DESIGN AND IMPLEMENTATION OF AN AUTOMATIC LIQUID DOSING SYSTEM

İZMİR KÂTİP ÇELEBİ UNIVERSITY 2010

Ayberk KILLI, Haydar Barış ÖCAL, Kadri Emre ORGUN, Ömer YÜCE

Supervisor: Asst. Prof. Dr. Serkan DOĞANAY

MEE DEPARTMENT OF MECHATRONICS ENGINEERING

Abstract

This project focuses on liquid dosing devices and transfer systems used in microbiology, chemistry, and medical test laboratories to precisely transfer liquids at low volume levels (micro/milliliters). Currently, these tasks are mainly carried out using micropipettes by trained technicians, but human-induced errors such as incorrect dosing, sample fluid loss, and incorrect force application can occur. These errors contribute significantly to overall laboratory errors. Additionally, manual sample preparation increases the time required for dosing. The main objective of the project is to develop an automatic liquid dosing system for laboratory testing that improves the speed of liquid transfer and dosing processes. The system aims to reduce errors compared to existing laboratory systems, minimize the need for manual labor, and decrease human-induced errors in the laboratory.

1. Introduction

In the 21st century, technology has continued to progress, leading to a growing demand for small-scale engineering systems and processes [1]. Among these, test applications on samples in medical laboratories are particularly crucial [2]. While medical engineering systems have gained significant importance in recent times, there are areas that can be further developed with advancing technology [3]. One key aspect that requires improvement in sample testing applications is the precise dosing of samples using injectors [4].

Our project aims to develop and implement an automatic liquid dosing system. The system will utilize a syringe injector to achieve precise dosing while navigating between various test containers. It will operate within an automated 3D cartesian coordinate system, allowing for efficient movement. Additionally, the system will be capable of changing syringes to accommodate different samples that need to be dosed.

2. Theoretical Background

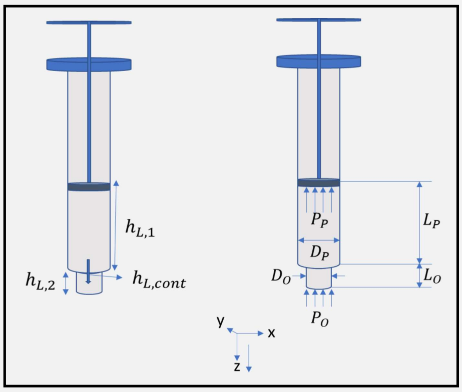

Figure 1. Schematic of the Syringe Including the Geometrical Parameters, and Pressure Acting on Syringe Piston

$$P_P = P_O - \frac{1}{2}\rho V_P{}^2 - \rho g \Delta z + \frac{1}{2}\rho\left(\frac{A_P}{A_O}V_P\right)^2 + \frac{1}{2}\rho f \frac{L_P}{D_P} V_P{}^2 + \frac{1}{2}\rho f \frac{L_O}{D_O}\left(\frac{A_P}{A_O}V_P\right)^2 + \frac{1}{2}\rho K_{L,cont}\left(\frac{A_P}{A_O}V_P\right)^2$$

3. CAD Model

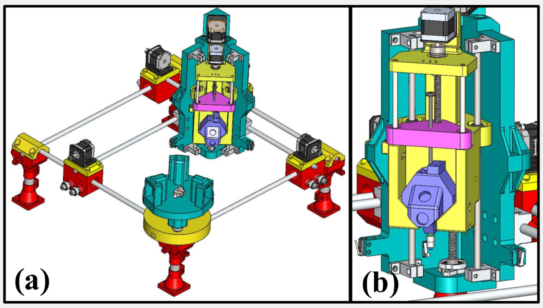

Figure 2. 3D CAD Model (a) Isometric View, (b) Close-look to dosing subsystem

4. Experimental Setup

To achieve 3D motion in our automatic liquid dosing machine, we have combined the 2D mechanism and 1D syringe pump mechanism. We have taken inspiration from the motion system used in 3D printers. After assembling the components, our mechanism is capable of extracting liquid samples from user-inputted coordinates on a computer and precisely dosing the liquid into the desired test containers. For the three-dimensional motion, we have employed five Nema 17 stepper motors: two for each x-axis and y-axis, and one for the z-axis. These motors control the motion of the syringe piston and the syringe changing mechanism.

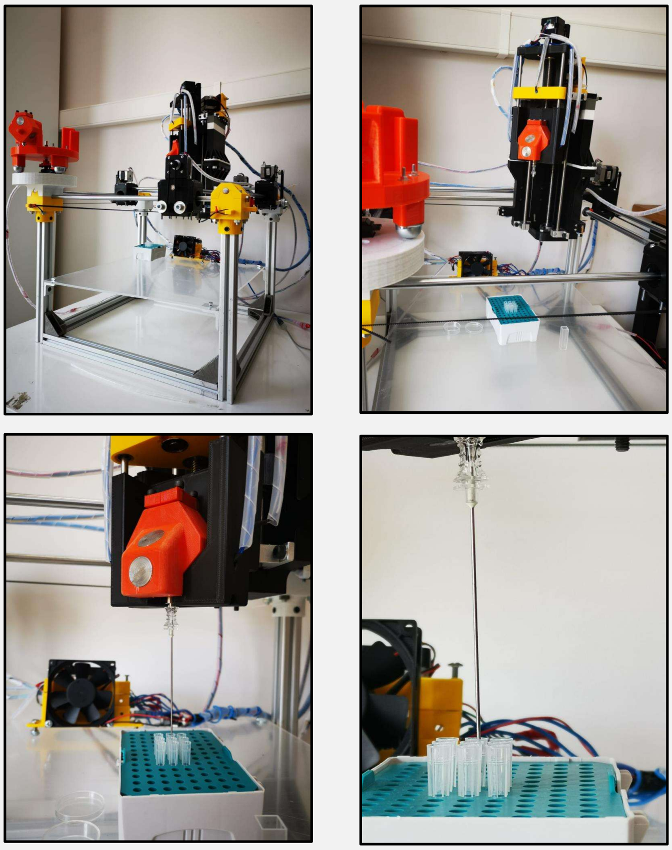

Figure 3. Experimental Setup

5. Conclusions

Our mechanism allows for 2-axis motion along the x and y directions. The x and y motors are connected in opposite directions using a single stepper motor driver. We use 1/32 microstepping mode with the DRV8825 step motor driver. The motion starts by resetting the mechanism using limit switches in both axes and moving the syringe dosing system to the upper position with a z-axis motor. Next, the body moves to the syringe replacement point, where a servo motor accurately positions one of three syringes using electromagnets. After a delay, the body returns to the reset point and then moves downwards until reaching a limit switch under the z-axis. The NEMA 17 motor moves upwards based on the container length, and dosing is performed using the x, y, and z motors.

References

[1] Bramsiepe, C., Sievers, S., Seifert, T., Stefanidis, G. D., Vlachos, D. G., Schnitzer, H., ... & Schembecker, G. (2012). Low-cost small scale processing technologies for production applications in various environments—Mass produced factories. Chemical Engineering and Processing: Process Intensification, 51, 32-52.
[2] Küme, T., Karakükcü, Ç., Uzun, N. K., & Pınar, A. (2016). Tıbbi Laboratuvarlarda Madde Analizleri. Türk Klinik Biyokimya Derg, 14(1), 58-71.
[3] Martin, R., & Barnhart, S. (2011). Global laboratory systems development: needs and approaches. Infectious Disease Clinics, 25(3), 677-691.
[4] He, Y., Xie, T., Tu, Q., & Tong, Y. (2022). Importance of sample input volume for accurate SARS-CoV-2 qPCR testing. Analytica chimica acta, 1199, 339585.