Shear Stress Sensor for Peristaltic Pump Head as an In-Line PAT Tool for Protein Solutions

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Purpose

Shear stress during processing can impact protein stability. Closed loop pumping of protein solutions, especially during tangential flow filtration, can impact the stability of sensitive proteins. Although shear stress rates have been modeled in tubular flow systems, direct, experimental measurement of the rate of shear stress on the protein in a peristaltic pump head has been challenging. In this study, we demonstrate the application of wall shear stress (WSS) sensor in quantitating shear experienced by viscous aqueous solutions in the peristaltic pump head.

Methods

An F-series Lenterra's RealShear™ stress sensor was adapted to measure wall shear stress on the wall of plastic tube within and outside Flexicon PF6 peristaltic filling machine (Figure 1). Water (1cP viscosity) and two PEG (20,000 molecular weight) water solutions (6 w% and 10 w%) with viscosities of 7 cP and 13 cP, respectively, were used in tests. Also, some tests were carried out without any fluid, effectively pumping air. Flexicon PF6 peristaltic filling machine motor speed was in the range from 30 RPM to 250 RPM. WSS sensor response was recorded during pumping of three different fluids at a range of RPMs. The WSS measurement rate was held at 500 Samples/s throughout the tests. Flow rates were determined by measuring the weight of the fluid accumulated in a beaker in a set time interval. Pulse amplitude data was analyzed for various RPM for different fluids, both for the setup where the sensor was inside and outside the pump.

Results

All raw data plots showed periodic structure with pulses corresponding to successive roller occurrences. The tests demonstrated that the flow properties inside the peristaltic pump are of complex nature. The measured values of WSS are much greater than those estimated from the fully developed flow model. It was shown that these high values of WSS could not be explained by probe vibration and movement experienced during the tests. The temporal dependence of WSS was found to be different for fluids with different viscosities.

Conclusion

Measured magnitudes of the generated WSS pulses (several hundreds Pa) were significantly higher than the expected wall shear stress in a circular cross-section in fully developed flow (a fraction of Pa for realized flow rates). The shape of the pulse varied for different fluids: for lower viscosity fluids the pulse had a shape of two partly overlapping peaks with earlier peak being higher than the later one, and for higher viscosity fluids the pulse shape showed a single peak with relatively slowly rising front edge and a sharp back edge. In addition, reversal of the flow direction was observed in the pipe that is being compressed by the roller. Understanding of the flow patterns and the wall shear forces inside the plastic tubing in the pump can help understand the stresses experienced by protein solutions during processing.

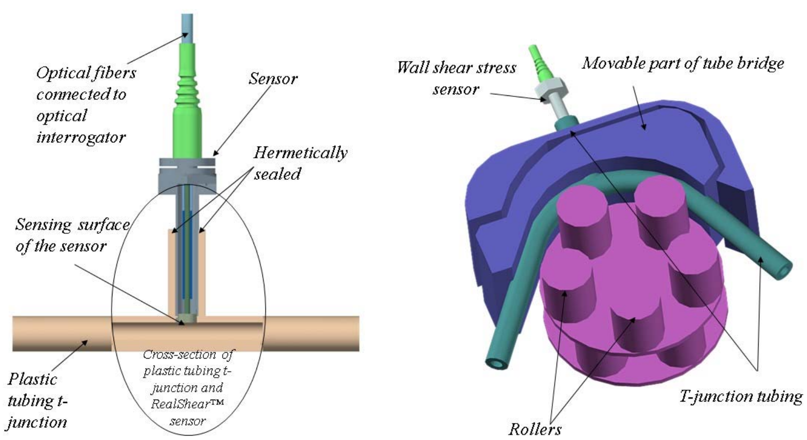

Figure 1. WSS port installed with PF6