Microfluidic measurement of an infusion pump using a loadcell

Sejong Chun[1], Hyun Wook Hwang[2], Seok Hwan Lee[1]

[1]*Division of Physical Metrology, KRISS, Gajeong-ro 267 Yuseong-gu, Daejeon, Republic of Korea*
[2]*Daiwha Corporation Ltd., Yeoksam-dong 733-18 Gangnam-gu, Seoul, Republic of Korea*
E-mail (corresponding author): sjchun@kriss.re.kr

Abstract

An infusion pump is used for precise dosage control to patients using an IV-set. The infusion pump is integrated with more than fifteen fingers to generate sine waves to a compliant tube. Spatial movement of the sine waves squeezes the compliant tube to provide patients drug at very low mass flow rate down to 10 mL/h. Even though the infusion pump is tested by gravimetric flow metering with a balance and a timer before its release, its performance is significantly influenced by the quality of the IV-set. However, the accuracy of the infusion pump has not been tested seriously during its operation. In this study, a loadcell was used to measure the weight of the IV-set when the infusion pump was operating. Timed measurements using a DAQ provided mass flow rate in units of g/h. The measurement indicated that the accuracy of mass flow metering by the loadcell was within 3.6 %, compared with the gravimetric flow metering with the balance. It was found that the loadcell could be used to check the mass flow rate of the infusion pump irrespective of the type of the IV-set. Such instrumentation will be useful for feedback control of the mass flow rate with the infusion pump in the future.

Keywords: gravimetric flow metering, infusion pump, loadcell, mass flow metering, micro flow, microfluidics

1. Introduction

Infusion pumps are used to dose pharmaceutical materials to patients precisely. The infusion pumps have complicated structure compared with popular IV-sets. However, the infusion pump can control dosage with accuracy less than ±5 %. Therefore, the infusion pumps are attached to the IV-sets to control flow rate of critical pharmaceutical materials, such as anti-cancer or anesthetic drugs.

The quality of the IV-sets is an important factor for maintaining the infusion pumps with good accuracy. However, the IV-sets are produced with very cheep prices in clinical applications. This means that the quality of the IV-sets is not controlled precisely. This can affect on the accuracy of the infusion pumps. One method to remedy this is to make databases for every kind of IV-sets to the infusion pumps. However, this method requires a lot of experiments. Nevertheless, the accuracy of the infusion pumps is not improved very much.

Feedback control of an infusion pump could be another remedy to increase the accuracy of the infusion pump. Load cells can be a good candidate to provide feedback signals to the infusion pump. However, there are not many studies on the feedback control of the infusion pump in the bio-medical industry.

This study focuses on the use of load cells to check whether the flow rate through the infusion pump can be measured accurately. Toward this end, the gravimetric method with a balance and a timer (PC clocks) is compared with the load cell signals as a function of time. This study can give some information on the usefulness of load cells to improve the accuracy of the infusion pumps.

2. Experimental Setup

An experimental setup for testing an infusion pump is shown in Fig. 1. An IV-set (Becton Dickinson, 20 drops/mL) was installed on a stand for load cell measurements. The infusion pump (Daehwa, Medifusion DI-2000) was located to connect the IV-set. Fifteen fingers in the infusion pump moved to squeeze the liquid in the IV-set constantly by sinusoidal motion. A load cell (Dacell, CB1) of which capacity was 1 kg, was located on top of the stand to measure the weight of water contained in the IV-set. Load-cell signals were connected to a 24-bit bridge module (NI, cDAQ-9219). A balance (Mettler Toledo, AX205) and a PC clock were used to measure flow rate by dynamic weighing.

Figure 1: Experimental setup of infusion pump.

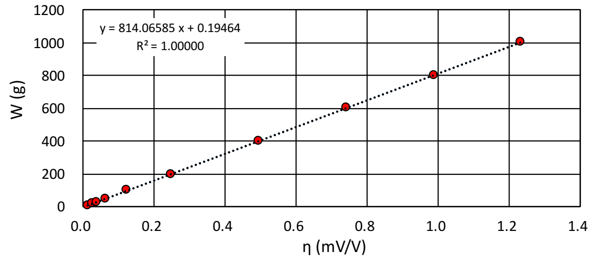

Figure 2: Calibration curve of load cells.

Table 1: Experimental conditions for testing an infusion pump.

q (mL/h)	t (h)	t (s)	f (S/s)	N (samples)
10	5	18000	0.25	4500
20	2.5	9000	0.25	2250
30	1.7	6120	0.25	1530
40	1.25	4500	0.25	1125
50	1	3600	0.25	900
60	0.85	3060	0.25	765

Several dead weights, of which weights were from 10 g to 1 kg, were used to calibrate the load cells before flow experiments. At first, the dead weights were calibrated by the balance. After that, the dead weights were applied to the load cells to relate their output signals to weight. The calibration curve is as follows.

$$W = 814.06585\eta + 0.19464 \quad (1)$$

Here, η is the output of a bridge module (mV/V) and W is the load cell weight (g). The measurement uncertainty of W was 0.55 % ($k = 4.3$).

The experimental conditions for the experiment are summarized in Table 1. It is noteworthy that water weight was maintained between 600 g and 700 g before experiment. The reason for this was to make the same starting point for load cell measurements. The measurement began whenever there were no air bubbles along the tube of the IV-set. The measurement was ended whenever the amount of water was attained 50 mL in a beaker located on the balance.

3. Experimental Results

The experimental results are displayed in Table 2. q is the nominal value of flow rate (mL/h), q_1 is the flow rate measured by the balance (mL/h), q_2 is the flow rate by the load cells (mL/h), and q_3 is the flow rate by a thermal mass flow meter (Sensirion, SLI-1000). E_{21} is the relative deviation between q_2 and q_1. E_{21} indicates that the accuracy of the load cells to the balance is less than 3.63 %. And this value is within the required accuracy of 5 %. This means that the load cells can be used as feedback signals for the infusion pump.

On the contrary, the thermal mass flow meter showed different values of q_3 compared with q_1 or q_2. One of the reason could be the low sampling frequency of the DAQ module (NI, PXIe-6341) as shown in Table 1. Another reason would be due to the sinusoidal motion of fingers in the infusion pump, which increases fluctuations of flow rate as shown in Fig. 3. This means that the thermal mass flow meter is not suitable for providing feedback

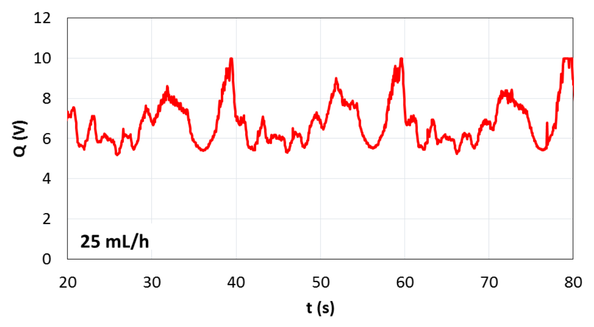

Figure 3: Flow signal of a thermal mass flow meter.

Table 2: Experimental results of the infusion pump.

q (mL/h)	q_1 (mL/h)	q_2 (mL/h)	q_3 (mL/h)	E_{21} (%)
10	8.62	8.93	33.68	3.63
20	20.60	20.76	36.03	0.77
30	27.31	27.56	41.29	0.91
40	39.49	39.70	38.27	0.53
50	49.08	49.26	39.43	0.36
60	58.58	58.95	41.34	0.62

signals to the infusion pump unless the thermal mass flow meter is not calibrated appropriately.

4. Conclusions

An infusion pump was tested to find out suitable feedback signals for the infusion pump, which is used for dosage control to a patient. A load cell was a good candidate for providing the feedback signals. The measurement accuracy of the load cells was less than 3.63 % compared with the flow rate by using a balance. On the contrary, a thermal mass flow meter was not a good candidate for the feedback signals. The relative deviation of the flow meter was too large to predict the flow rate correctly. Thus, appropriate calibration of the flow meter was an important part to apply the flow meter to feedback control of the infusion pump.

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