A Novel Complex Flow Phantom for Doppler Ultrasound

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Background

Traditional Doppler Ultrasound methods and newer Ultrasound technologies, including vector flow imaging and volume quantification, are used to measure blood flow in cardiovascular systems exhibiting complexities such as recirculation, turbulence, jets and vortices. Existing Doppler phantoms struggle to confirm the accuracy of Ultrasound methods in measuring complex flow. A novel phantom, designed to produce complex flows that are physiologically relevant, stable, predictable, controllable and reproducible, is presented. A vortex ring is chosen as the reference flow for the development of the proposed phantom.

Methods

A vortex ring forms when a column of fluid is pushed through a smaller orifice into a neighbouring fluid environment. The fluid "rolls up" at the orifice face, forming a toroidal vortex that (for specific Reynolds numbers) propagates along its axisymmetric axis. The phantom design proposed uses a piston/cylinder system to propel a slug of fluid through an orifice that connects to an open tank full of fluid. Different orifices diameters can be provided on demand. Main vortex parameters, which are related to the piston displacement and piston speed, can be controlled by a programmable microcontroller and a linear stepper motor. Orgasol® particles (10um) were chosen to provide a scattering signal for vortex visualisation using Ultrasound.

Results

The assembled phantom is shown in Figure 1. Laser-PIV (particle image velocimetry) measurements have shown that vortex ring velocities ranging from 8cm/s to 80cm/s can be produced with reproducibility better than +/-8% (Figure 2). Figure 3 shows the Ultrasound scans of the ring vortex with examples of B-mode (3a), Colour Flow Doppler (3b), Pulsed Wave Doppler spectrum (3c) and Echo-PIV (3d) images.

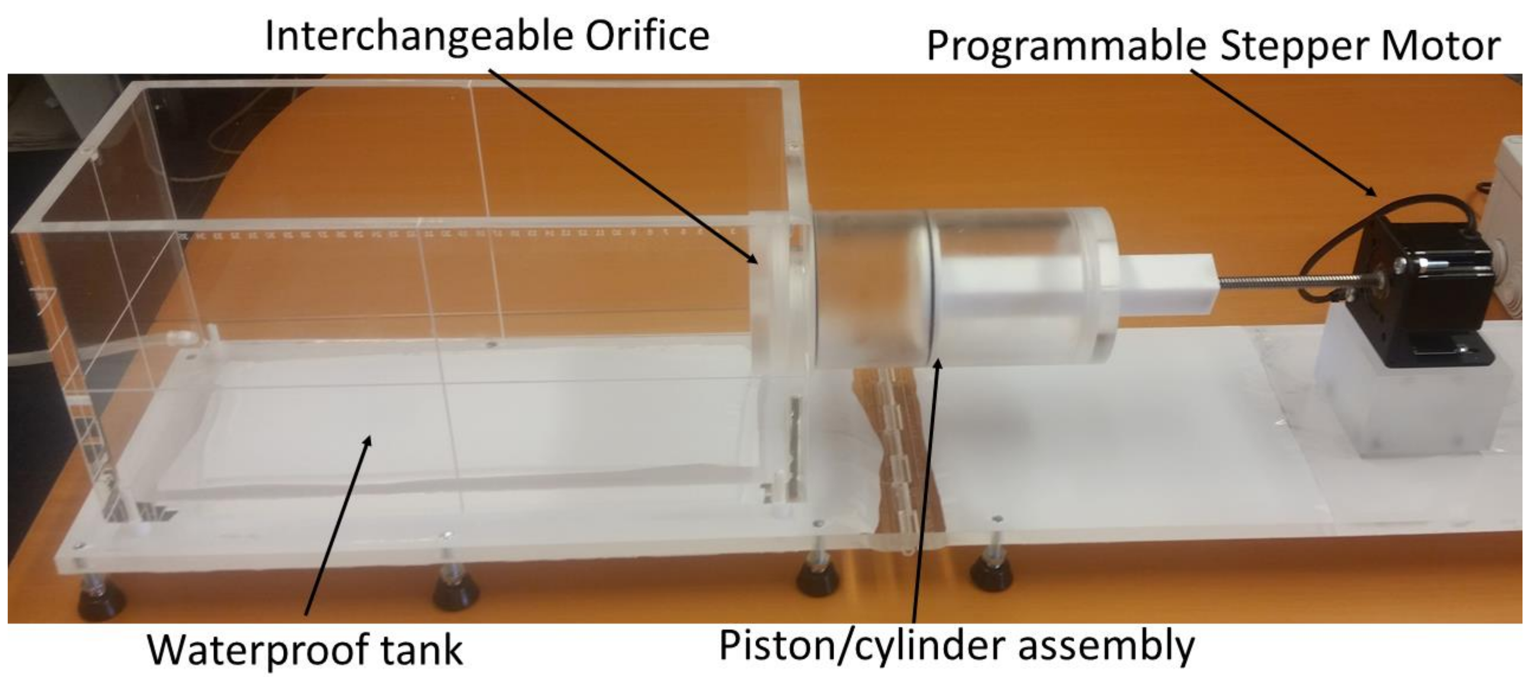

Figure 1. Complex Flow Phantom – Assembled system

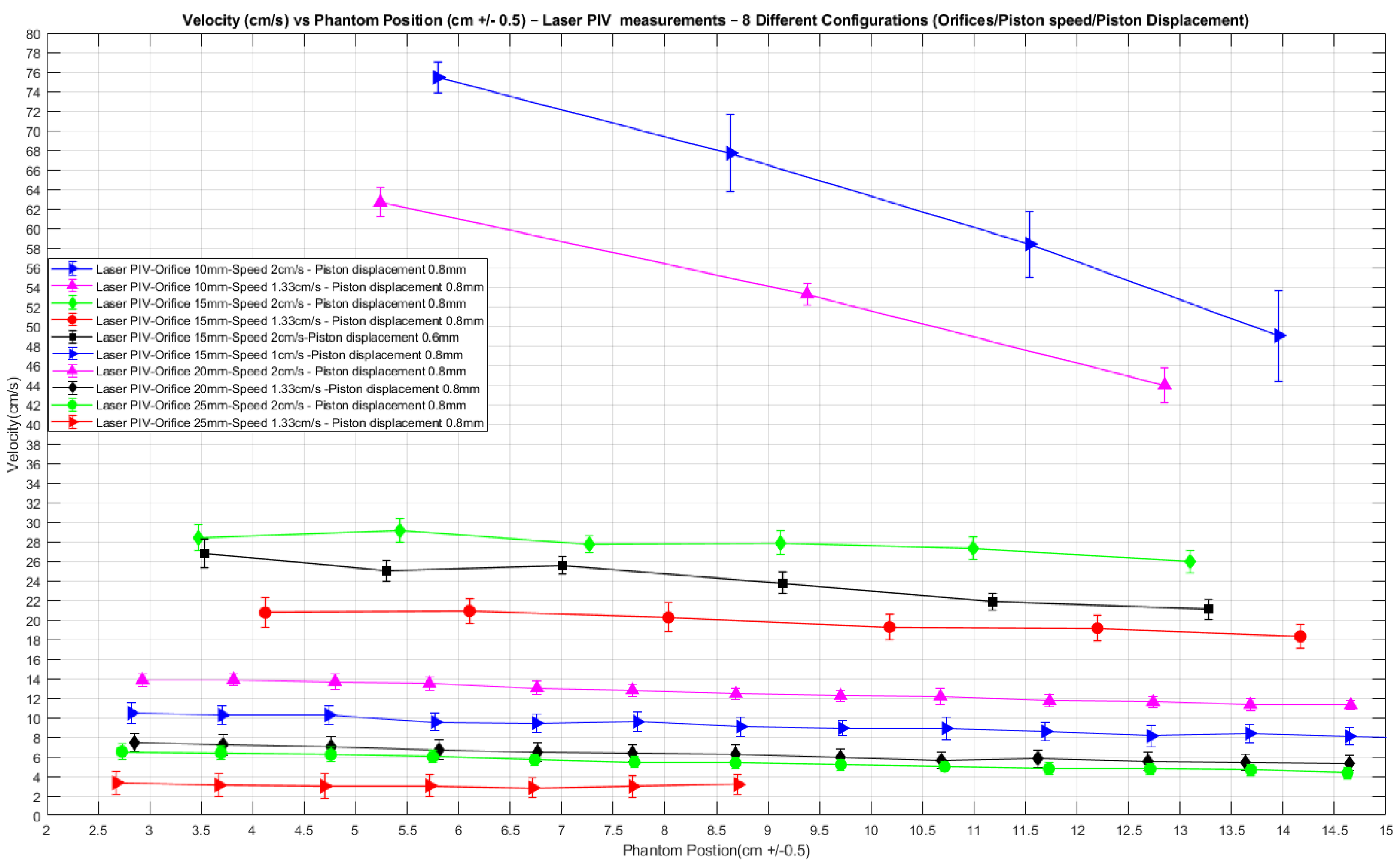

Figure 2. Laser-PIV measurement results

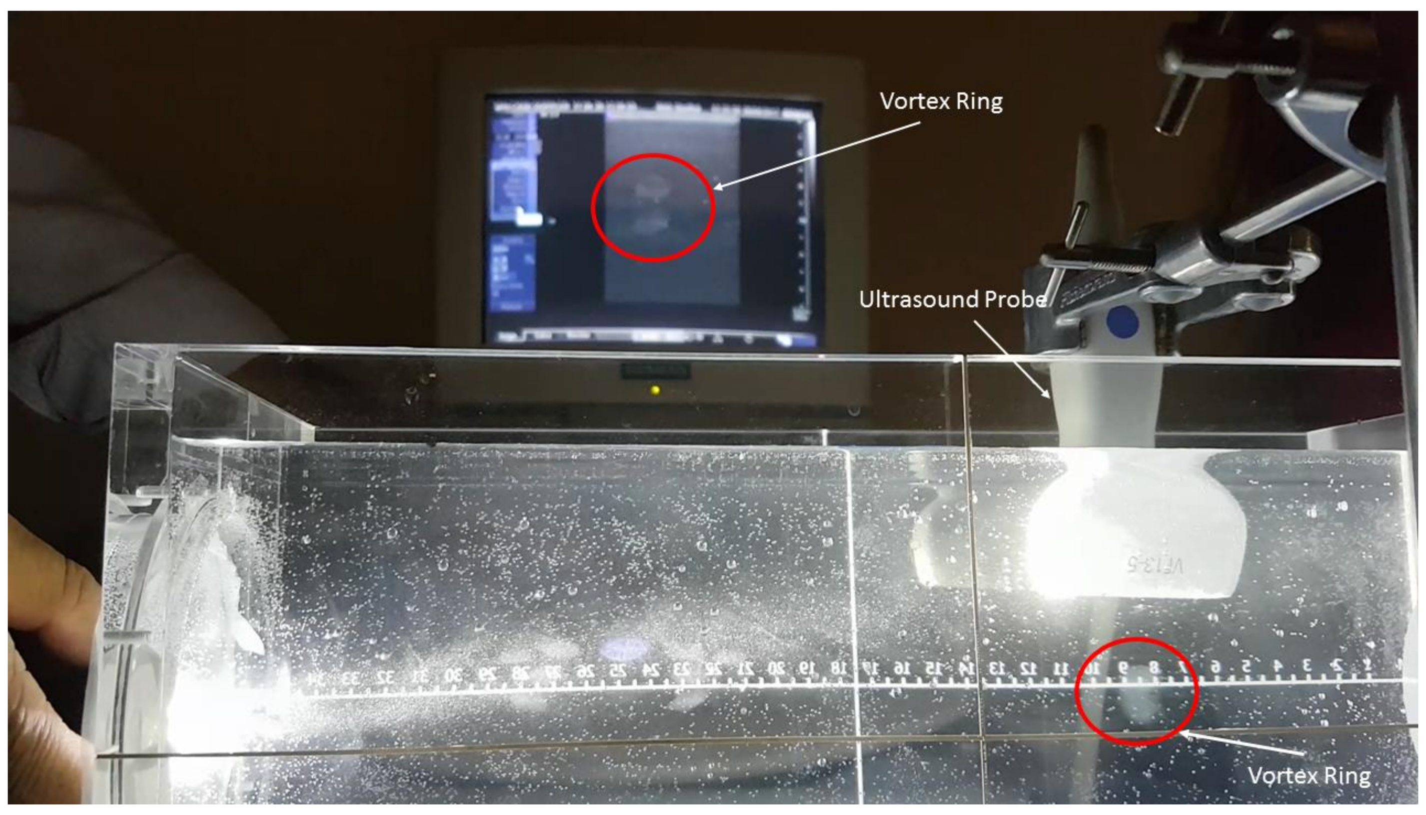

Figure 3. Ultrasound scan with examples of B-mode imaging (3a), Colour Flow Doppler imaging (3b), Pulsed Wave Spectral Doppler imaging (3c) and Echo-PIV (3d).

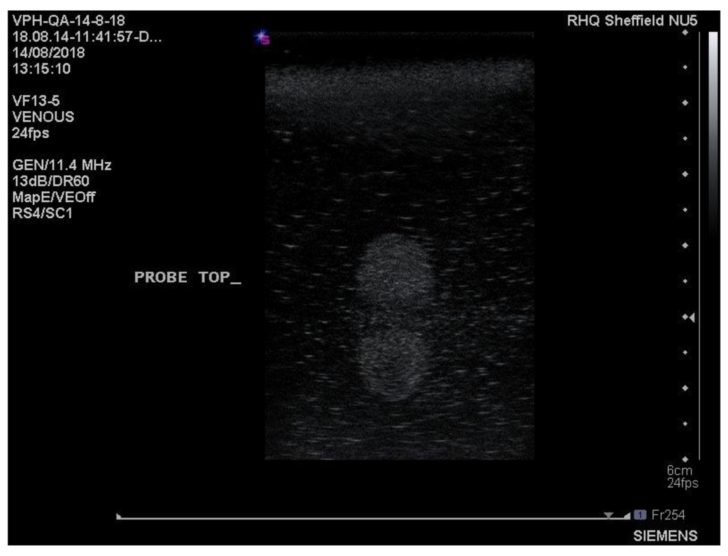

Figure 3.a B-mode imaging

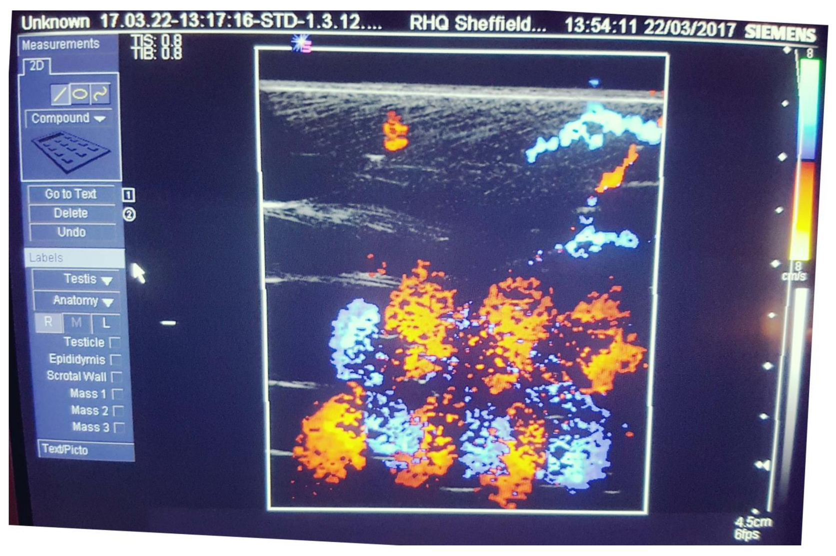

Figure 3.b Colour Flow Doppler imaging

Figure 3.c Pulsed Wave Spectral Doppler imaging

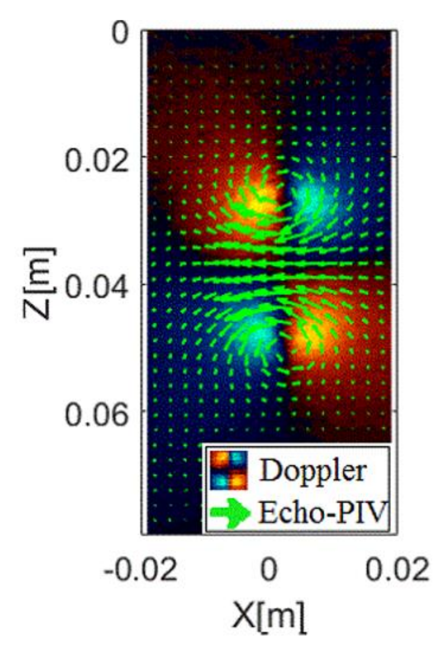

Figure 3.d Echo-PIV applied in post-processing

Conclusion

A novel, cost-effective, vortex ring flow phantom has been presented. Early results point to its potential as an Ultrasound flow phantom that can test scanners operating in standard Doppler modes and advanced flow mapping modes.

Acknowledgements

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