Abstract:
The development of implantable ventricular assist devices—in particular, continuous-flow axial and centrifugal pumps—offers hope to many heart attack victims waiting for donor hearts. These autonomous devices are intended as a medium-term bridge to transplant, or, if enough progress is made, even as a permanent clinical solution. One challenge that needs to be addressed in the design phase of blood pumps is the elevated level of shear stress, and the hemolysis response of the red blood cells, which depends on both the dose and time of exposure. The distribution of the shear stress levels in a complex flow field of a rotary blood pump chamber, as well as the measure of the blood cells' exposure to these pathological conditions, are difficult to obtain experimentally. Device designers often have to make decisions on the details of pump configuration guided only by the global, time- and space-averaged indicators of the shear stress inside the pump, such as the hemoglobin release measurements made on the exiting blood stream. In the context of fluid mechanical
modeling of the implantable GYRO blood pump being developed at the Baylor College of Medicine, we are devising tensor-based measures of accumulated strain experienced by individual blood cells, and correlating them with available blood damage data. In the first approximation, red blood cells under shear are modeled as deforming droplets, and their deformation is tracked along pathlines of the computed flow field. We propose ways of deriving standard blood damage indicator from the measure of cell deformation and report blood damage results in an unsteady blood flow simulation in a model two-dimensional pump.