Performance Prediction of Volute Housing for A Rotodynamic Blood Pump

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1 Abstract

For the treatment of patients with heart failure, a number of cardiac assist devices and pump systems have been developed during the last decade. Rotary blood pump is more favorable as a research and development topic as it is small in size, simple in design, high is efficiency and cost-effective. High shear stresses occur due to high rotational speed and small clearances between rotor and housing may lead to hemolysis, i.e., red blood cell (RBC) damage. Particularly for mid- and long-term applications of such devices, it would be desirable to develop pump geometries with low shear stresses and exposure times. For verification of design modifications, in vitro hemolysis tests are commonly performed. These tests require considerable experimental efforts and quite a number of repetitions due to large statistical variations. Computational fluid dynamics (CFD) has been used for decades to simulate and analyze the fluid flow within and around interesting objects. Nowadays, CFD is beginning to significantly impact the development of mechanical circulatory assist devices.

2 Materials and Methods

In this study, a general approach of hemolysis analysis by means of computational fluid dynamics (CFD) is discussed. A commercial CFD code, CFX-5 was employed. A validated computational model of a rotodynamic blood pump is developed for detailed analysis of shear stress distribution. An experimental loop was set up to carry out the hemolysis testing and hydraulic performance measurement of a blood pump developed by Cleveland Clinic Foundation. Designed as a Ventricle Assist Device (VAD), this blood pump can give 5L/min flow and 100 mmHg pressure at a rotational speed of 2600 rpm. The foundation of the hemolysis testing loop is a water bath, which serves the purpose of inlet pressure control through tank head, as well as temperature control. A pump-heater exchanger system maintains the water at a fixed temperature, while circulating it. A 1500 cc

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nominal capacity cardiopulmonary bypass venous reservoir (Avacor Corp P/N RV-1500) rests inside the tank, with polyurethane tubes passing through sealed ports in the tank wall to reach the inlet and outlet of the pump. Fresh bovine blood will be used as testing fluid. The blood absolute viscosity is measured at 37C using a Wells-Brookfield Digital Viscometer Model LVTDV-IICP, supported by a GCA Precision R 10a constant temperature water source for the water jacket. The blood pH is measured with a Beckman I40 pH meter. Hematocrit is determined by the Microhematocrit method. Plasma hemoglobin before and after will be measured using a Ciba-Corning 288 machine. The details of hematology and biochemistry assays will be referred to Gu [1]. Index of hemolysis shall be calculated from the formula:

$$IH = \frac{V(100 - Hct)\Delta S_{Hgb}}{Flow * Time/100} = \frac{GramsHgb\ Re\ leased}{100\ Liters\ Pumped} \tag{1}$$

where $V=$ the actual volume in the circuit, calculated form the trapped saline priming volume, the infused blood volume, and the samples withdrawn

Hct = the hematocrit

ΔS_{Hgb} = the difference between the plasma hemoglobin at the end and at the beginning of the time interval.

$Flow$ = the average flow rate during the interval, in liters per minutes

$Time$ = the length of the time interval in minutes.

3 Results

The results show that CFD offers a convenient tool for the general assessment of shear-induced hemolysis. The CFD also predicted results correlated well with the experimental data including pressure-flow performance and specific flow field features. The results show that CFD offers a convenient tool for the general assessment of shear-induced hemolysis and hydraulic performance