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Original Article

THE DEVELOPMENT OF 3D PRINTING MODIFICATION OF LIQUID HANDLING SYSTEM CONCEPT FOR PIPETTING SYSTEM PROCESS IN THE MEDICAL AREA

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ABSTRACT

Background. The development of electromedical technology in the healthcare field is increasing. However, the measurement of liquid samples in the pipetting process is still done manually which makes it highly contaminated from human hands. A Liquid Handling System (LHS) is a device used to automatically transfer fluids to prevent contamination. 3D Printing is a tool used to create creative design objects using filament material. The mechanism of this tool is similar to that of a liquid handling system but is simpler and has a smaller capacity. In the future,
Research Purpose. To determine 3D printing modification of liquid handling system for pipetting system process in the medical area.
Research Method. This research uses the research and development (R&D) method by designing and constructing a Prototype Liquid Handling System with a modified 3D Printing 3-axis, placing measuring cups and sample tubes, and designing G-Code programs and servo motor coding to test the capabilities of the designed Prototype Liquid Handling System.
Findings. Based on the functional test results of the liquid handling system using NaCl solution, the pipetting results were 0.82 ml with a processing time of 5.6 seconds. The electromedical device has a percentage error rate of 2.4% with a pulling force of 6.56 N and an injection pressure of 8.44 Pa.
Conclusion. This electromedical device will be able to automatically process extraction fluids or pipetting processes with high accuracy.

Keywords: 3-axis, 3D Printing, Electromedical, Liquid Handling, Pippeting System.

BACKGROUND

In response to the concept of digitalization it influences the way we work, shop, travel, educate, manage, and live. Especially with the latest developments in the Industrial Revolution 4.0, digital technology has had a significant impact on all fields, including the medical and health fields. In this case, the digital transformation 4.0 that is occurring in the medical world is also really needed to be able to help work and facilitate the implementation of laboratory testing processes [1], for example in electromedical technology.

The current pipetting system requires quite a lot of labor and the accuracy in measuring volumes is low. This can cause human error and hamper time efficiency in the laboratory, resulting in inaccurate results and can have a negative impact on diagnosis or research results. In this research, the Liquid Handling System is used as a method for making

pipetting system mechanisms with the aim of increasing the accuracy and speed of the system.

Liquid Handling System (LHS) is an automatic laboratory tool and is included in electromedical equipment which is designed to handle and flow liquids in small quantities with high precision. This system is commonly used in various laboratory applications such as molecular biology research, medical diagnostics, drug testing, and chemical research [2]. Liquid handling systems are still relatively expensive, so it is necessary to modify equipment that is simpler, cheaper and easier to operate.

This research aims to introduce a new concept in developing pipetting systems in the health sector, by combining liquid handling system technology and a 3-axis 3D printing machine. 3D printing machines have the advantages of using simple, compact machine construction and using an uncomplicated control system. However, it can operate with high precision and relatively low production costs. It is hoped that the development of this new concept can help increase accuracy and speed in carrying out the pipetting process in the health sector on a laboratory scale [3].

This research was conducted to answer the need for an accurate and efficient pipetting system in the health sector on a laboratory scale. The current pipetting system still has weaknesses in terms of accuracy and time efficiency in carrying out low-volume measurements. Therefore, new innovations are needed in the development of pipetting systems. In this research, the development of a pipetting system uses a liquid handling system with a modification of a 3-axis 3D printing machine. With the development of this pipetting system, it is hoped that it will help increase time efficiency and accuracy in carrying out the pipetting process in the health sector on a laboratory scale. Therefore, a design and design of a modified 3-axis 3D Printing Prototype Liquid Handling System tool is needed as a pipetting process for the development of electromedical equipment in the health sector on a laboratory scale.

RESEARCH METHOD

This applied research uses the R&D method, where this research is carried out by conducting research aimed at obtaining information that is developed. According to [4], research and development is intended to study literature to produce the design to be made. The research procedure is:

1. The proposing team discusses literature studies and research methods.
2. 3D design of liquid handling system tools with 3D printing machine modifications;
3. After the applied research is approved, the proposing team coordinates to discuss the design and construction of the prototype liquid handling system.
4. In designing the building, construction uses a modification of the 3D printing machine, the control system uses Arduino Uno with IDE software and GRBL laser, the liquid object used as a test is NaCl liquid and the place for transferring the liquid uses a measuring cup and sample cup.
5. Carry out calculations of the mechanical structure of the tool and the tool control system.
6. The design is complete, then testing is carried out in the laboratory to carry out system suitability tests.
7. In implementing this program, students are assisted in designing the tools, starting from surveying raw materials to providing instruments for data collection and assisting in data processing.

FINDINGS

In the results of this discussion, after designing a liquid handling system with modifications to the 3D-printing machine system, we then designed a hydraulic system using a rack and pinion mechanism. The liquid used is NaCl for the tool function test process. Then design the control system for the liquid handling system with hydraulic actuators, then start doing research on the control system for the liquid handling system and hydraulic actuators. The software mechanics in this prototype use UGS (Universal G-Code Sender) firmware and also Arduino Uno after all the processes have been carried out. The process of testing the function of this liquid handling system prototype tool from the process of determining the machine's 0 coordinate point to a predetermined point, placing the sample tube and measuring cup, programming the MG996R Arduino motor for the hydraulic actuator. After all the tests have been carried out, the next process is analyzing the test results.

Table 1. Test Results Time speed function of rack and pinion actuators

Test	I	II	III	Average
Pipette Rise and Fall Time (seconds)	10.58	10.22	10.24	10.34
Liquid Taking Time (seconds)	01.29	01.22	01.65	01.35
Liquid Dispensing Time (seconds)	01.05	01.08	01.16	01.09
Volume (ml)	4.72	4.51	4.45	4.56

In this case, the actual reading of the function test on the Rack and Pinion hydraulic actuator using a stopwatch uses 3 experiments to test the speed of time with 180 degrees when the pipette goes down and up, when taking liquid, and when removing liquid. For the first function test, it can be seen in Table 1 as above which shows that the time speed obtained when the pipette goes down and up before taking the liquid has an average of 10.34 seconds, then when taking the liquid it takes an average of 01.35 seconds. and when removing the liquid it takes an average of 01.09 to produce an average volume of liquid of 4.56 ml.

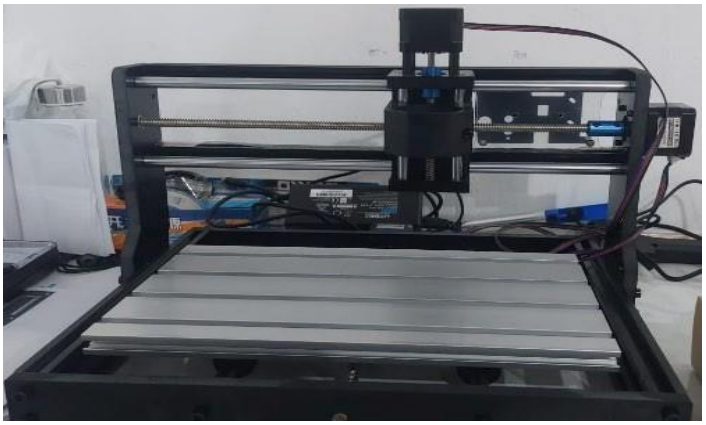

Figure 1. Liquid Handling System (source: from the primary data)

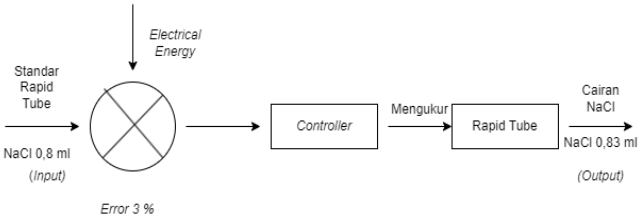

Figure 2. Function Test Block diagram

Figure 2 explains the block diagram of the Arduino IDE and LHS machine in a trial where the input was 0.8 ml of liquid NaCl in a standard rapid tube, then produced an output of 0.82 ml of liquid NaCl and the time in this test from point 0 to point 5 required 25.81 seconds, where there was an error of 2.4% after carrying out an average of 3 trials.

$$Error = \frac{|approximate\ value - exact\ value|}{exact\ value} x\ 100\ |$$

$$\%\ Error = \frac{|0,8-0,82|}{0,82} x\ 100$$

$$\%\ Error = \frac{0,02}{0,82} x\ 100$$

$$\%\ Error = 0,024\ x\ 100$$

$$\%\ Error = 2,4\ \%$$

In the error percentage, it is explained that the estimated value is the input value of 0.8 ml with the desired standard rapid tube minus the exact value, namely 0.82 ml from the results of the average volume of the trial table and the error results which add up to 2.4%.

DISCUSSIONS

Liquid Handling System (LHS) is an important part of all experiments related to life science, especially in pipetting processes in the health sector. Genomic research usually requires a liquid pipetting process to add one liquid to another liquid [2]. The Liquid Handling System is a tool consisting of a series of linear guided actuators (LGA) which can move on three axes, namely the X Axis, Y Axis and Z Axis. The automatic liquid handling system is based on the novel vision-guided micropipette. Micromachines [3]. The LHS for the Y Axis is combined with the LHS for the Z Axis and the other components required.

3D printing machine or three-dimensional printing is a printing technology that uses raw materials to form three-dimensional objects. This technology involves the process of building objects by controlling the deposition of raw materials, usually using layer-by-layer technology. 3D printing technology consists of several technologies, such as fused deposition modeling (FDM), stereolithography (SLA), selective laser sintering (SLS), and many more. One of the most commonly used 3D printing technologies is FDM. This technology involves the use of meltable materials such as plastic or metal. This material is heated until it reaches a temperature high enough to be melted and then expelled from the nozzle in the form of filaments. After that, the printer lays down the filament layer by layer until it forms the desired object. 3D printing technology also involves the use of 3D computer designs created using 3D design software.

Stepper motors are a type of motor that is widely used as an actuator for various applications. To control a stepper motor accurately, it is necessary to use a microprocessor or microcontroller to send the appropriate pulses and ensure that a large enough current flows in each phase winding. Before operating a stepper motor, it is necessary to design a logic sequencer to determine the sequence of the motor phase windings and a driver that meets the current requirements for each phase winding must be provided. Stepper motor specifications usually include information about this.

A servo motor is an electronic component that combines a DC motor with a feedback system to provide actual rotation position information that can be controlled by a microcontroller [3]. Servo motors are widely used as actuators that require precise rotational position [5]. Servo motors can not only be controlled for speed and direction like DC motors but also for angle/degree parameters. The main components that make up a servo motor are a DC motor, gears, potentiometers, and servo controls [3].

Arduino is a platform that provides hardware and software to easily create microcontroller-based electronic circuit prototypes. Using the Arduino IDE, one can write programs called sketches on Arduino, compile them, and upload them to the Arduino board [6]. Arduino Uno uses the simpler C/C++ language to program devices. To write program code, users can use the Arduino IDE software which is an integration of various types of programming that can be used to control Arduino devices. Once written, the program code will be uploaded to the Arduino Uno using a data cable. This IDE will help streamline the programming process and test program code on the Arduino Uno device. Software is very important in supporting hardware capabilities. IDE (Integrated Development Environment) is software used to develop microcontroller applications starting from writing source programs, compiling, uploading compilation results and testing terminally [6].

Rack and Pinion is a mechanical device that is often used in various applications, including car steering systems and machine tools. In a rack and pinion mechanism, the rack is a rod with teeth on one side, while the pinion is a small gear with teeth that mesh with the teeth on the rack [7,8]. If the pinion rotates about a fixed axis, the rack will move linearly. It can be used to produce rectilinear motion in automobiles or machine tools, depending on how the tool is designed and installed, in machine tool applications, the rack is mounted on a work table, while the pinion is mounted on a shaft that is rotated with a hand crank [9]. When the shaft is rotated, the pinion rotates and moves the rack, which then moves the work table. This allows operators to move the workbench quickly and easily, which is critical in production processes that require accurate and efficient table movements. The rack and pinion mechanism is a good example of how a simple mechanical device can be used to produce complex movements and is useful in a variety of applications including liquid handling systems [10,11]. Human resources and equipment make health service work procedures easier and will be an option in the future [12, 13, 14].

CONCLUSION

The results of the Prototype Liquid Handling System function test used NaCl infusion fluid of 0.1494 ml/s and a volume of 0.82 ml for each NaCl infusion fluid taken in 5.6 seconds. The Hydraulic Actuator with Rack and Pinion Mechanism in the Prototype Liquid Handling System has a tensile force of 6.56 N. The resulting injection pressure is 8.44 Pa. For the function test results of the Rack and Pinion, the time speed obtained was able to take in and release 5 ml of liquid for 3 trials according to the injection capacity. The total fluid volume obtained was 4.56 ml. Based on these results, an error percentage of 2.4% was obtained after

carrying out an average of 3 trials. And the average time from point O to point 5 is 25.81 seconds.

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