PROGRAMMABLE SYRINGE PUMP

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ABSTRACT

This project paper presents on the Programmable Syringe Pump. Since there are many kind of syringe pump in the market which are used in hospitals and medical labs, most often the flow rate of dispensing is always tends to be in-accurate. Problems like start-up delays, occlusion, piston gaskets gets stuck has been widely being studied. Researches feel that different type of pump can use only a certain size of syringe to solve the problems. However, in this project, a volume rate syringe pump was designed, instead of flow rate. It is understood that the problems also largely is attribute to the mechanical assembly of the pump, whereby friction and complicated gears has been another root cause aside to syringe size. This project has dealt with a simple designed pump with simple mechanical movement, using a ball screw actuator which overcomes friction problem and a suitable stepper motor. In this project, focused was on a discontinuous pump, where volume is dispensed with respect to time and also position indication in length being measured. The calibration is done using time interval and control is done via a Micro-controller. The experiment was done by defining two kinds of volume rate which is a low volume rate (0.4mL/min) and a high volume rate (1mL/min). Measurements of time reach for every minutes of liquid dispensed and also position reached by the syringe was taken down. The experiment is repeated again this time for a different small size of syringe. It is found that, there was no start up delay occurred for both high and volume rate. Furthermore both time and position accuracy was linear, except that for high volume dispensed the position had a slight deviation. Using a small syringe size proved to be much improvement in a high volume dispensed.

ABSTRAK

Kerja project ini menganbarkan rekabentuk sebuah Pam picagari kawalan perisian. Di dalam pasaran ada terlalu banyak rekabentuk pembuatan pam picagari sering digunakan di hospital dan makmal perubatan. Tetapi setiap pam yang ada kini hanya beroperasi untuk menentukan kadar aliran cecair keluar dari injap picagari yang cekap namun sering mengalami pelbagai massalah. Antara massalah yang terjadi ialah injap picagari tersekat, kelewatan masa untuk beroperasi, dana kadar aliran a yang tidak menepati masa yang di tetapkan. Kebanyakkan penyelidik hanya menentukan jenis saiz picagari yang tidak mempunyai masaalah dengan pengunaan pam yang sesuai sebagai penyelesaian. Maasalah seperti rekabentuk pam yang terlalu sulit kerana mekanismanya diabaikan, malah kesulitan inilah yang membentuk pelbagai massalah. Dalam project ini, rekabentuk mekanisma system yang mudah di reka untuk membentuk sebuah pam. Kawalan Micro controller dimana perisian algoritma direka and dikalibrasikan dengan masa yang ditetapkan untuk setiap 2 pembahagian divisi atas skala picagari. Dalam rekabentuk pam ini, alat aktuator ball screw yang mempunyai geseran yang terlalu rendah dipasang. System rekabentuk pam ini adalah system yang tidak mengikuti kadar aliran injap setiap masa tetapi lebih kepada penyaluran isispadu dalam seminit, tetapi tidak mengikuti rangka masa yang nyata. Simulasi eksperiment pam ini dijalankan atas 2 jenis kadar isipadu penyaluran iaitu kadar isipadu yang rendah (0.4mL/min) dan kadar isipadu yang tinggi (1mL/min). Eksperimen mengunakan picagari saiz kecil dilakukan untuk pemerhatian kadar isipadu penyaluran. Hasil semua eksperimen yang disimulasikan, semua keputusan di perhatikan dari segi masa dan jarak yang diukur, didapati bahawa penyaluran isipadu padar kadar yang rendah mempunyai kecekapan yang linear berbanding dengan kadar isipadu yang tinggi. Yang penting dalam eksperimen ini, tiada kelewatan masa permulaan injap bergerak yang terjadi. Penggunaan picagari bersaiz kecil dapat memperbaikan kecekapan penyaluran isipadu setiap minit dengan jarak yang ditetapkan.

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mL	-	milliliter
cc	-	cubic centimeter
F	-	Force
$x°$	-	Degree angle
t	-	time
mL/hr		milliliter per hour

CHAPTER 1

INTRODUCTION

The syringe pump is a piece of equipment which is used in hospitals, medical labs and any application which requires drug administration over a prescribed time. This thesis seeks to relate on the workings of the syringe pump, its uses as well as any weakness and improvements which can be made to it. This thesis is based on a experiment carried out using various syringes and also the length of time the drug needs to be administered.

1.1 General overview of the syringe pump

The syringe pump or syringe infuser consists of a simple piston pump that requires a plunger either push or pull liquid in a syringe. All syringes are fitted with a plunger on one end and a needle at the other end to allow the outflow of the liquid. The syringe pump infuser is used in hospitals to dispense the right amount of medicinal liquid as prescribed by the doctor or medical staff. However, the concern of doctors with regards to the usage of the syringe pump is not the amount of concentration of the liquid but rather the dispense rate that is usually stated as millilitre per hour or mL/h.

These syringe pumps usually can accommodate a single syringe but in some syringes, multiple syringes are possible which are then fitted either horizontally or vertically depending on the design of the hardware. The syringe pump has come a long way where many improvements were made. The issues concern the dispensing of the drugs as well as the safety issues while diffusing drugs into patients were also were taken into account by syringe pump manufacturers. Syringe pump manufacturers such as Harvard Apparatus have a history of syringe pump manufacturing which dates back to the year 1950. Their first pump was developed using a lead screw type which is attached to the motor spindle and in the early 1980's the first microcontroller pump was introduced by this manufacturer. Some pumps are designed to be used in specific fields such as in research laboratories, where small volumetric syringes are used, in anaesthetic departments where higher volumetric pumps are used for continuous drug delivery into the patient and also pumps that administer only certain type of drugs, for example, insulin for diabetic patients.

There are also general-purpose syringe pumps which use different types of syringes with various volume sizes in mL It is used mainly in hospitals and some care centres, (for example, a patient's home and/or a home for the old and in physician's clinics) where liquid medications needs to be administered with great care. Any of these kinds of pumps has been to achieve success in improving the patient's life, improvements in medical research, discoveries in medical drugs and its administration of drug delivery. Figure 1.1 shows different types of syringe pumps with single or multiple syringes available for different application environments. All of these syringe pumps are micro-controlled stand alone devices.

Figure 1.1: Various types of infusion pumps in the market.

1.2 Syringe Pump Operating Principles

A syringe consists of a piston pump enclosed in the cylindrical tubing at one end and a needle at the other end. Liquid is pulled into the syringe via the needle opening. Once the verified dosage is reached, the piston is pushed to inject the drug into the patient’s veins.

This procedure is manually done by the user of the syringe pump. When the syringe is fitted on a pump, the pushing of the piston is done by the plunger which in turn operates the stepper motor. This system is partially automated as the administering of the drug dosage and the flow rate settings is done by the user. It has to be noted that the syringe is used for direct dispense of liquid into the patient via a qualified medical personnel whilst the pumps are used for the continuous low flow rate infusion delivery to the patient where time is concerned.

As mentioned earlier, syringes come in many scales of millilitres or micro-litres that define the size of syringes. Most common sizes are 5 mL, 6 mL, 10 mL and 20 mL sizes. Some sizes such as 3 mL, or 10 µL are being used in research areas that require precision bolus of liquid to be studied. Furthermore, some syringe scale is printed with the required capacity in terms of CC, which means Cubic Centimetre per millilitre. For example, 10 cm^3 equates to 10 millilitres of liquid and each millilitre is one metric unit of volume. A typical syringe of different sizes is shown in Figure 1.2.

Figure 1.2: Syringe size with different mL ranges.

1.2 Literature Review

Syringe pumps have its risks. Safety of the patient and safety of the usage of the user is regarded as the most important feature in the development of the syringe pumps. This is due to the fact that it is an important tool in hospitals where precise and accurate dosage is important to the doctors who administer the drugs and the patients who receive it. It has been noted that despite it having same specification, different manufacturers have different safety and accuracy features.

However, based on certain statistics that was reported, different pumps that has a different standard of safety and accuracy while some pumps having contains only free risk with also different accuracy, only 40 percent failure due to wrong settings by the user and 60 percent was due to occlusion occurred while diffusing liquids. In this case, a standard operating procedure was developed to validate and verify the pumps manufactured following standard guidelines.

Furthermore, syringe pumps were designed to incorporate positioning of the syringe orientation which has been influenced by the flow rate. Citing a case by Igarashi, Obata, Nakajima, Canadian Journal (2005), where a few pumps were tested horizontally and vertically to assess the internal pressure of the syringe by determining the change in blood pressure of the animal. The pumps that were at a horizontal position did not make much difference in the blood pressure; however the blood pressure showed a significant difference on the vertical position. The difference was in the internal pressure. It was to be understood that gravity has a part to play where a gravimetric influence disrupts the flow rate of the pumps. The verification of newly manufactured pumps had to be sent to the laboratory for multiple tests on the safety protection against gravity free flow and accuracy issues that comes with it. Only then is the pump safe to be used with the correct accuracy that complies with the specification guides.

Accuracy is a primary key data that is to be noted when looking at the syringe pump specifications. Pump analyzers are used to determine the accuracy of flow rate as well as to test on safety measures implemented for occlusion prevention. Occlusion is a major problem that effects the operations and reliability of pumps.

Occlusion can happen on any parts of the pumps. The tubing section from the needle and into the patient in which a self test of the pump could create a large bolus purging into the patients vein or a hardware failure, for example, motor stalled or the plunger was obstructed. In any of this situation, critical accidents are able to occur such as overdose drug or extremely low infusions that may cause intermittent bolus.

Furthermore, a continuous flow with a lower flow rate is desirable for a syringe pump where specified drugs are infused to the patients especially in an intensive care unit. The reason as explained by Dunster & Coldtiz (1995), higher flow rates deemed not suitable and can cause blood pressure fluctuations in patient.

When the flow rate is high, there is a tendency for the piston to get stick with the inner structure of the syringe. A further push by the plunger with a higher necessary torque to overcome this obstruction may result in purge or overdose situation. The key point here, the pumps with low flow rate is better than pumps that do not have a continuous flow rate. Many manufacturers failed to examine these aspects. Numerous literatures reviews mainly focus on the safety study among many syringe pumps of different types, different sizes and for different application.

As we know, a syringe pump is not a fully automated device that works on its own, manual operations by the user also plays a vital role. In this case, human errors do happen when handling these pumps. However, many medical instrument tests emphasize that alertness in terms of alarm or any kind of beep devices must be paid special attention by the manufacturer. Incidence occurs when users failed to be alert on abnormal occurrence on operations in the pumps. Citing a report made by Farbood & Akazemi, (2010), abnormal activity by the pump could put a patient’s life in danger.

Therefore, user alertness on the running pump has to be taken seriously so that prompt action by the user to rectify the situation is vital. Some hospitals and clinics emphasize their own standard operating procedures in training, handling pumps and failure identification for the user to address potential hazards. However, considering the duties of the user (operator), leaving operating pumps unattended for a very long time can be a risky. (Draper, Nielsen, Noland, 2004).

Having alarms activated to alert user must a priority for pump designers, but recent studies show that many different syringe pumps of different syringe size has different activation times. Different models have a great influence on the delay time occurrence to trigger the alarms. It has been a major concern for researches to distinguish the right type of pump need for the right applications, and the buyer of the pumps has to be advised on its advantage and disadvantage on the operations.

The occurrence of abnormality on operations such as occlusion condition, incidentally free flow rates or hardware problem occurrence still may occur on many pumps. Larger syringe sizes with high volume metric has a high delay time before it is triggered compared to smaller syringe sizes. (Donmez, Araz, Kayhan, 2005). Reducing this delay time occurrence is still under further studies especially when instrument size has the great influence on it. In addition to that, delay time in initiating the start running of pump for fluid delivery varies among many different pumps. Death space volume, it’s a situation where during the liquid intake into the syringe, (manually done by user) has some air gap between the liquid and the piston. This air gap does not re-act chemically with the liquid or whatsoever but the delay start of infusion does have an influence on the flow rate. Such problems as these are minimized by having the user to dispense some mL bolus before fitting it into the syringe pump. However, dead space volume varies among syringe sizes. (Neff, 2001). Syringe size has a large influence in parameters settings (in specifications/datasheets) apart from hardware designed.

No doubt that a good hardware and software design is needed but the performance of the pumps varies on what size of syringe it is made for. Most syringe pumps are specified for a one size syringes and at present there are not many robust application pumps that have been designed to accommodate multiple syringe sizes as it will create redundant errors that deviates the original specifications.

1.3 Volume Dispense Syringe Pump

From the literature reviewed so far, as technically understood, flow rate is concerned with the continuous time translational motion of the motor and the mechanical actuator that drives the syringe piston. The syringe piston moves non-stop with respect to time set until the infusion of the drug delivery to the patient is completed. Time can be in hourly rate or minutes.

Since, the flow rate is categorised by time and volume dispensed, whether it is a high flow rate or low flow rate, during the pump operation, the piston motion is not stoppable once it is set. General syringe pumps does not include any 'stop' buttons or program as such that the pump can be stopped in the mid way during diffusion. This in turn, if there are any blockages around the syringe or the tubing section will result in a pressurised flow that would be dangerous to the patients. Most manufacturers, usually programs a beeper and fits in a pressure sensor devices to monitor the pressure of the flow.

1.3.1 Flow Rate and Volume Rate

A high pressure flow is due to many obstacles described earlier. Hardware, syringe types, poor maintenance of the mechanical assembly of the pump, stalled motor and complicated fittings of gear and belts which could be worn out. Once, a blockage happens, the pump would still operate and as over time, high pressure would build up and this will create a pressure on the flow to keep moving. At this stage, it is where the pump sends an alert beep or interrupts the motion of the infusion delivery. Other causes are often neglect by manufacturers during the assembly fittings. Too much complexity does lead to frictional problems which will disrupt the motion of the plunger, thus affecting performance and accuracy.

In this project, instead of flow rate, a volume rate pump was designed to diffuse liquid volume in every time interval. It means that the pump designed in this project was focussed only for a discontinued motion. The program was designed as such that, the volume dispensed can be stop at any time and resumed back operating. A few designed changes, with simple mechanical hardware fitting to minimise frictional contacts that could lead problems with performance and accuracy.

Details of the volume pump designed are explained in the subsequent chapters. The performance of this volume dispense pump is analyze based on studying the accuracy of motion by the syringe piston movement, and the length measured by the with respect to the syringe scale. In the Figure 1.3 below shows the syringes pump assembly's components which are of common use by most manufacturers. In this project, only the important components are applied in the designed syringe pump which would be elaborated further in the methodologies section.

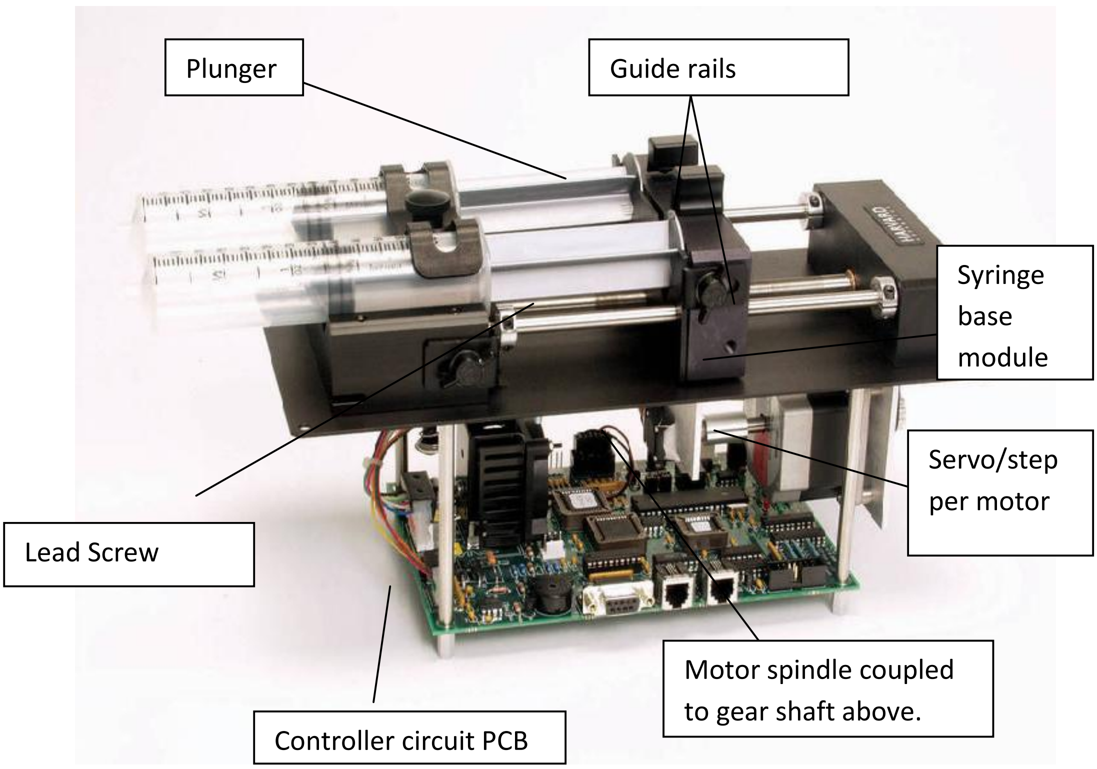

Figure 1.3: Cross sectional of the syringe pump architecture

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