Design and Fabrication of Thal Pump

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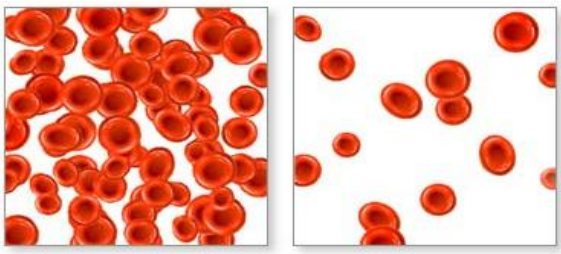
Abstract: Thal-pump is a type of infusion pump that is used for injecting iron chelating agent into the body of a patient suffering from Thalassemia disease. Currently the device used for treatment of Thalassemia patients in India is imported from European countries like Denmark and because of the import duty the cost of this equipment is considerably high(approx 50,000 INR) which makes it unaffordable to many hospitals in India. Similar desired output of Thal-pump has been developed by us with a total cost of 6,000 INR. The main objective of the Thal-pump is to inject the iron chelating agent at a desired rate (ranges from 0.5ml/hr to 10ml/hr) with high precision. This paper explains the working of the Thal-pump based on the application of Mechatronics wherein the injecting rate of the chelating agent depends on the stepper motor speed used. The speed of this stepper motor is controlled through circuits governed by an arduino sketch. The discharge rate of Thal-pump can be varied and because of this it has different medical applications.

Keywords: (ranges from 0.5ml/hr to 10ml/hr), (approx 50,000 INR), 6,000 INR.

I. INTRODUCTION

A **Thal-pump** is a biomedical device. It is of utmost need in the medical field. The name Thal-pump is derived from the name of the disease **'Thalassemia'**. Thalassemia is a blood disorder passed down through families **(inherited)** in which the body makes an **abnormal form of hemoglobin**. Hemoglobin is the protein in red blood cells that carries oxygen. The disorder results in large numbers of red blood cells being destroyed, which leads to **anaemia** (low levels of red blood cells)



Normal amount of RBC **Anemic amount of RBC**

Children with Thalassemia do not create enough hemoglobin. This may mean:

- Their body does not make enough red blood cells to begin with. Their red blood cells break down faster than normal.
- Their red blood cells are smaller than normal.
- They have less haemoglobin in their red blood cells than normal.
- The most severe form of this condition is called **Cooley anaemia**, also known as Thalassemia major.

II. THALASSEMIA IN CHILDREN

This disease is passed down from parents to children (**genetic**). The pattern is complex and can vary with the type of Thalassemia. In some cases, a parent with a mild form of the disease (Thalassemia trait) passes it to a child. In other cases, the child gets a gene for Thalassemia from both parents and has a more severe form of the disease. Some children need little or no treatment for Thalassemia because it causes only mild symptoms or no symptoms at all. Your child may simply need to see the doctor for regular check-ups or if symptoms ever develop or get worse. Some children with Thalassemia may need a blood **transfusion** from time to time, such as when they have a major viral illness. The purpose of a transfusion for a child with Thalassemia is to give the child healthy red blood cells and hemoglobin. This helps their bodies get the oxygen they need.

Children with severe Thalessemia (also called Cooley's anemia or Thalassemia major) must have regular blood transfusions throughout their life to survive. This is the most severe form of Thalassemia.

Transfused blood contains iron. Patients with severe Thalessemia cannot use this iron to make their own blood cells, so after many transfusions the iron builds up in some of their organs. This is called **iron overload**.

The iron build-up can harm the heart, liver and glands that make hormones. So the doctor will check your child's iron level. If it starts to get too high, your child will need a treatment called chelation therapy to remove the excess iron. This involves giving medicine that binds to iron so it can leave the body in urine. **Chelation therapy** is done by using **Thal-pump**.

Thal-pump is a biomedical device used for the treatment of Thalassemia disease. It is used to infuse iron chelating agent in blood. It injects chelating agent at the rate of 1.5 ml/hr for 3hrs.

It is very important to inject chelating agent at a rate of **1.5 ml/hr** for **3 hours** with constant speed without any fluctuation.

This disease is more common in people of Southeast Asia, India, China, Philippines, Africa and the Mediterranean. In a country like in India, costly medical treatments are not so affordable for common people. There are many diseases which has treatment that are out of common man reach. Thalassemia is also in this list of disease with costly medical treatment.

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Thal-pump which is used for the purpose of treatment of this disease is too costly for government hospital .At present Thal-pump in India is imported from European countries like Denmark. These countries sell these devices to India at a huge amount. Also for importing these devices Indian government imposes heavy import duty. Because of all these things the cost of a Thal-pump goes around Rs.50000/-.Such a high cost medical device is not affordable for Government hospitals in India. Government hospitals which should have at least 15-20 such devices but this hospitals at present could afford only 4-6 of them so our aim in developing this device is to make an efficient and low cost device. Our cost estimate of making this device is Rs.7000/- so that even government hospitals could afford it.

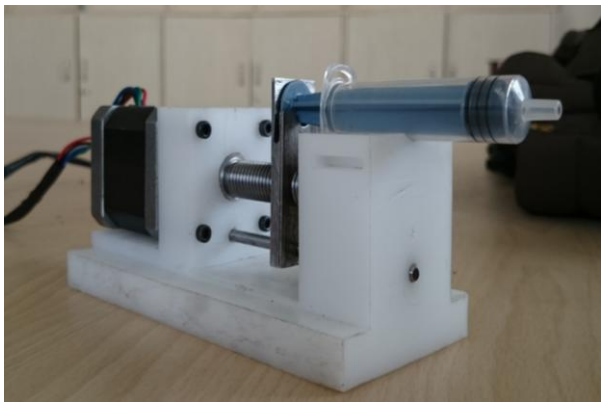

Fig. 1. Thal-Pump assembly

III. DESIGN/CONCEPT

The main purpose of Thal-pump is to supply iron chelating agent at set rate. The mechanism consists of a lead screw attached to the shaft of a stepper motor through a grub screw. A plunger runs on the lead screw.

The plunger and lead screw arrangement is used to convert the rotary motion of the stepper motor into translational motion of the syringe. Thus when the lead screw rotates the plunger moves laterally. The press of the syringe rest on the seat of the plunger .An adequate torque of the stepper motor pumps the chelating agent from the syringe into the body of the patient.

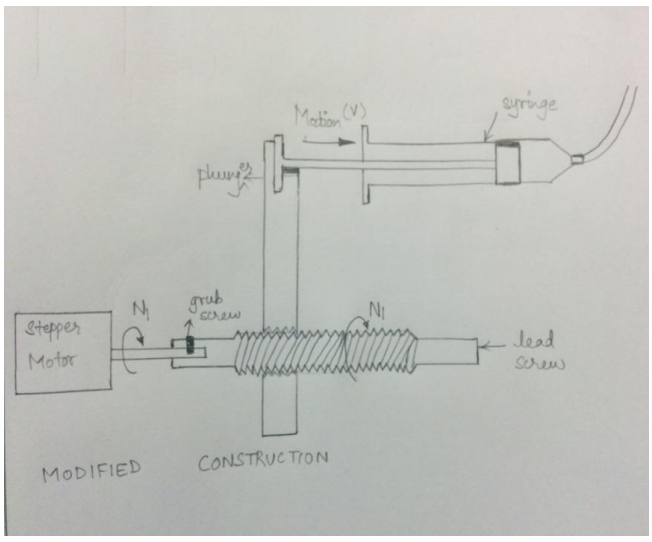

Fig. 2. Thal-pump mechanism set-up

A. Mechanical components of Thal-Pump:

1. Supporting structure: Supporting structure is manufactured by using VMC. No. of operations like milling, drilling are performed on a block of Delrin to get desired shape so we can mount mechanical components on structure.
2. Lead screw: The lead screw is manufactured on a lathe-machine by turning and threading operations. It is attached to a stepper motor through a grub screw and then inserted into the supporting structure.
3. Plunger: The plunger manufacturing is done on drilling machine and milling machine by milling, tapping , drilling and wire cutting operations. The plunger runs on the threads of the lead screw. A seat is also provided on the plunger for the rear end of the syringe.
4. Guide rod: The guiding rod is used to guide the plunger in a straight line. The oscillatory motions of the plunger are also eliminated because of the use of guiding rod.
5. Bush bearings: The manufacturing of the bearing is done on a lathe machine by turning and drilling operations. The bush bearings are provided on the supporting structure to reduce the friction between the rotating lead screw and supporting structure.

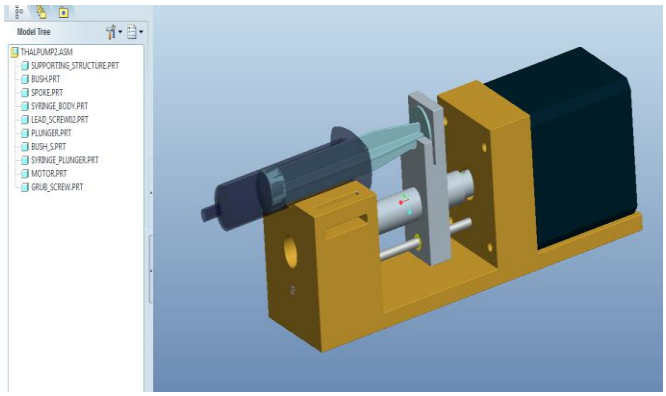

Fig. 3. Thal-pump assembly parametric model

B. Materials used for the components:

1. Delrin: It is an advanced engineering thermoplastic largely used in medical equipment's. Its chemical name is polyoxymethylene. The supporting structure of this device is made up of Delrin.
2. Mild steel: Mild steel is an alloy of iron containing carbon as the main alloying element in the range of 0.12-2%. A metal abundantly used in engineering applications is used in the lead screw and plunger of this device.
3. Silver steel: It is a common tool steel having a very polished surface. The guide rod in this device is made up of silver steel.
4. Gun metal: It is a type of bronze containing copper, tin and zinc. Gun metal is soft and easy to manufacture with low coefficient of friction, hence it is used as bush bearings for the lead screw.

C. Important features of the design:

1. Simple design with less complication.
2. Compact design.

3. Light-weight.
4. Less costly.
5. Advanced materials used.
6. Improved aesthetics.
7. Electronically controlled.

IV. MECHATRONICS INTEGRATION

To obtain a set rate some electronic devices such as motor, embedded circuit, control buttons, etc. are used. The electronics used is split into two discernable units viz. stepper motor and controller. The controller packs the embedded circuits, push buttons, a potentiometer and an LCD panel.

The stepper motor used is NEMA 17 with a rated current of 2 A. It is a bipolar motor with a step angle of 1.8 /step. Due to its bipolarity, four wires run out from the motor. This 48.3 mm long motor has a holding torque of 0.63 Nm and an actual torque of 25 Nm. The motor weighs about 0.36 kg.

The primary objective of Thal-pump is to supply 3.5 ml of iron chelating agent for the treatment of Thalassemia. For a lead screw of 10 mm diameter and 1.75 mm pitch to carry out this operation, 20 revolutions have to be made by the screw to make the plunger move to a distance equivalent to 3.5 ml of a syringe (6ml standard). 4000 pulses are given to the stepper motor in order to complete 20 revolutions of the lead screw (each pulse giving one step of 1.8). To make the rotation smooth and to reduce the vibrations micro stepping is done. Microstepping a motor means breaking the minimum step of the motor into number of steps. For example, if a motor with step angle 1.8 /step is half microstep then for each pulse given to the motor the motor would rotate by 0.9 /step. For Thal-pump 1/8 microstepping is used making it 0.225 /step changing the total number of pulses. This is possible by using driver circuits such as microstepdriver, ---, etc. In this case Microstepdriver 2M415 is used with voltage limits 15-40 V. The peak output current can be varied using a combination of switches provided on the driver circuit. 1.05 A peak current is set on the circuit. The microstepdriver has 10 pins; 4 for motor connections, 2 for power source (V+ and GND), one for Direction control and one for 5 V supply from a microcontroller. The power source is a laptop charger with 19 V and 3.95 A.

In order to control the speed of the plunger on the lead screw, the pulse rate supplied to the motor has to be defined. This is done by using a microcontroller. An open source electronic operating platform, Arduino Mega 2560 with microcontroller, ATmega 2560, is the brain of the circuit. This programmable brain has a storage capacity of 256 kB and 8 kB RAM and interprets sketches written in C++ coding language. A 9 V 500 mA supply is given to the arduino board using an adaptor. The program that is written in the programming software, Arduino IDE, is known as a sketch. A range of discharge rates can be programmed. In Thal-pump the range set is 0.5 ml/hr to 10 ml/hr covering the primary objective of supplying 3.5 ml of iron chelating agent at the rate of 1.5 ml/hr. For an adjustable discharge rate Thal-pump, a 10k kulo type potentiometer is used to vary the discharge rate. The potentiometer has three pins. The first and third pins are for voltage and ground. The middle pin is connected to the wiper which moves along the resistive material in the pot. It supplies analog signal from the pot to the arduino board.

While setting the discharge rate the operator should be able to view the set rate. For this purpose an LCD panel is used. The 16 x 2 LCD panel displays the discharge rate in ml/hr and time in seconds. A push button is used to move the plunger in forward direction at a set discharge rate. Another push button is used to move the plunger in reverse direction at the fastest speed possible. Two small push buttons are used; one to stop the motion of the plunger and the other to reset the countdown timer. An ON/OFF switch is used for emergency purpose to make or break the circuit.

V.RESULTS/DISCUSSION

The Thal-pump made provides a range of discharge rates and hence is applicable for different purposes. The major disadvantage of this setup is that it does not have a sensor to detect any blockage in the flow to stop the operation. An LVDT is to be attached to the syringe to measure the distance covered by the syringe in a given period of time . The distance measured and the time would give us the actual discharge rate. Thus by comparing the theoretical discharge rate with the actual discharge rate we get the errors of the device. These errors would give us the disturbances in the device.

VI. RESULTS

Sr. No	I/P speed Ml/hr	O/P speed Ml/hr	
		1	2
1	0.5	0.32	0.33
2	1.5	1.44	1.40
3	2.5	2.40	2.38
4	3.5	3.36	3.32
5	4.5	4.32	4.29
6	5.5	5.28	5.26
7	6.5	6.24	6.31
8	7.5	7.20	7.16
9	8.5	8.16	8.18
10	9.5	9.12	9.12
11	10	9.61	9.78

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