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Design and Production of Multiple drugs Counting and Dispensing Machine

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Abstract
There are issues related to the quality of service delivered in public health facilities as well as drug retail outlets. In the aspect of counting and dispensing of drugs, patients complain about the poor level of attention that they get from such places. Patient attendants working under pressure as a result of a great number of patients to be attended to in a short period of time may make mistakes and errors in the number of tablets counted. This usually leads to packaging of either few or more pills which invariably leads to drug abuse. This research is concerned with the design and production of a drug counting and dispensing machine to solve these problems. The machine was successfully designed, produced and tested The motor inertia torque was 0.88 kg m^2 ,the RMS torque was 3.30 Nm with a peak acceleration and torque of 7.3435 Nm and 758.872 rad/sec respectively .The required voltage and ampere was 5V and 1 A respectively. The machine was able to dispense 5 tablets for 3.5 seconds or 0.7 second for a tablet for paracetamol, gelusil and vitamin C tablets respectively. The efficiency obtained was 78.5%. Further research should be carried out to improve on the dispensing rate higher than (78.5%). The development of this machine at a large scale production is required.
Keywords: Drugs counter, dispensing, mechatronics, machine, servo motor, 3D-printing.

I. Introduction

Counting has been part of human existence from antiquity to present age. People count the number of items they have, the population of people in their community, the number of animals in their possession and any other thing that is countable. The essence of counting is to determine the size of something for record purposes or for administration – as in the case of medicine. In traditional medicine, it is known that diseases can only be treated when the right substance is administered in the right dosage i.e. the right amount or quantity. This makes measurement vital in health care.

Modern medicine is administered in several ways namely; oral, intravenous injection, topical, sublingual and rectal. Oral administration is the most frequently used route of drug administration and is the most convenient and economical [1].

According to [2] “a tablet is a pharmaceutical dosage comprising a mixture of active substances and excipients usually in powder form, pressed or compacted from a powder into a solid dose”. Tablets vary in shape and differ greatly in size and weight, depending on the amount of medicinal substances and the intended mode of administration. It is the most popular form and 70% of the total medicines are dispensed in the form of tablet. All medicaments are available in the tablet form, except cases where there is difficulty in formulation or administration [3].

Before a tablet drug is dispensed for the treatment of an ailment, it is required that not only the right substance should be taken in to consideration. Also, the right dosage or amount should be taken into consideration. The number of patent medicine stores in Nigeria involved in the counting and dispensing of drug has been on a rapid increase over the years. However, the number of drugs stores (commonly called chemist) is not commensurate with the quality of healthcare that ought to be at the disposal of Nigerians [4]. The poor state of the healthcare system in the country cannot be attributed to in adequate infrastructure alone, but also to the quality of service provided at the pharmacies and other drug retail outlets.

Until 1970, tablet and capsule counting and dispensing was a highly time consuming manual operation and most times resulting in costly errors [5]. Advancements in electronics and computer technology have led to the development of electrochemical counting machines. Such machines reduce error in counting and save time in drug dispensing by ensuring that the correct quantity of drug is dispensed quickly.

In the conventional counting of using spoon and the plastic tablets top counter, the pills get in contact with the counter surface. Thus, there is a possibility that other drugs can get mixed with other drugs. In a study conducted by [4], it was discovered that "72% of patent medicine drug dealers use manufacturer’s spoon. Also, that 2% shakes drugs out of their containers during dispensing, thus causing breakage of the tablets".

Sometimes, it is also possible for the medicine vendors to use their hand, paper or any other material for counting the drugs and this is totally unhygienic because it leads to drug contamination. Automated counting addresses such concern by preventing contact with the surface of the counter itself.

To improve the quality of service delivery to customers in the most cost effective way without jeopardizing standards and contamination concerns, this project was carried out.

The use of medication is nearly as old as man. There are several reasons why people get ill. When they do, it becomes necessary to find solutions to the anomaly in health. Traditional medicines are administered orally, topically (i.e. on the skin) and through enema. By these means, individuals have administered or received treatments from time immemorial. In the modern society however, the mode of administering treatment has expanded to include intravenous injection and various forms of radiotherapy [1].

The difficulty in swallowing pills was a main cause of concern in the early years of development of pills. Significant effort had been made to make them go down easier. In medieval times, people coated pills with slippery plant substances. In the 19th century, the approach was to gild them in gold and silver; although it often meant that they would pass through the digestive tract with no effect. In the 1800s, sugar coating and gelatin coating was invented [6]. In 1843, the British painter and inventor, William. Brockedon was granted a patent for a machine capable of “shaping pills”. The invented machine was capable of compressing powder into tablet without the use of an adhesive [7].

With the advent of William Brockedon's machine, the necessity of counting of drugs became crucial for record purposes and for administration purposes. At the initial stage, counting of drugs was done using the conventional spoon and the plastic tablets top counter. However, using this traditional method for counting drugs, the drugs get in contact with the counter surface. Sometimes, it is also possible for the medicine vendors to use their hand, paper or any other material for counting the drugs and this is totally unhygienic [8].

Until now, some of these early counting devices for drugs are in use in some areas. However, this simple way of counting was difficult to use for large counts because of their awkward nature. The methods were used until the invention of the mechanical counting device.

Counting involves determination of the number of items or the rate at which something happens. Counting is often done to determine the magnitude, or the size of a certain number of items. The determination can be done by hand or by the use of a manual or automatic machine - depending on what is counted and the expected counting rate. Digital counters are also in use today. A digital counter is a device that generates binary numbers in a specified count sequence. The counter progresses through the specified. sequence of numbers when triggered by an incoming clock waveform, and it advances from one number to the next only on a clock pulse[9].

Even before humans could read or write, they needed to count. First, they used their fingers, but when they had to deal with numbers over ten, a counting device became necessary. Pebbles and bits of wood arranged on the ground were used to count goods and to figure prices. These were the predecessors of the abacus.

So it is no wonder that such boards cannot be found. Other early counting devices include; salamis tablet, slide rule, Napier's bones and arithometer [10].

The first counting device - a mechanical "Calculating Clock" was invented by William Schickard in 1624, but was forgotten for a long time. So the man usually credited with inventing the first mechanical calculator is Blaise Pascal in 1642 [10].

Tablet Counters have been designed to facilitate effective counting of tablets administered to patients. There are two main types of tablet counters, namely: manual tablets counters and automatic tablets counters.

Manual tablet counters employs the use of conventional spoon (spatula) and the plastic top counter for counting of drugs. In this method, the pills get in contact with the counter surface. Sometimes, it is also possible for the medicine vendors to use their hand, paper or any other material in place of spatula for counting the drugs and this is totally unhygienic [11].

The tablet counter aided the pharmacy industry with time-consuming manual counting of drug prescriptions [8].

The counting machine consistently counted medications accurately and quickly. This aspect of pharmacy automation was quickly adopted, and innovations emerged every decade to aid the pharmacy industry to deliver medications quickly, safely, and economically. Modern pharmacies have many new options to improve their workflow by using the new technology and can choose intelligently from the many options available [12].. These early electronic counters were simple to operate machines designed to help pharmacies replace the common (but often inaccurate) practice of counting medications by hand [8].

Between 1982 and 1983, two separate facilities for fabricating the drug counter machine had been created. In America, overseen by Rodney Lester; and in England, overseen by the Kirby brothers [8].

In the late 1980s and early 1990s there was more technological advancement and this led to the development of high-speed machines for counting and bottle filling [13]. Like their pharmacy based counterparts, these industrial units were designed to be fast and simple to operate, yet remain small and cost effective.

This was a step forward to verify all 100% of prescriptions that were dispensed by pharmacy staff [13]. In America, in 2009, further advanced counters were designed that included the ability to dispense hands-free – a feature that many operators had desired. This allowed pharmacies to automate their most commonly dispensed medications via calibrated cassettes [13].

While one tablet is unlikely to leave enough residues to cause harm to a future patient, the risk of contamination increases sevenfold as the machine processes thousands of varying pills throughout the course of a day [11].

Thoroughly cleaning pharmacy automated tablet counters is recommended to prevent the chance of cross-contamination. This method is widely preached by manufacturers of these machines, but is not always easily followed. Performing an efficient cleaning of an automated tablet counter significantly increases the amount of time spent on counts by users [12].

Power sources employed in drugs counting include :generator and batteries

Batteries are the main component of a drug tablet counter and dispenser. Batteries can be classified into; rechargeable and non-rechargeable. Non-rechargeable batteries deliver more power based on their size.

A sensor is a device, module or system whose purpose is to detect event or changes in its environment and send the information to other electronics or a computer processor. A sensor is always used with other electronics whether as simple as a light or as complex as a computer.

The sensor used in drug tablet counter is a photoelectric sensor. It is an equipment used to discover the distance, absence, or presence of an object by using a light transmitter, often infrared, and a photoelectric receiver. This sensor is used to detect the presence of drugs in the stack. Some of the sensors include: self contained photoelectric sensor, remote photoelectric sensors, self contained photoelectric sensor contains the optics, along with the electronics. It requires only a power source. The sensor performs its own modulation, demodulation, amplification, and output switching. Some self-contained sensors provide such options as built-in control timers or counters. Because of technological progress, self-contained photoelectric sensors have become increasingly smaller. Remote photoelectric sensors is used for remote sensing and it contains only the optical components of a sensor. The circuitry for power input, amplification and output switching are located elsewhere, typically in a control panel. This allows the sensor, itself, to be very small. Also, the controls for the sensor are more accessible, since they may be bigger. Fiber optics when space is restricted or the environment too hostile even for remote sensors, fiber optics may be used. Fiber optics are passive mechanical sensing components. They may be used with either remote or self-contained sensors. They have no electrical circuitry and no moving parts, and can safely pipe light into and out of hostile environments

According to [15], the following mechanisms are majors employed in drug tablet counters; crank and lever mechanism, single slider crank chain mechanism and scotch yoke mechanism,

Engineering design software helps to model, validate and communicate ideas before production. In embedded systems, the use of software facilitates the ease of manufacture, ease of assembly, a great reduction in cost and lead time [16]. Simulation software helps manufacturer verify and validate the intended function of a product under development, as well the manufacturability of the product. According to [4], for the design and simulation of drug tablet counters, the following softwares are majorly used: solids works, autodesk inventor and autocad.

II. Materials and Methods

2.1 Design Considerations

Some of the factors which were taken into account while designing the multi-purpose drug tablets counter and dispenser are as described: Drug tablets factors such as size, shape, surface texture was considered in the design of the machine.

Machine factors such as reliability, durability, wear, noise and weather condition to which it's exposed will be considered in the selection of appropriate material and in sizing and shaping of the various machine components. Machine was constructed of locally available materials to enhance the possibility of replacing damaged parts with less expensive but equivalently satisfactory parts that is readily available.

The overall cost was considered through critical value analysis in the phases of design and production which at the end would make it affordable by pharmacist and other intending users.

2.2 Design Analysis

The major designs were on the drug stack column, servo power requirement and picker velocity

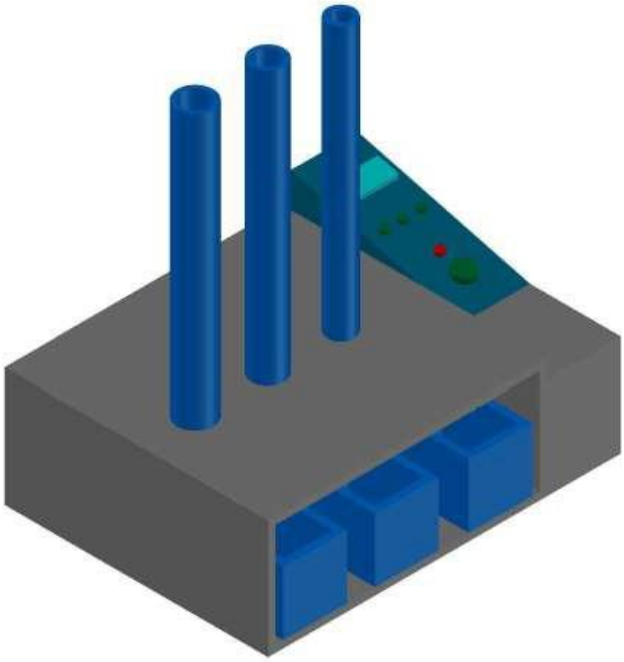

Figure 1: Assembly drawing of the machine

The drug stack for paracetamol tablets is expected to have a targeted capacity of 30 tablets. Therefore, a stack that is cylindrical was selected with opening at both ends with and internal diameter of 14mm and external diameter of 16mm and height of 130mm to ensure the easy stacking of drugs.

The drug stack for gelusil antacid tablets is expected to have a targeted capacity of 30 tablets. Therefore, a stack that is cylindrical was selected with opening at both ends with and internal diameter of 3.5mm and external diameter of 5.5mm and height of 130mm to ensure the easy stacking of drugs.

The drug stack for vitamin C tablets is expected to have a targeted capacity of 30 tablets. Therefore, a stack that is cylindrical was selected with opening at both ends with and internal diameter of 10.8mmand external diameter of 12.8mm and height of 130mm to ensure the easy stacking of drugs.
Therefore the volume of each drug stack is determined using Equation 1

$$V = (\pi \tau \text{ x } (r_2)^2 \times h) - (\pi \times (r_1)^2 \times h) \qquad 1$$

where $r_{1,} r_2$ are the radii and h the height, π - constant

The detection of tablets is very important in the operation of the counter. Hence, provision is made for electronic detections of the tablets. The sensor is designed to detect the movement of each tablet through the outlet channel as it passes into the dispenser tray. The designed sensor codes are installed on the microcontroller (arduino uno). A servo motor with five wires is used. One wire is for power supply to the servo motor and the other four wires are connected to the windings of the servo motor. Equation 2 gives the speed of the servo motor.
Speed of Servo Motor, S_0

$$S_0 = (2\pi / 6) \div n \qquad 2$$

n is the time taken to complete one revolution, π is constant

The torque required of the servo motor was determined using Equation3.

$$T = I\alpha = (2\pi / 6) \div n \qquad 3$$

where;
T is the Torque, Nm, α is the angular acceleration rad/sec ^{2} and I is the Inertia, kgm^2

The power output of the servo motor was determined using Equation 4
.

$$P = 0.105 \times T \times N \qquad 4$$

where; P is the rated output, N is the rated speed, RMS

The picker is used to open or close the way to the tablets. Equation 5 gives the speed of the picker.
Speed of Picker

$$S_p = d \div t \qquad 5$$

where,

d is the distance travelled by(m) t is the time.
The multi-purpose drug tablet counter and dispenser is made up of different components as listed in Table 1

Table 1: List of materials used

Serial Number	Description	1
1	LCD Board	2
2	Vero Board	3
3	Sevo Motor	
4	Tapping Screw	4
5	Ribbon (Acrylonitrile Butadiene Styrene)	-
6	Power switch	1
7	Photoelectric sensor	3
8	Banana wires	3
9	Push Button	3
10	Adhesive	5
11	12V Battery	1
12	Battery Clips	3
13	Dispense Button	1
14	Male Pin Socket	14
15	Female Pin Socket	14
16	Arduino Uno	1
17	Cork	-

The machine is powered by the use of a rechargeable battery (with rating 5.0V / 1A).
Figure 2 shows the slider crank mechanism. It cost ₦ 159,800.00 (One hundred and fifty nine thousand, eight hundred naira) to produce the machine.

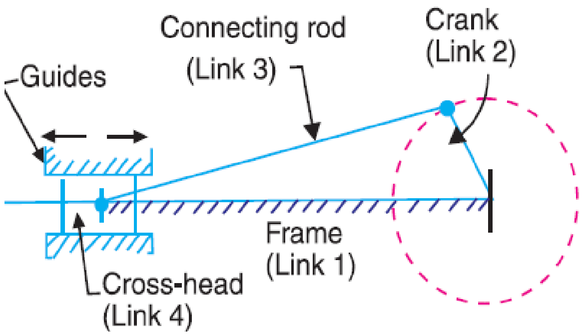

Figure:2:SliderCrankMechanism

When the dispense button is pressed, the arduino uno sends signal to the servo motor. The servo motor blade which acts as the crank undergoes a rotary motion. As the crank rotates, the picker reciprocates in the guides and thus opening and closing the slide docker which allows for the falling of a drug tablet onto the picker surface from whence it is pushed into the collection tray by the picker. This cycle is continued until the counter function stored is completely dispatched. Figure 3 shows the applied mechatronics principle.

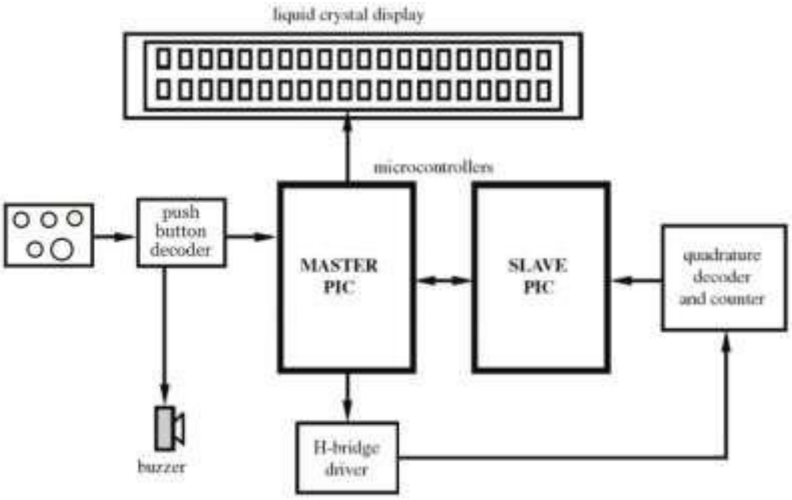

Figure 3: Machine mechatronics principle

The input to the machine is sent through the push button. When the push button is pressed, the push decoder interprets the input and sends a signal to the buzzer which in turn makes a beep. The buzzer makes a beep anytime a push button is pressed and also at the end of dispensing. The input to the system is then sent to the arduino uno which is the master PIC. The arduino uno coordinates and controls the electrical system, control system and mechanical system. The arduino uno sends signal to the liquid crystal display which is the screen. The arduino uno also sends signal to the servomotor which is the slave PIC and also to the vero board (H bridge drive). The cycle continues whenever there is a counting and dispensing operation

Production of the multi-purpose drug tablets counter and dispenser was done using locally available materials. The manufacturing process applied was additive manufacturing - 3D printing.

The multi-purpose drugs tablet counter and dispenser consist of three basic units : feeding unit, counting unit and dispensing.

The feeding unit is made up drug stack column. The different tablet drugs are fed through the drug stack column into the machine. The drug stack column is made from polyethylene terephthalate (PETT) which is a polymer with opening at one end. It is not inclined to ease the stacking of drugs

The counting unit is the unit which senses the drugs by the use of a sensor and where the counting of the drugs is done. The unit consists of slide docker, picker, arduino uno (microcontroller).

Underneath the counting unit is the dispensing unit. It is where the counted drug is collected. The unit consists of a collection tray. The collection tray is different for each drug in order to avoid issues of cross contamination and mix-ups.

III. Results and Discussion

3.1 Results

Table 2 presents the basic drug design data

Table 2: Summarized Drug Design Data

DRUG	Mean diameter, mm	Mean thickness, mm	MASS, kg
Paracetamol	13.03	4.02	0.024
Gelusil Antacid	16.35	3.30	0.026
Vitamin C	10.73	4.02	0.018

Table 3 shows the calculated motor torque values.

Table 3: Servo Motor Calculated Values

Servo Motor Parameters	Values
Motor Inertia, Jm	0.88 kg m^2
RMS Torque, T_{rms}	3.30 Nm
Peak Torque, T_{peak}	7.3435 Nm
Peak Angular Acceleration, α	758.872 rad/sec^2
Required Voltage	5V
Required Ampere	1A

Figure 4 presents the dispensing rate of the drugs.

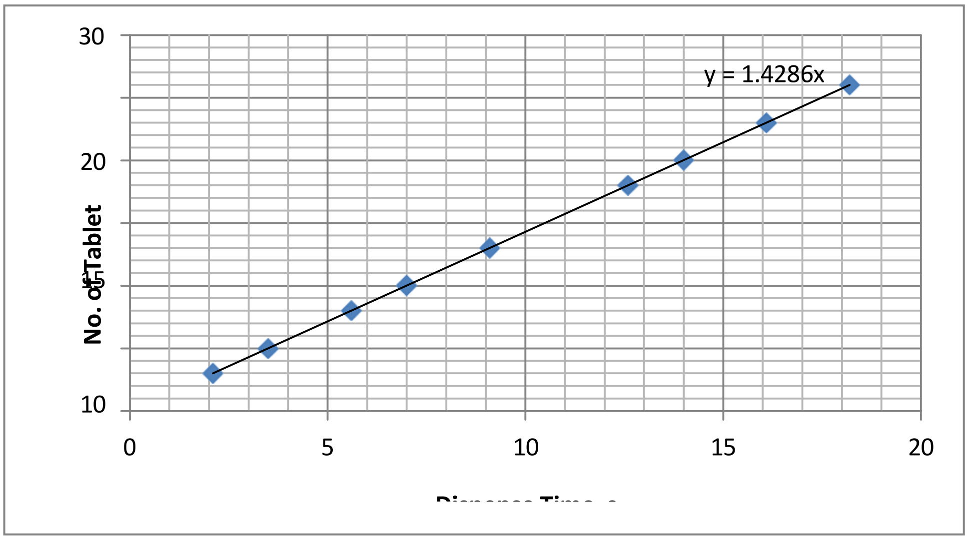

Figure 4: Number of drug tablets dispensed against dispensing time.

3.2 Discussion

The Table 2 shows the mean data obtained for the dispensed drugs. The obtained data is essential for the design of the drug stack column and the picker. Table 3 shows the motor inertia torque, RMS, peak power torque, peak acceleration, the required voltage and current respectively

From Figure 4, the number of tablet dispensed varies directly with dispensing time i.e. as the number of tablet to be dispensed increases, the time taken by the drug counter and dispenser for dispensing also increases. It can be deduced from the graph that the time taken to dispense a tablet is 0.7s.

Time taken by the machine to dispense a tablet is deduced from the graph - time taken to dispense 5 tablets is 3.5 sec, time taken to dispense 1 tablet is 0.7 second Time taken by a standard drug tablet counter and dispenser to dispense a drug is 0.55second .The efficiency of the drug tablet counter in comparison to a standard drug tablet counter is 78.5%.

IV. Conclusion

The multi-purpose drug tablet counter and dispensing machine was successfully designed, produced and tested. The motor inertia torque was 0.88 kg m^2 ,the RMS torque was 3.30 Nm with a peak acceleration and torque of 7.3435 Nm and 758.872 rad/sec^2 respectively .The required voltage and ampere was 5V and 1 A respectively. The machine was able to dispense 5 tablets for 3.5 seconds or 0.7second for a tablet. The efficiency obtained was 78.5%. Further research should be carried out to improve on the dispensing rate. The development of this machine at a large scale production is required.

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