WHITEPAPER

Improving the Accuracy of Pumping and Dispensing:

How Servo Control Enables High Flow and Dispensing Control





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Servo Control

Controlling High Flow and Dispensing with the Same Pump is a Difficult Design Challenge

Building a pump that has good high flow control characteristics and also is able to accurately control precise, low volume dispensing or metering has long been a difficult design problem. Typical pump systems employ velocity control techniques that have good control near a system's maximum speed, but are highly inaccurate at low operating speeds. To maintain good accuracy the motors must run near their maximum speeds. This typically requires manufacturers to supply a number of different gear reductions and pump heads for use at different flow rates. Problems encountered at low pump speeds become even more apparent when dispensing precise quantities or when varying doses of fluid must be dispensed by the same pump system.

Traditional non-servo pumping controls have a very significant error in the lower speed ranges which is increased by large torque variations associated with large viscosity changes due to temperature or changes in tube flexibility in peristaltic pumps.

A peristaltic pump is a positive displacement pump used to transfer a variety of fluids in laboratory applications. The transferred fluid is completely contained in a flexible tube fitted inside the pump head and does not come into contact with the pump or other parts of the fluid transmission system outside the tube. Fluid is moved through the tube by a series of rollers attached to a rotor that compress and close a section of the flexible tube and squeeze measured amounts of fluid through the tube as they rotate. Loads can vary significantly over relatively short time periods with changing flexibility of the tube, viscosity of the fluid and temperature.

When dispensing doses the system must stop and start for each dose dispensed which requires the system to operate in the low speed range for every dose. This leads to significant dispensing errors that vary with dose volume and motor running speed for any particular pump head and tube combination. Additional errors occur as a result of variations in supply voltage, mechanical wear, ambient temperature, motor temperature, fluid viscosity, and a number of other factors.

Figure 1 compares flow rate errors of typical servo and non-servo drive pumps as a function of motor speed and volume pumped.

Data results for the non-servo control method show that dispensing error is dependent on motor speed as well as volume dispensed. Because the error varies with volume pumped and pumping speed the non-servo pump drive must vary speed as the pumped volume increases in order to minimize error. This error is compounded by the poor low speed control characteristics of non-servo velocity control systems.

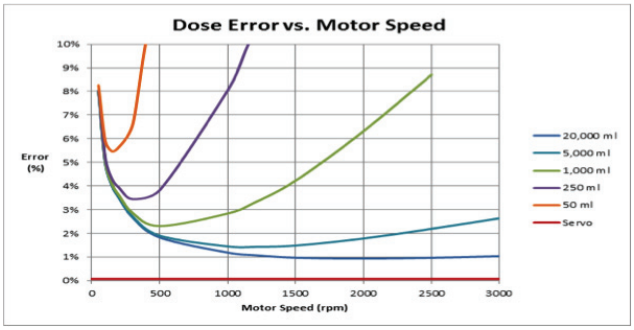

Figure 1 – Dose Error as a function of motor RPM and volume pumped.

Servo Control Simplifies Design and Improves Accuracy

The servo control system, as shown in the bottom trace in Figure 1, has essentially zero error over the entire range of speed and volume pumped. The error for the servo pump is a function of position which stays constant over time and greatly improves the precision and control for high volume pumping tasks and low rpm fluid transfer. The servo control algorithm controls motor shaft and pump head rotational position within a fraction of a degree over the full speed range for the entire time the pump motor is running in a speed range from less than 1rpm to 3000 rpm.

A servo controlled pump system eliminates dispensing errors associated with the motor drive. In this case, the closed loop servo control reacts to changing torque or line power conditions and changes power to the motor to maintain rpm and position with a high degree of accuracy. This allows precise performance over the entire speed range from high flow down to very low dispensing speeds.

A servo controlled pump system eliminates dispensing errors associated with the motor drive.

Full Torque through Entire Speed Range Enables Precise Control at Low Speeds

Precise low speed control characteristics of servo control systems also make dispensing functions more accurate and easier to implement. Dispensing entails metering a precise amount of a new fluid into the pumping process. A non-servo pump drive controls dispensed volumes by commanding the pump to run at a fixed speed for a fixed period of time. Achieving high accuracy requires calculation of a velocity / time profile with adjustments made for starting, acceleration, deceleration and stopping. The errors associated with starting and stopping are variable and increase significantly as pumping time increases.

With the servo system, no calculations or corrections for acceleration and deceleration are necessary. Because the volume pumped is directly proportional to pump head rotational position, the drive simply commands a specific rotation that directly controls dispensed volume. This allows the pump to accurately control dispensed volumes as small as the volume of a teardrop. In addition to lower cumulative pumping error and more accurate dosing, the servo system also maintains higher accuracy over a wide speed range.

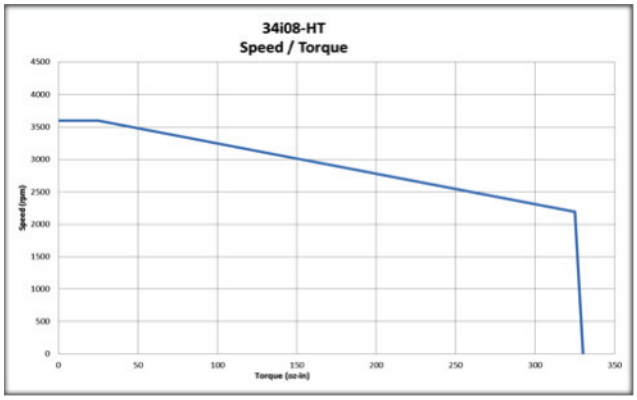

Figure 2 - Speed / Torque Curve for a Typical Servo Controlled System

As shown in figure 2, the servo control system can maintain motor speeds from 3600 rpm down to 0 with full torque and pump head control. This means pump functions can be accomplished at the speed of a clock's minute hand with no degradation in accuracy or control. It also allows the pump manufacturer to use lower gear ratios for low speed control which expands the high speed end of the operating range and may also reduce gear box complexity and cost. For example, a 5:1 gear box could be used instead of a 15:1 or 30:1. In some applications it could eliminate the need for a gear box altogether.

Advantages for Many Applications

While this discussion has focused on pumping applications servo control technology can also improve the functionality of many other applications. Any product or system that requires precise velocity or position control through a broad range of loads or speed ranges will benefit from the servo control characteristics of the integrated servo control. Some specific applications include:

- **Printing**
- **Chemical process industry**
- **Automated doors and gates**
- **Food preparation**
- **Food dispensing**
- **Diverters**

In addition, system flexibility, ease of use and integrated design provide a fully integrated package that can be incorporated into a mechanical design with minimum time and effort and provide a significant reduction in development time and cost.

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About Specialty Motors

Specialty Motors (SMI) was established in 1971 to provide armature and field sets to leading companies such as KitchenAid and Whirlpool. Motor design and manufacturing followed shortly after, as SMI began producing several product lines for the U.S. military, as well as serving other industrial and commercial markets. In the early 1980's, in order to meet customer demand, larger scale motor manufacturing became the focus of SMI.

Today, Specialty Motors designs and manufactures custom fractional horsepower motors that are used in a wide range of applications including: pitching machines, treadmills, peristaltic medical pumps, buffers, polishers, grinders, and more. The company maintains an experienced and sophisticated engineering design and support team to serve its customers using AutoCAD design with electronic interface and rapid prototyping supported by a complete in house machine shop.

As a US manufacturer with a focus on short lead times and smaller volume runs, Specialty Motors also serves as the ideal inventory solution for its customers enabling them to carry less inventory than typically required with overseas vendors.

SMI has been a MIL I and MIL Q certified supplier for over twenty years.