Stick-Slip Reduction

Reduction of the Influence of Stick-Slip on the Movement of a Piston in Laboratory Automation

Students

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Initial Situation: In laboratory automation, it is crucial to be able to dispense liquids precisely. The piston of a Dosing-Drive (D-Drive) must therefore be able to be moved very accurately. Stick-slip effects pose a challenge here. Stick-slip is a phenomenon in which the motion alternates between sticking due to static friction and sudden slipping when the force exceeds the friction threshold, leading to irregular movement of the piston as shown in Figure 2. The effects can be partially reduced by using special material combinations, but cannot be completely avoided. The aim of this thesis is to investigate how the influence of stick-slip can be further reduced through control technology measures.

Approach: For this thesis, the hardware including various D-Drives for reliable testing of the methods were provided by Hamilton Bonaduz. The hardware was controlled using a Serial Peripheral Interface (SPI) via a Speedgoat test system in combination with Matlab. This allowed the control system to be conveniently developed and tested directly on the hardware in real time. First, the individual D-Drives provided were characterized and classified with the aim of narrowing down suitable methods for solving the given challenge. In this phase, analyzing the behavior and collecting empirical values for method development resulted in the definition of three types of movement characteristics. Second, additional requirements for the methods were defined by the project partner Hamilton Bonaduz. The highest priority was to reduce the stick-slip behavior during the entire movement.The method had to be suitable for a wide range of applications and D-Drives. In addition, it should not impair the stability, robustness and speed of the existing system.

With the definition of these requirements and the research already conducted, six possible approaches were presented, of which two were implemented. The first approach is based on the idea of superposing an additional current impulse at the start of the movement to set the piston in motion earlier. The second included an additional integral controller which, similar to the first approach, superposed an additional current to influence the piston. This current was accumulated dynamically until the piston started to move and was then set to zero.

Result: Using the first approach, some piston movements were achieved in which the stick-slip could already be reduced. However, it was observed that the stick-slip effect behaved differently for each movement. Consequently, the parameters of the impulse needed to be adjusted for every operation. This approach proved as impracticable for broader application.

In contrast to the first approach, the additional integral controller dynamically adjusted the amplitude and timing of the added current to the actual error of the system. During the initial phase of the D-Drive's movement, the additional current was superposed to the system, ensuring a reliable reduction of stick-slip effects. This dynamic adjustment significantly improved the approach's applicability and consistency across different movements and D-Drives, hence making it more practicable.

Figure 1: Magnetic Pipette (MagPip) with labeled Dosing-Drive
https://www.hamiltoncompany.com/automated-liquid-handling

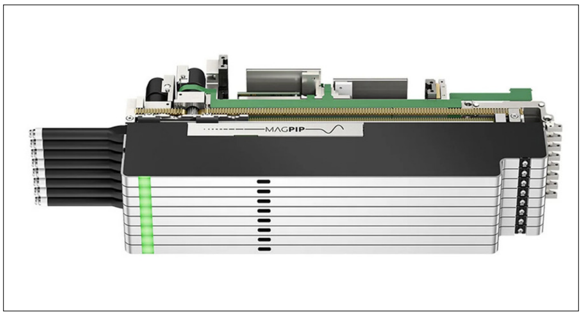


Figure 2: Measurement of Stick-Slip during a Movement
Own presentment

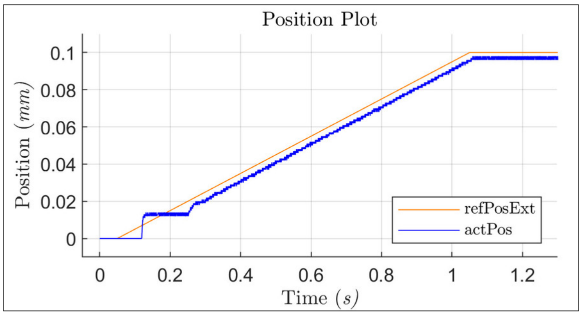
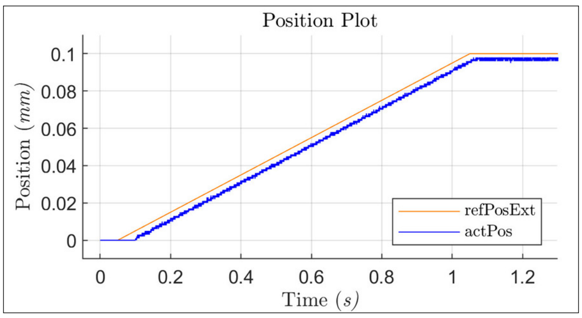


Figure 3: Measurement of reduced Stick-Slip with the implemented Method
Own presentment



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Subject Area
Regelungstechnik / Control Theory

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