RESEARCH ARTICLE

SAMRIDDHI Volume 13, Issue 2, 2021 Print ISSN : 2229-7111 Online ISSN : 2454-5767

Design and Control of Electronic Syringe Pump using AVR Microcontroller

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ABSTRACT

The infusion and retract rate of the electronic syringe injection pump is one of the major challenge in the designing and control of electrospinning system. The selective droplet materials of a small size with controlled structured and patterned is released through a needle of the syringe pump very important. This investigation focuses on control parameter like infusion and retract rate, flow rate, the droplet volume, and syringe size dimension. It is observed the infusion rate 1ml for 5.7sec to 7.11 sec, retract rate 1ml for 1600-2000 signals pulses of stepper motor, the droplet volume is 0.0001 to 0.02ml increasing after every 300-500 signal pulses observed on CRO with different types of syringe injection pump. It is observed that the average error for the measured flow rate is 10% and average error for the measured volume is 1.91%. In this study the design and control of low cost and simple system is discussed using prototype of electronic syringe injection pump designed using AVR microcontroller for changeable and small delivery rates for the control of low volumes.

Keywords: Electrospinning, Syringe Pump.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology, (2021); DOI : 10.18090/samriddhi.v13i02.1

INTRODUCTION

The electronics syringe injection pump plays an important role in the designing of Electrospinning system. The Electrospinning system consist of three subsections which produce continuous nanofibers using a high-voltage power supply, electronics syringe injection pump and collector drum / plate[1]. Now a day nanofibers have several promising scientific and commercial applications like bio medical, medical and pharmacy drug delivery, food and seed coating material, various cancer diagnosis, fossil and lithium-air battery, electronic sensors, devices, clothing and filtration. The precise amount of solution from the electronic syringe pump is preferred in the research fields. Various parameter like Molecular weight, architecture of the polymer Solution properties like viscosity, conductivity and surface tension etc., needle electric potential, flow rate and concentration on tip of needle, distance between the capillary and collection screen, ambient parameters (temperature, humidity and air velocity in the chamber), motion and size of target screen (collector), needle gauge are important in the design[2].

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How to cite this article : Zope, P.H., Suralkar, S.R. (2021). Design and Control of Electronic Syringe Pump using AVR Microcontroller.
SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology, Volume 13, Issue (2), 65-69.

Source of support : Nil

Conflict of interest : None

This research studies the performance monitoring and design of electronic syringe pump using AVR microcontroller. The infusion and retract capable syringe pump control while maintaining a sufficient level of dispense resolution and repeatability is one of the challenging task. The design of electronic syringe, 3-D model, the startup time, desired and

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measured volume, standard deviation, means infusion error are discussed in the following section.

SYSTEM DESIGN

The system consist of AVR microcontroller, stepper motor driver circuit, keyboard, LCD display and power supply with syringe pump setup as shown in Figure 1. The internal timer / counter section of microcontroller plays an important role in the generation of stepping signal for the stepper motor. To obtain micro ml/hr infusion rate of syringe pump different types of stepping sequence were monitored with algorithm. The half stepping sequence is better as compared to other stepping sequence of the stepper motor. The tip of syringe pump should deliver expected infusion rate following equation 1-3 are proposed for calculation. It is necessary to determine the volume and define the flow rate of the solution which is filled in the syringe pump[3]. Once you know the volume of the liquid and the delivery time taken for the infusion, then flow rate per hour is deterministic. The keypad is provided for the variation of stepping movement accordingly the infusion and retracts rate may change[4-5].

Length =
Volume x 4 / Pi x diameter x diameter 1
Number of Steps =
(Length x Steps of Stepper Motor) /
Pitch of Lead screw 2
Flow rate (Q) =
Pitch of Lead screw x Motor Speed x Area 3

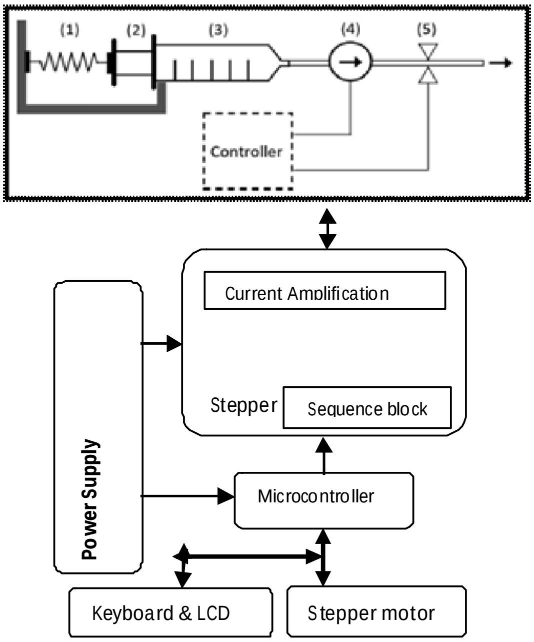

Figure 1: Mechanical Assembly for Electronic Syringe Pump

The actual setup of syringe pump stand is shown in Figure 2. The acrylic / flexible sheet material blocks are used in the designing for holding the syringe and the plunger to pushed-pulled by the steel rod connected with actuator. The acrylic plate is used as the base for the complete mechanism to provide the slide mechanism with reasonable stability. The processed steel rod of 5mm with 1.74mm pitches of the screw is used for screwing the lead screw mechanism. Copper alloyed with zinc bushes are used along the suspension and smooth movement.

Figure 2: Actual setup of syringe pump stand

Figure 3 shows full setup of Microcontroller driven Stepper motor drive and the syringe pump setup. The programmable microcontroller is used to drive the stepper motor, it rotate the stepper motor in forward and reverse direction, the forward rotation is called as infusion similarly the reverse rotation is called as Retract of syringe pump.

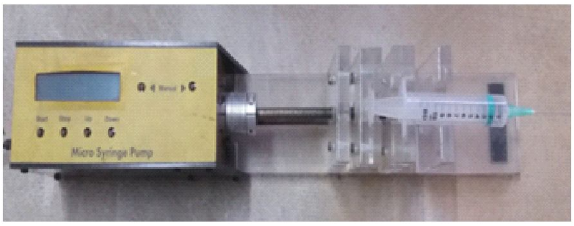

Figure 3: Full setup of Stepper motor drive and the syringe pump setup

The materials used in the fabrication of the mechanical assembly of the syringe pump have been shown in fig. 4. The acrylic / flexible sheet material blocks are used in the designing for holding the syringe and the plunger to pushed-pulled by the steel rod connected with actuator.

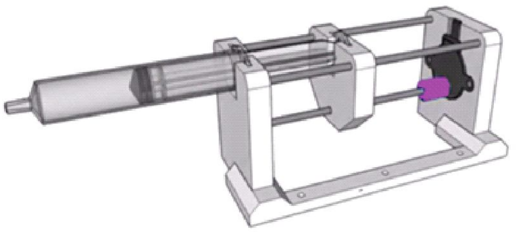

Figure 4: 3 D view of setup

The 3 D view of the setup of Mechanical Assembly for Electronic Syringe Pump is shown in Figure 1-3.

RESULTS AND DISCUSSION

Infusion and retract delay calculation

To decide the infusion rate and retract rate designing delay programs in microcontroller, calculating the initial value that has to be loaded in to TH and TL registers, Assume 12MHZ crystal oscillator , timer clock input will be 12MHz/12 = 1MHz, the speed of stepping signal is time taken for the timer to make one increment = 1/1MHz = 1uS.

Let the required delay be 1000uS (ie; 1mS).

That means X = 1000

65536 – X = 65536 – 1000 = 64536.

64536 is considered in decimal and converting it t0 hexadecimal gives FC18

```
Delay: MOV TMOD,#00000001B // Sets Timer 0 to MODE1
MOV TH0,#0FCH  // Loads TH0 register with FCH
MOV TL0,#018H    // Loads TL0 register with 18H
SETB TR0             // Starts the Timer 0
HERE: JNB TF0,HERE  // Loops here until TF0 is set
                          //(ie;until roll over)
CLR TR0    // Stops Timer 0
CLR TF0    // Clears TF0 flag
RET
```

It is observed; every ml 2000 steps required for moving injection. If we assume every motor pulse is 3 ms, then it need following calculation for to obtain duration for 1-ml.

To find the equation, it is important to find out the time required for the motor to move 2000 pulses. It is calculated from cathode ray oscilloscope waveform on every motor pulse is 3 ms, we have:

Ti - Initial time of movement for every motor pulse

Tf - Final time required for 2000 motor pulses

Therefore, Tf is equal to:

Tf = Ti * 2000 = 3ms * 2000 = 6000ms = 6s.

Practically we go Tf = 7.11s

Similarly the retract rate is used.

Startup time and Infusion rate error

The syringe pump setup start up time and infusion rate error obtained at the tip of the syringe pump is tested with desired volume and measured volume rate as shown below in Table-1. To calibrate the syringe pump with different volume of syringe are considered to find out the flow rate of the syringe pump with respect to time. The desired volume of the solution flow rate through the syringe needle tip is considered between 0.5ml to 8 ml. the desired volume of the solution is measured with the help of micropipette (1ml – 100 ml) or dropplet pipette (1ml - 10ml).

Polymer solution was filled in the 12 ml syringe which is fitted on acrylic stand, the syringe is kept in infusion mode with flow rate = 0.5 ml/h. The measured values and flow rate obtained from pipette and flow meter are approximately matched for the density of polymer at 28°C laboratory temperature. Three measurements are carried out to find mean plot, the approximate start up time is 95% it is defined as the onset time for distill water / polymer delivery it is very similar to RC (R-Resistance C-capacitance) time constant. The RC time period is equals to the resistance (pressure per volume/time) multiplied by the capacitance / compliance (volume/ pressure) of the entire infusion setup.

The investigated start-up time between these three different tests of polymer is shown in Figure 5a, it is the time required for T= 0 h to reach at t=0.2s-0.4s at 95% and 50% of flow rate. The infusion rate error shown in Figure 5b it shows the variation from initial position of drop of the solution.

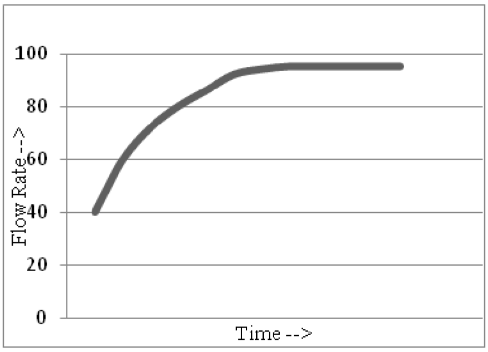

Figure 5a : Startup time

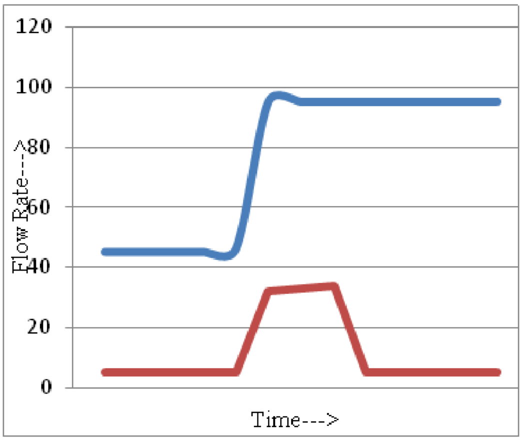

Figure 5-b: Infusion rate error

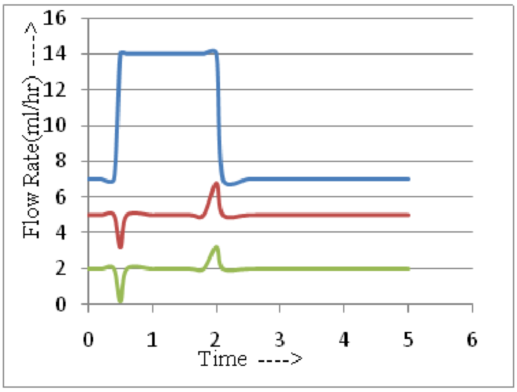

Figure 6: flow rates F1, F2, F3

Figure 6 shows practical flow rates with initial set point values of pumps F1= 7, F2 = 5, and F3 = 2 ml/h, respectively. The deviations in the green and red lines are caused by the "mechanical compliance" of the "red" and "green" syringes; if these compliances would have been zero, the deviations in the red and green lines would disappear.

From Figure 6, two significant phenomena can be seen.

1. In all cases, the deviations from the constant set point values of the red and green lines take place in a direction "opposite" to the direction of the change (in set point value) of the blue line.

2. The depth of the dip in the red line at *t* =0.5 h, with respect to the red steady-state line of 2 ml/h, is approximately

1.3 ml/h. This is equal to the depth of the dip in the green line, at the same point in time, with respect to the green steady-state line of 5 ml/h, because all syringes have the same compliance. As a result, when expressed as a percentage of the intended (set point) flow rate, the relative deviation caused by the dip in the red line at *t* =0.5 h is much larger than the relative deviation caused by the dip in the green line at the same point in time.

CONCLUSIONS

In this paper the infusion rate and retract rate monitoring and control is carried out. The microcontroller algorithm is help to control the stepping speed of the motor and the mechanism which holds the syringe and as a holder for the plunger to be moved by the actuator greatly.

To discuss about the performance of the complete setup, there is a need for an accurate measurement of essential parameters infusion setup, such as the mechanical compliance of the syringes. A next step would be to control the pump setpoints to deliver the required oulet. In this process, the flow rate dependency of these effects for low and high flow rates should be taken into account. Thus, an increased focus and effort directed to the metrology of compressibility at low flow rates, combined with the preferential use of innovative techniques minimalizing "push-out" effects, will lead to enhanced controllability of solution delivery and consequently to better production of nanofibers.

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Table 1: Data measured for injected volume and flow rate of the syringe pump

Desired Volume (mL)	Syringe	0.5	1	2	3	4	5	6	7	8
Measured Volume (mL)	12ml	0.47	1	2	3	3.6	4.8	5.5	6.6	7.6
	6ml	0.49	1	2	3	3.9	5	6	7.1	8.2
	3ml	0.43	1	2	2.9	3.78	4.85	5.52	6.84	7.65
	1ml	0.5	0.98	1.95	2.89	3.82	4.78	5.76	6.72	7.68
Time (s)	12ml	3.21	7.11	14.04	22.13	28.56	35.14	42.41	49.18	54.26
	6ml	3.57	7.45	15.05	23.56	29.07	37.42	44.16	51.12	55.12
	3ml	3.11	8.15	16.22	26.46	29.48	38.15	46.45	52.68	57.25
	1ml	3.98	8.43	16.98	27.12	30.78	39.1	47.85	53.86	58.69
Flow rate (mL/min)	12ml	8.78	8.43	8.54	8.13	7.56	8.19	7.78	8.05	8.4
	6ml	8.23	8.05	7.97	7.64	8.04	8.01	8.15	8.33	8.92
	3ml	8.29	7.36	7.39	6.57	7.69	7.62	7.12	7.78	8.01
	1ml	7.53	6.97	6.89	6.39	7.44	7.33	7.22	7.48	7.85