Mechatronic System Design on Microliter Level Liquid Delivery for Lab on-a-chip Device

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Abstract

In this study, we designed a pumping system with a mechatronic system design approach in order to obtain a constant flow rate at low flow rates. The system was modelled and simulations were made via Matlab Simulink. Then the 3D design of the setup was built and produced. To achieve a constant flow rate, a closed loop control strategy has been developed. Finally, the performance tests of the system were made.

1. Introduction

Recent developments in advanced engineering systems have brought the problem of liquid delivery with tiny amounts for small-scale devices. For this purpose, generally, the syringe pumps are used to deliver the required liquid to the patients or devices with the target of a constant flow rate over a definite period of time [1]. Therefore, they have an important area of use in the medical field [2,3], industry and research [4]. Operation is based on the conversion of the stepper motor's angular motion into linear motion using the lead screw and half nut mechanism. The syringe pumps currently on the market are devices that do not have control feature, open loop systems and the desired values are entered manually by the user [5]. In this work, closed loop pump system is designed to overcome fluctuations appear in open loop pumps.

2. Material and Method

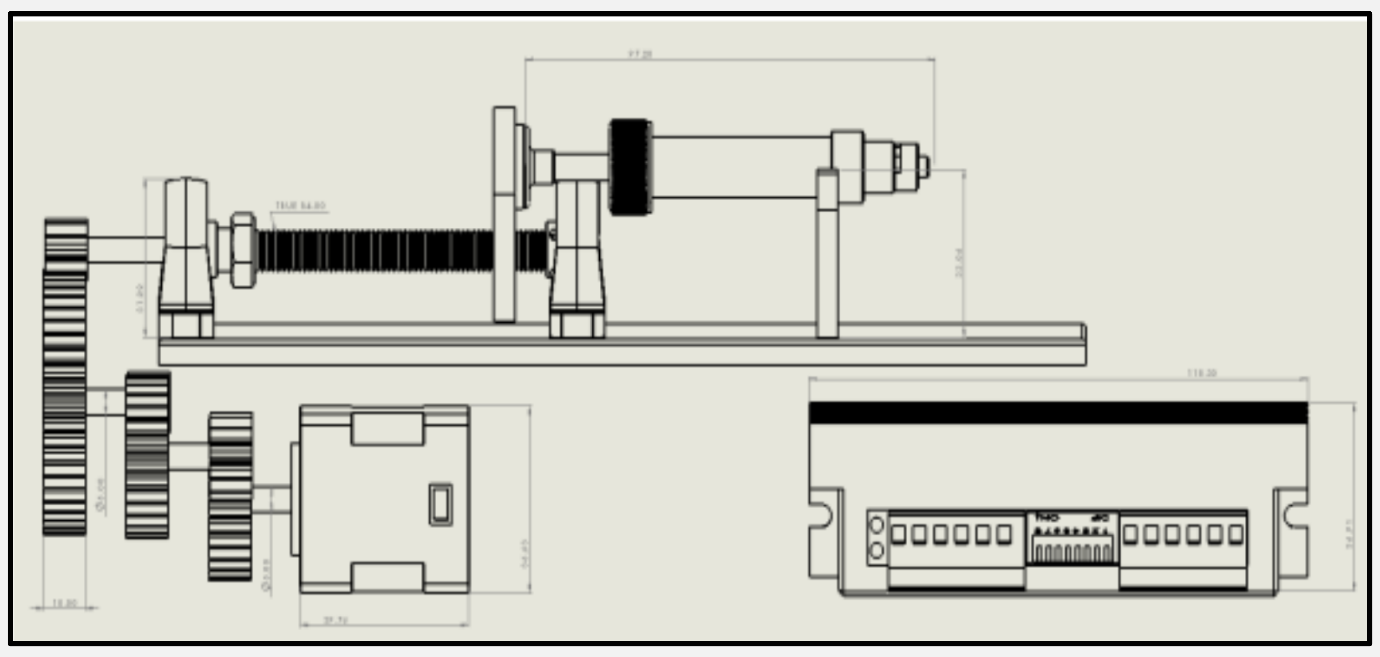

Figure 1. Drawing of the pumping system.

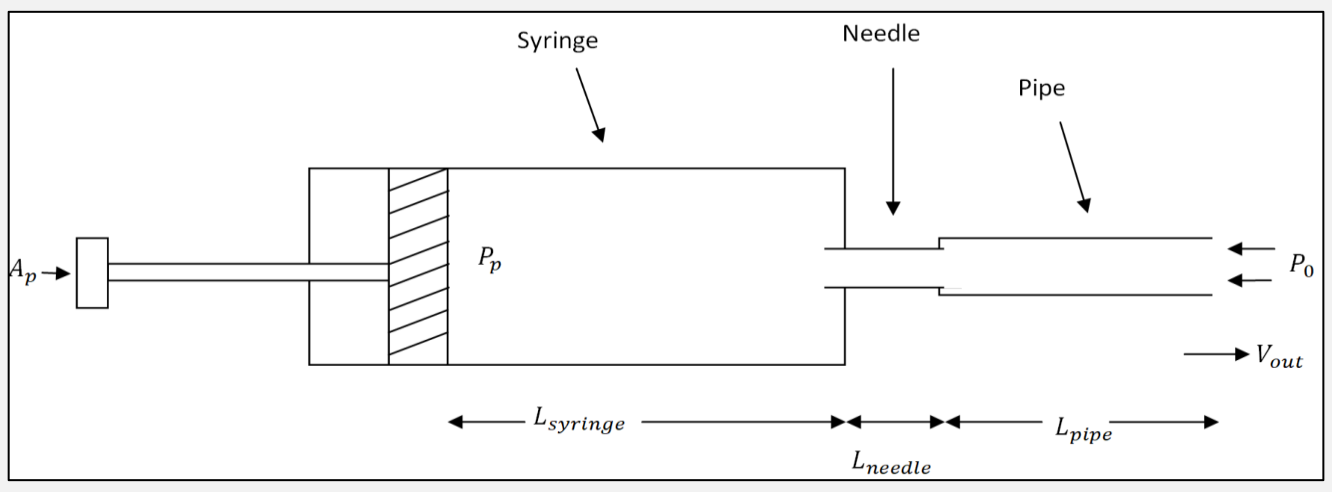

Figure 2. Schematic of the syringe part.

$$P_p = P_o + 0.5\rho V_{out}^{\ 2} - 0.5\rho V_{out}^{\ 2}\left(\frac{A_{pipe}}{A_p}\right)^2 + 0.5\rho V_{out}^{\ 2}$$
$$\left[\frac{f}{L_{syr}}\left(\frac{A_{pipe}}{A_p}\right)^2 + \frac{f}{L_{needle}}\left(\frac{A_{pipe}}{A_{needle}}\right)^2 + \frac{f}{L_{needle}} + K_{L,cont}\left(\frac{A_{pipe}}{A_{needle}}\right)^2 + K_{L,\exp}\left(\frac{A_{pipe}}{A_{needle}}\right)^2\right] \qquad (1)$$

$$\tau_{raise} = \frac{Fd_m}{2}\left(\frac{l+\pi\mu+d_m}{\pi d_m-\mu l}\right) + \frac{Fd_m}{2}\tan(\phi+\lambda) \qquad (2)$$

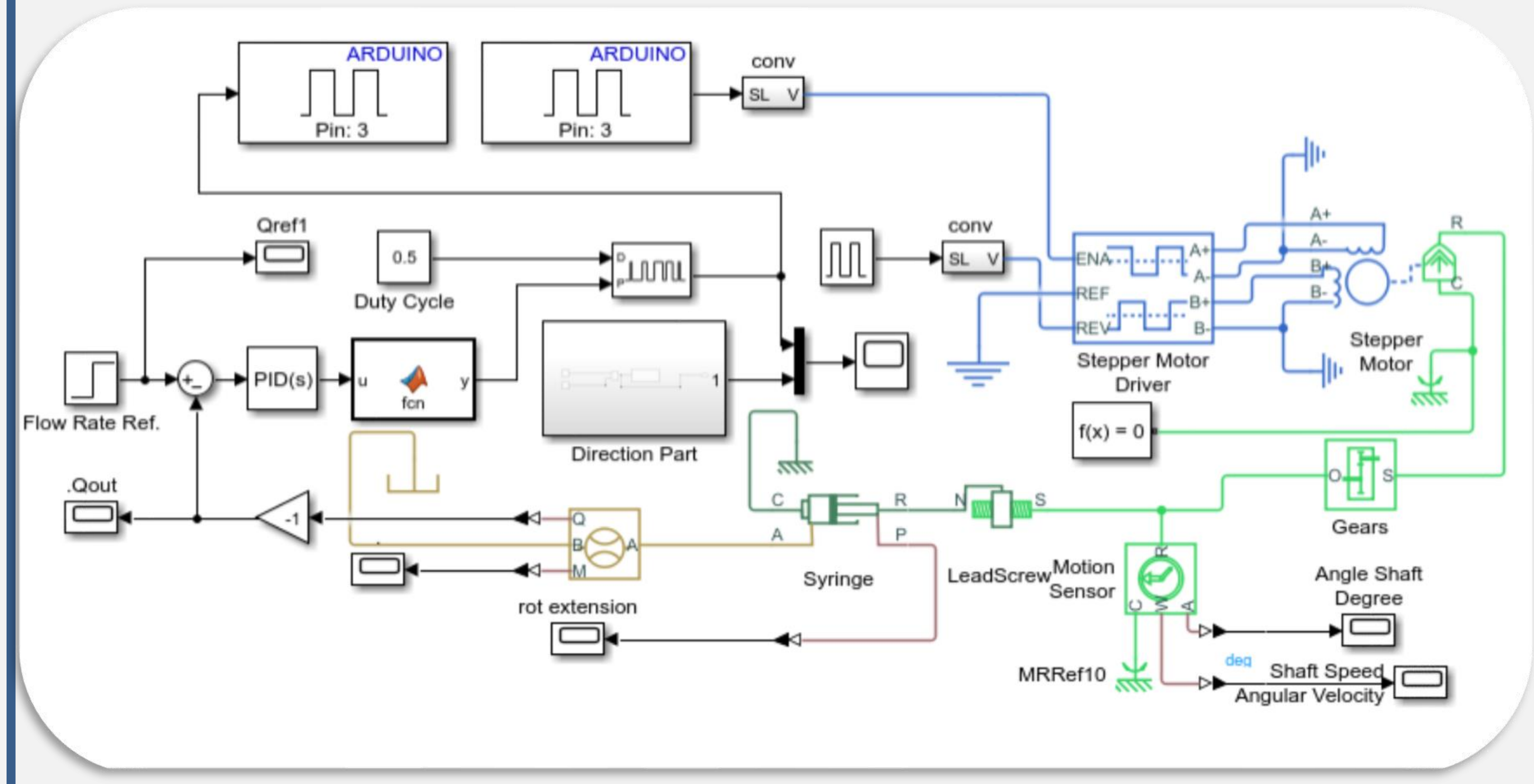

Figure 3. Model by Matlab Simulink.

3. Results and Discussions

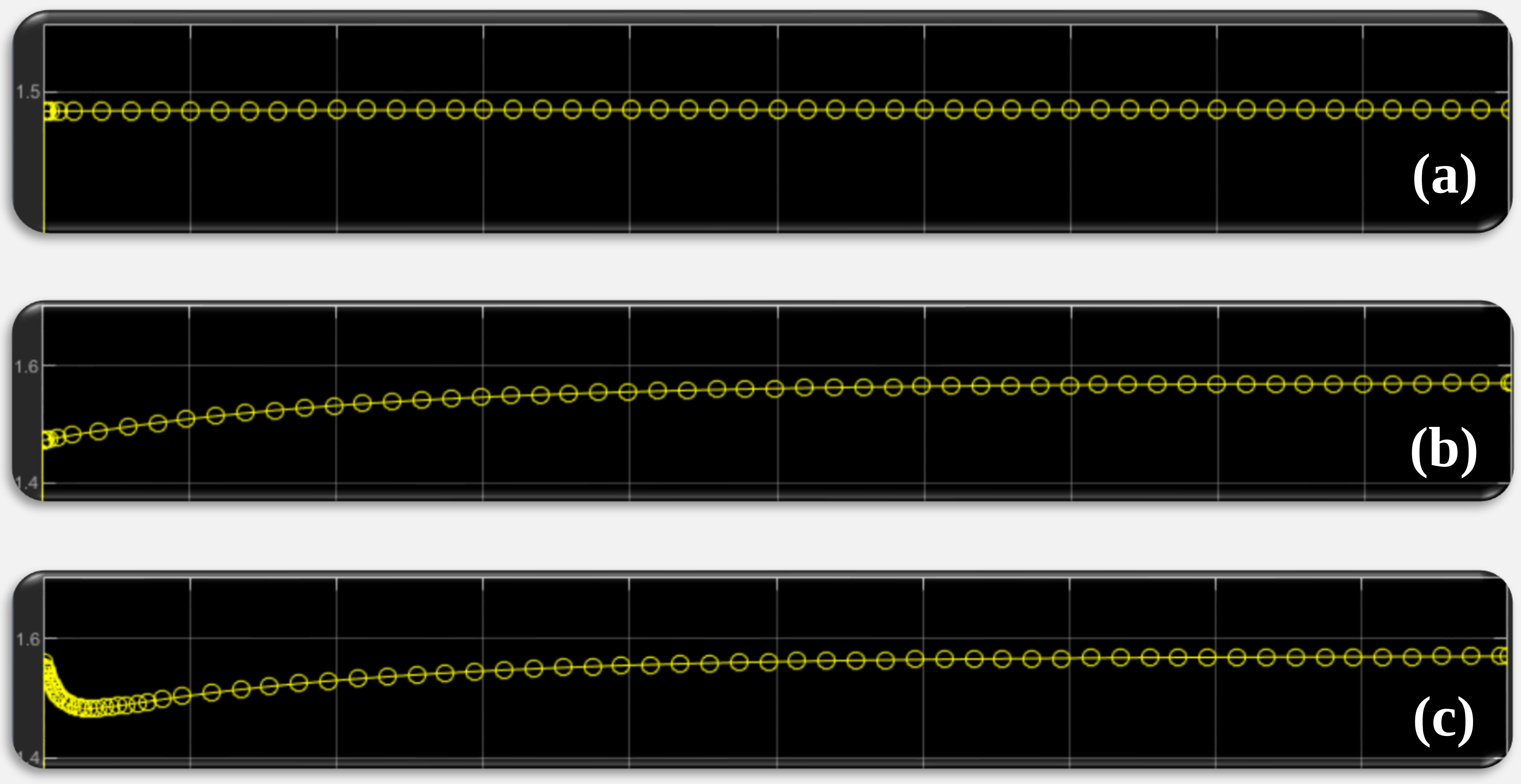

Figure 4. Simulation results for (a) P, (b) PI, and (c) PID control.

4. Conclusions

A stable closed loop system was provided with PID control. PID values were determined according to overshoot and settling time values acceptable in practice. Thus, according to the losses that may occur, the system automatically gives the desired flow rate in the optimum time.

References

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