Continuous, Fluid-powered, Slurry Feeding into High-pressure, High-temperature Environments

Using Teledyne ISCO Syringe Pumps

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Syringe Pump Application Note
AN35

Doug Hendry[1], Malithi Wickramathilaka[2], Nikolas Wilkinson[2], Andrew Miller[1], Chandrasekar Venkitasamy[2], and William Jacoby[1,2],
Department of Biological Engineering[1], Department of Chemical Engineering[2], University of Missouri, Columbia, MO

Abstract and Introduction

Supercritical fluids provide unique opportunities for processing and separations of biomass and other carbonaceous materials. Continuous operation, rather than batch processing, is necessary for supercritical fluid technology to be used on a large scale. This application note describes a novel feeder capable of feeding a variety of high-solids slurries into high-pressure (and high-temperature) environments for processing with supercritical fluids. The feeder operates continuously and allows precise measurement of feeding rates for research purposes. Teledyne ISCO syringe pumps are essential parts of the experiential apparatus used in the investigation, which is located in the Carbon Recycling Center in the Department of Biological Engineering at the University of Missouri. The pumps provide fluid power to drive a piston accomplishing positive displacement of slurry. The feeder is a dual node design, each node operating semi-continuously so that both nodes together operate continuously. This feeder is currently used on a laboratory scale, but is amenable to scale up.

Feeder Description and Experimental Procedures

The schematic of the high pressure slurry feeder is shown in Figure 1. As shown in the figure, the fluid power feeding chamber is plumbed to an ISCO syringe pump that supplies fluid power to drive the solid slurry. Water is used as the incompressible fluid. Design and construction of the feeding mechanism was completed in-house. The delivery method (fluid power) enables pumping solids at higher concentrations than previously reported (Antal 2000, Guo 2010, Kruse 2008). A recent publication from our group describes the capabilities of the fluid power feeding mechanism (Miller 2012).

Fluid Power Feeding Chamber

Because the feeding chamber was driven by fluid power via an ISCO syringe pump, the chamber was capable of pumping slurries into supercritical fluid reaction environments with very high pressures. In our lab, we use the 260D model syringe pump [see note], which is capable of pumping against pressures of more than 50 MPa. Results from our lab also show that this design can pump a variety of solid slurries with different compositions, solids content, and particle size. The design has proved capable of pumping slurries with solids contents as high as 70%. At such low moisture contents, the slurry was a thick paste rather than an aqueous suspension. Another advantage of using a syringe pump as a source of fluid power was the ability to precisely control flow rate (i.e. operate in constant flow mode). Precisely knowing flow rate is important for research purposes when completing mass and energy balances.

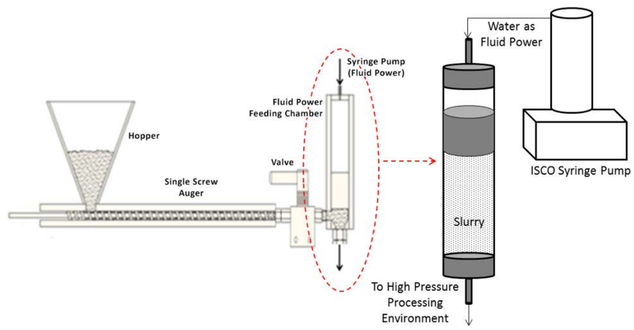

Figure 1: Schematic of Fluid Powered Feeder

Reloading and Dual Node Design

While the fluid power feeding chamber is the most important part of the design, it can only operate semi-continuously because it needs to reload after emptying. The reloading system consists of the hopper and screw auger in Figure 1 and acts similarly to an extrusion system. This mechanism by itself can feed a variety of solid slurries against a pressure differential of up to 3 MPa. This is sufficient to reload the feeding chamber but not sufficient to feed slurries into high pressure environments for supercritical fluid processing. This reloading mechanism, in combination with the fluid power feeding chamber, constitutes one node of the dual node design, operating semi-continuously. In this way, the dual node system operates continuously (i.e., one node pumps while the other reloads). Figure 2 depicts how the system would look with both nodes.

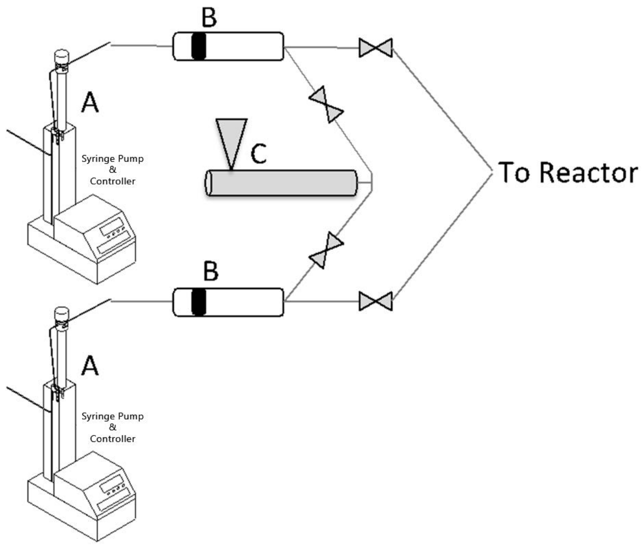

Figure 2: Schematic of the high pressure solids feeder. (A) is the ISCO syringe pumps that drives the pistons in each node. (B) is the node that pumps the solids feed. (C) is the low pressure solids feeder that refills each node while the other is pumping.

Applications

There are a number of applications of this feeder design. Currently in the Carbon Recycling Center (CRC) at the University of Missouri, we use the feeder to pump biomass slurries into our supercritical water gasification reactor. This reactor continuously decomposes biomass into fuel gas (hydrogen and methane) (Miller 2012). In addition to biomass, we use the feeder to feed biomass model compounds and coal, as well as other low value carbonaceous waste materials into the supercritical water gasification reactor. In the future, we will also implement this feeder design for continuous counter current extraction of oil crops with supercritical carbon dioxide. One can imagine many other applications of a reliable, high pressure solid slurry feeder in a supercritical fluid refinery context.

Conclusion

A feeder capable of continuously feeding highly viscous solid slurries into high pressure environments up to 50 MPa has been developed. The feeder is in operation on a lab scale and is easily amenable to scale up. A Teledyne ISCO syringe pump is used to provide fluid power to drive a piston. The design consists of two nodes, each operating semi-continuously so that both nodes in combination act as a continuous feeder. The ISCO syringe pump allows precise measurements of flow rates which is essential for research purposes. There are a number of potential applications. In our lab, we use the feeder to pump biomass slurries into our supercritical water gasification reactor (P = 30 MPa) for thermal degradation into hydrogen and methane.

Reference

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Note:

The 260D model pump, which was used during the original experiment, is discontinued. Current model 260x is the recommended replacement for the older 260D model.

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Product model names have been updated in this document to reflect current pump offerings.

Teledyne ISCO
P.O. Box 82531, Lincoln, Nebraska, 68501 USA
Toll-free: (800) 228-4373 • Phone: (402) 464-0231 • Fax: (402) 465-3091
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