Study of flow field in an advanced bladeless rotary blood pump using Particle Image Velocimetry

S. Sastry[1], J.R. Kadambi[1], J.M. Sankovic[2], V. Izraelev[3]

1: Department of Mechanical Engineering, Case Western Reserve University, Cleveland, OH., USA,
sudeep.sastryhu@case.edu , jxk11@mae.case.edu
2: National Aeronautics and Space Administration, John H. Glenn Research Center, Cleveland, Ohio, USA,
John.M.Sankovic@nasa.gov
3: Advanced Bionics Inc., Hopkins, Minnesota, USA, austin-mh@juno.com

Keywords: Rotary Blood Pump, PIV

Understanding the flow characteristics of a rotary blood pump is the first step towards increasing its acceptance as cardiac assist device. One has to consider the damage to the blood cells due to hemolysis and thrombosis that occur in the pumps. Hemolysis or red blood cell damage occurs in regions of high shear stresses. The shear stresses cannot be eliminated, but can be substantially reduced through proper design of the pump. Therefore characterizing the different flow regimes in various areas of the pump is very important. A better understanding of the flow fields can be very useful in the judicious design of the pump. Furthermore, experimental data are needed to validate the CFD codes used for design purposes. Hence focus of this investigation is to obtain flow characteristics for various flow regimes using non-intrusive Particle Image Velocimetry.

A three disc optically clear magnetic drive bladeless pump, which is an evolved version of the Tesla pump, is investigated. The casing and the impeller discs are made of acrylic. The impeller can be considered to be made of two hollow acrylic cylinders between which three disks have been placed and held together by four symmetrically located pins. The flow enters the impeller axially. The pump schematic and the flow path are shown in Figure 1. The refractive indices of the impeller, the hollow cylinder and pump casing material (all made out of acrylic) and the blood simulant liquid are matched (1.485). This minimizes the scattering of laser light at the liquid solid interfaces and facilitates the application of PIV. The impeller floats in this liquid. On the fore part of the aft cylinder, magnetic strips are placed. The casing is held circumferentially and coupling magnets are placed in line with the magnetic strips on the impeller. The coupling magnets and the pump rotor are driven by a DC motor.

The blood simulant fluid is composed of saturated aqueous sodium iodide (NaI) solution, glycerin and distilled water. The fluid approximates the steady flow kinematic viscosity of blood (3.2 cS at 20°C) and the refractive index of the fluid matches that of the test section. Neutrally buoyant silver coated hollow glass spheres (14μm dia.) are used as seed. Velocity profiles are obtained in region between the rotating cylinder (impeller) and the housing, in back flow region and between the discs.
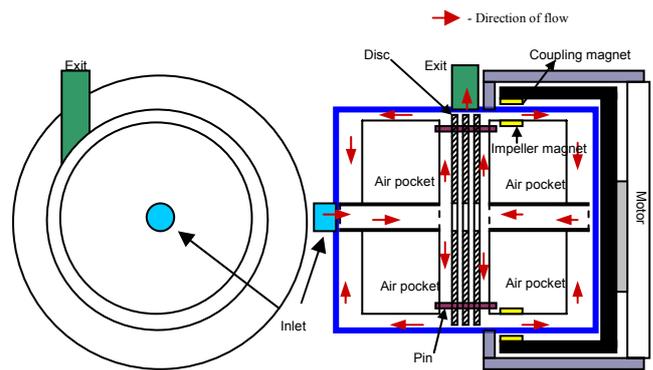

Fig. 1 Schematic Diagram of the Disc Blood Pump

The PIV images are analyzed using the cross correlation technique. The velocities obtained are an average of 700 - 1000 image pairs. An uncertainty analysis is carried out to ensure that the error levels encountered were in the acceptable range. An ensemble size of 750 data sets results in an uncertainty level of ±1.3%.

Flow fields in the space between the impeller and the housing reveal that the flow is not similar to Couette flow between cylinders. The deviation occurs due to existence of flow velocities in the axial and the radial direction. However, near the outer stationary surface the experimental velocity profile is similar to the Couette flow. Unstable flow is encountered at these locations due to the wobble of the impeller.

In a region in front of the impeller and below the inlet tube where back flow is encountered, one can observe that the velocity of the fluid increases with increase in angular velocity and radius along the rotating impeller. And at large radius the velocities decreases due to the proximity of the pump housing and the wall effects which take precedence over influence of the rotating impeller. Flow between the discs is found to be consistent with flow over a disc with velocities higher at increasing radius of the disc. These and other results are discussed in this paper.