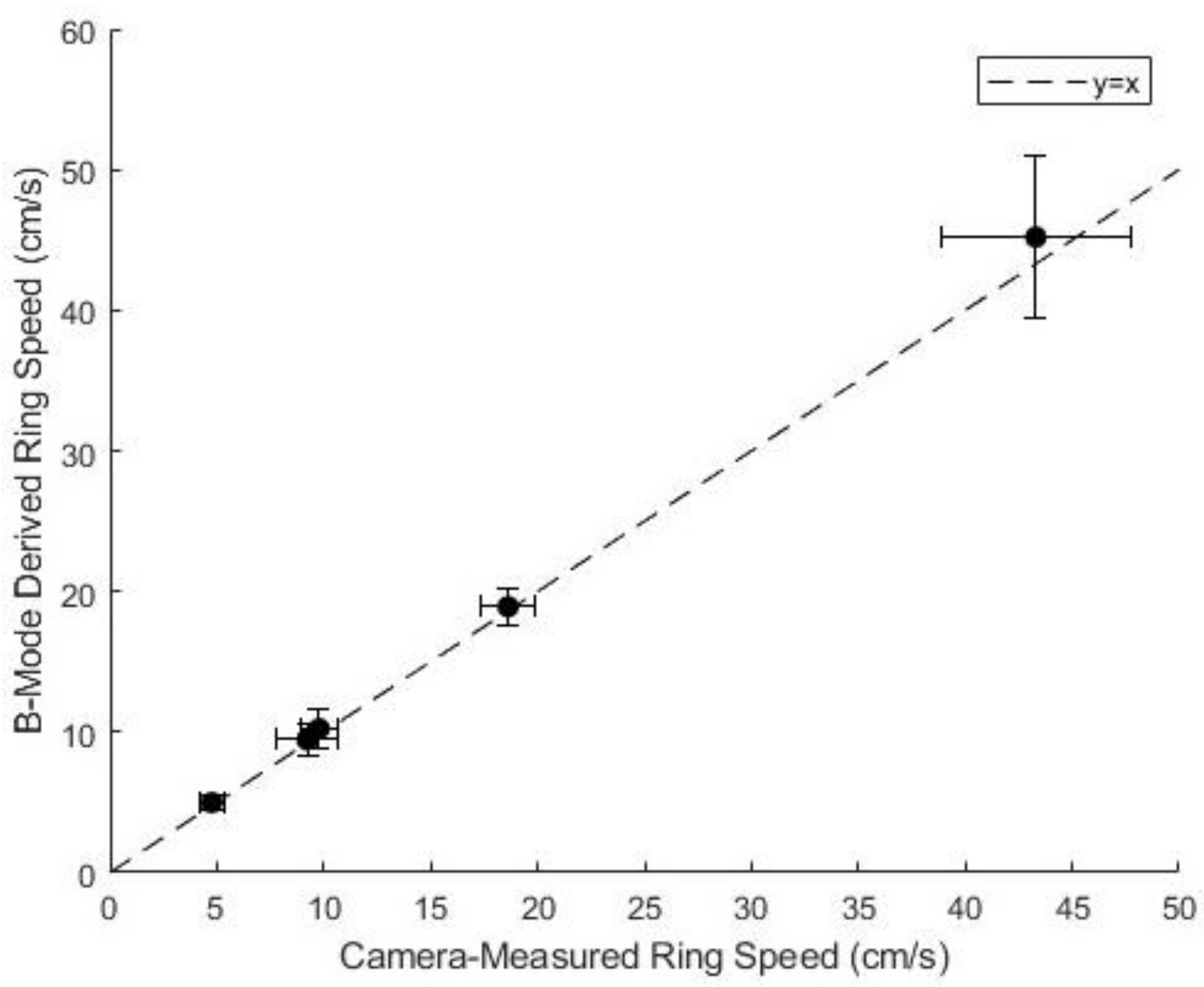

Figure 3: Graph presenting the agreement between ring speed when measured using B-Mode datasets and camera data respectively

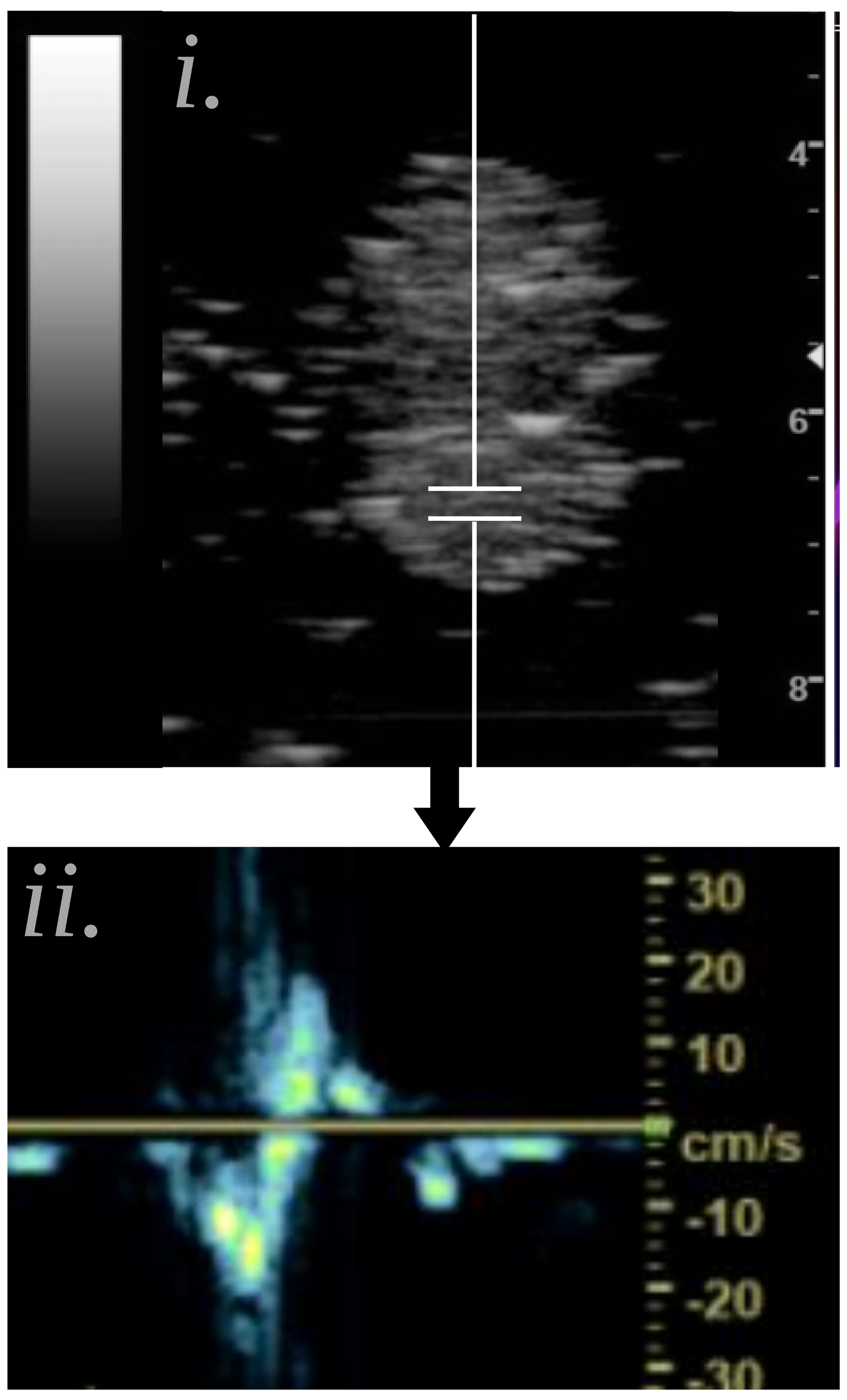

Figure 4: (i)Example B-Mode image with example annotated PW-D gate
(ii) Example PW-D trace when measured over the vortex core

PW Doppler Results – Micro Measurements

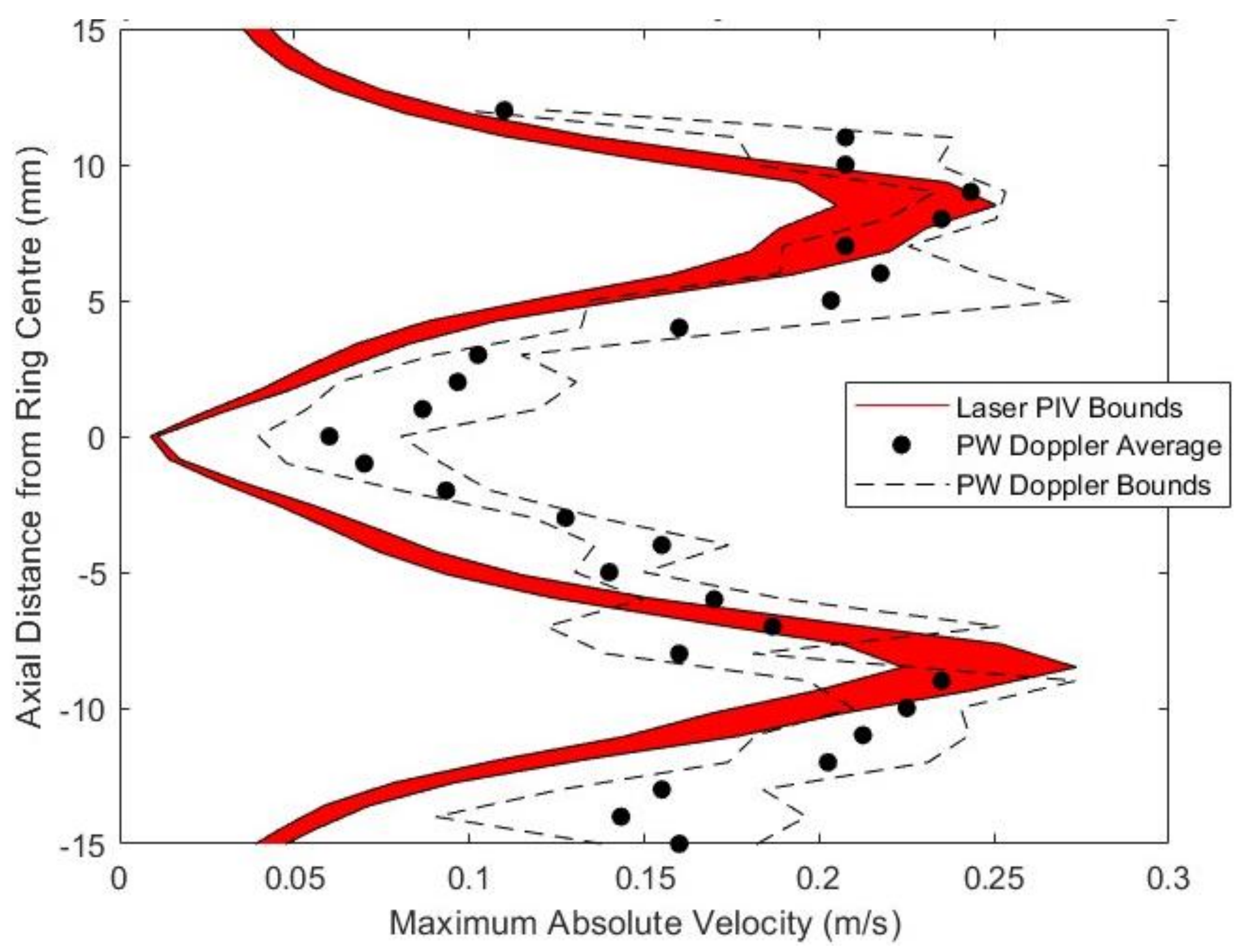

Figure 5: Graph presenting the maximum local velocities measured down the ring, using Laser PIV and PW-D respectively.

Conclusions

The results indicate that B-Mode–derived velocity values at the macro-scale are accurate to within 10% when compared to the phantom benchmark datasets. More notably, PW Doppler consistently detects the expected velocity profiles from intra-ring micro-flow velocities, which are quantitatively comparable to the Laser PIV datasets also. This initial study shows promise for the ring vortex phantom in Doppler US QA, with further work required to compare inter-scanner and inter-probe variation.

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