Multiplane scanning Stereo-PIV measurements of flow inside a spiral vortex pulsatile blood pump

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A multiplane scanning Stereo-PIV (MS-SPIV) system was developed to allow three-dimensional volume mapping measurements of Stereo PIV in liquid flows enclosed by complex geometries, such as biomedical flows. MS-SPIV measurements were carried out inside a spiral vortex (SV) pulsatile blood pump (Fig.1-2). The present study aims to reveal the mechanism of the highly three-dimensional unsteady vortex. A full-scale Perspex model of the SV pump was used in an in vitro cardiovascular flow simulator. Typical driving conditions were adopted as follows: a heart rate of 72 beats/min, averaged flow rate of 5.0 L/min and systolic fraction of 32%. The mean bulk Reynolds number Re_{mean} and the Womersley number Wo were approximately Re_{mean} = 1600 and Wo=15, respectively. Phase-locked MS-SPIV measurements enabled to reveal the complex behaviour of the three-dimensional unsteady vortex. The results demonstrated that an initial vortex structure developed during filling was a principal factor of determining a near-wall swirling velocity gradient during systole (Fig.3). Although the diastolic vortex was expected to have an axisymmetric vortex structure so as to produce a uniform wall shear rate throughout a diaphragm-housing junction, it was found that the rotating axis was inclined with respect to the pump centerline (Fig.4). Among several relevant factors, it was demonstrated that the filling flow inside a chamber exhibited a significant diffusivity towards a pump apex. As the fluid mechanics of a pulsatile artificial heart, it is essential to control the diffusive tangential inflow during diastole.

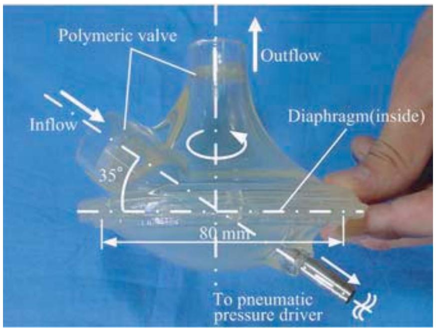

Fig.1 Spiral vortex pulsatile blood pump

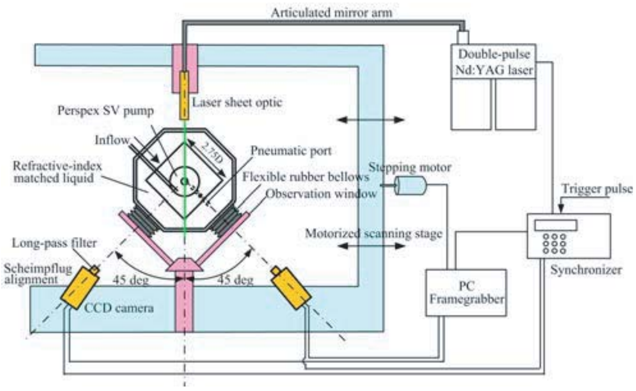

Fig.2 Overhead view of multiplane scanning Stereo-PIV system

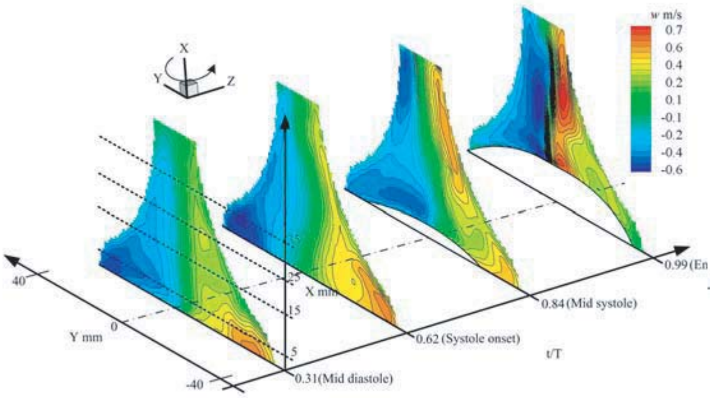

Fig.3 Phase-locked mean swirling velocity distributions at a center plane

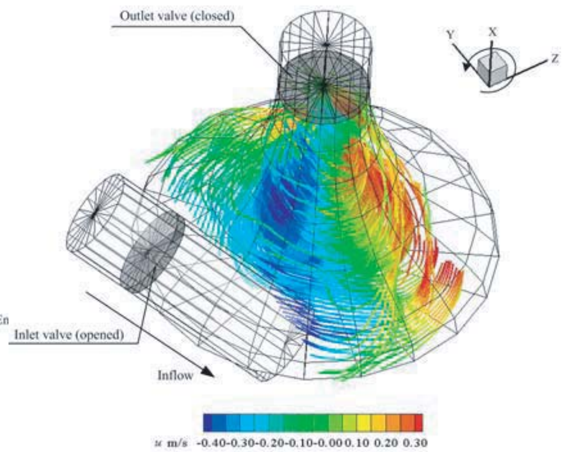

Fig.4 3D streamlines with axial velocity distributions at mid diastole