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Design and Fabrication of Tube Rotatory Mixer using Additive Manufacturing

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Abstract

This paper describes the design sequence, 3D printing of instrument parts and electronic control system design for a pellet mixer. The work includes design of printable files, geometric design, and embedded system design for mobile control of the instrument. The assembled portable instrument functionality can be controlled through a smart phone from any location.

Keywords: 3D printing, embedded systems, instrumentation, sensor systems

I. INTRODUCTION

In laboratories working with material science require instruments to mix solid and liquid reagents. This is normally achieved using different types of instruments. This includes centrifuges, mixers, shakers, and other type of motorized systems. Traditionally mixing solid and liquid state reagents are performed with stirrers in glassware's. Later motorized systems provided the necessary energy required to break up the solid state reagents in solutions. With the development in control electronics heating beds were included to mix materials of two different states in short period of time.

One of the most common laboratory equipment in Chemical and Biotechnology laboratories are Pellet mixers. They are currently available in different formats based on the requirement. Most of them are based on rotatory motion of an Alternating current motor (AC motor) [1 and 2].

A. Pellet Mixer

In the chemical process, mixing is the important section for the chemical preparations. The mixing of two liquid reagents is easier process. But mixing soluble solid pellets of certain materials is time consuming. In such cases especially in case denser liquids mixers are used for the processes. To achieve uniform homogenous resultant reagents, long duration mixing is achieved using motorized mixers [3 and 4].

Mixing is the process allows the heat and energy transfer between the reagents. The Mixer allows mixing liquid and solid pellets at different speeds and sequences. Commercially different types of mixers are available in the market. The prices range from 50$ to 1000$ [5]. Most of the commercial mixers available in the market comes in various shapes and sizes for different types of requirement. The basic functional block diagram of a mixer is shown in Figure 1.

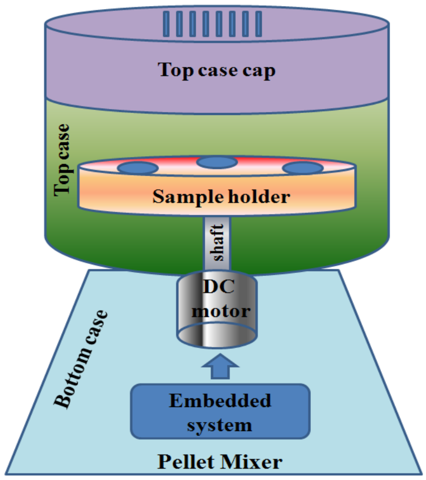

Figure 1: Block diagram of Pellet mixer.

The rotary motion for mixing two reagents is provided by a motor. The motor is housed in supporting unit. The vials are placed in sample holders. The sample holder is normally designed to hold more than two vials at a time. Such types of mixers are also called as tube rotatory mixers. The mixing of the reagents achieved through clockwise and anticlockwise rotation of the motor in equal time period. The motor controls and timing is provided in a display system. The motor is controlled using Embedded System as shown in Figure 1.

B. Additive manufacturing technology

The commercially available mixers are manufactured using traditional techniques like molding. This restricts the user to modify the functionality and structure of the instrument. In this paper the design, printing and assembly of a user friendly portable pellet mixer is described. The parts of the mixer are printed using Additive manufacturing technology. This is achieved by using 3D printers. These printers provide flexibility to design and modify 3D structures in solid state without the required of a die. This allows for cost effective design of customizable instruments and devices.

3D printing is based on depositing layers of materials in 3 dimensional Cartesian systems. Even circular and elliptical structures are printed using approximation techniques. In this work commercially available open source tools are used for the Computer-aided design (CAD) design of the 3D structures [6 and 7]. These are converted to printable "Stereolithography (STL)" files. The materials used are mostly Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA), Polypropylene (PP), Resin (3D Printing Liquid), Polycarbonate (PC), Polyethylene Terephthalate PET, Nylon etc. [8, 9 and 10]. The pellet mixer is fabricated with both PLA and ABS materials.

II. MATERIAL AND METHODS

A. 3D modeling

The machine parts have been designed in "Fusion 360 Autodesk" tool [11]. The tool has the facility to store the date in the cloud. The designed parts CAD file diagrams with dimensions are shown in Figure 2.

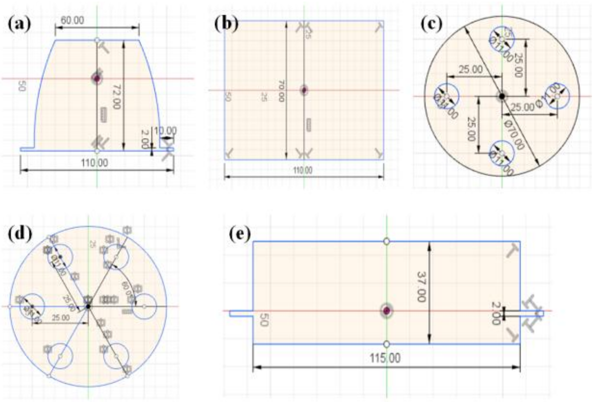

Figure 2: CAD design of pellet mixer parts **(a)** bottom case, **(b)** top case, **(c)** sample holder-1, **(d)** sample holder-2 and **(e)** top case cap.

The designed CAD file is imported in STL format. The designed parts are printed by 3D printer. The STL file provides the facilities to make the cross section of models. This allows the model to be printed layer by layer. The 3D printer worked on G-code, which is exported by STL files. The STL file diagram is shown in Figure 3.

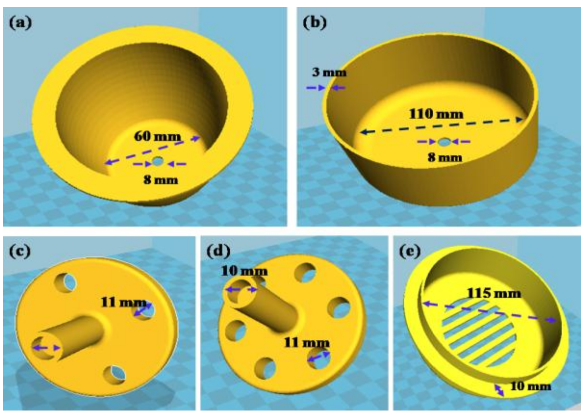

Figure 3: STL files of pellet mixer parts **(a)** bottom case, **(b)** top case, **(c)** sample holder-1**(d)** sample holder-2 **(e)** top case cap.

B. 3D printing

The Pellet mixer parts are printed by Prusa-i3 and INDIE 3D printers [12 and 13]. The bottom case of the mixer is printed by Indie with ABS Semi-transparent material. The other parts like top case, sample holder and top cap are printed by Prusai3 as shown in Figure 3. Totally two types of sample holders are printed as given in Figure 3c and Figure 3d to compare and analyze the mixing time and spill over within the case. The 3D printer is shown in figure 4.

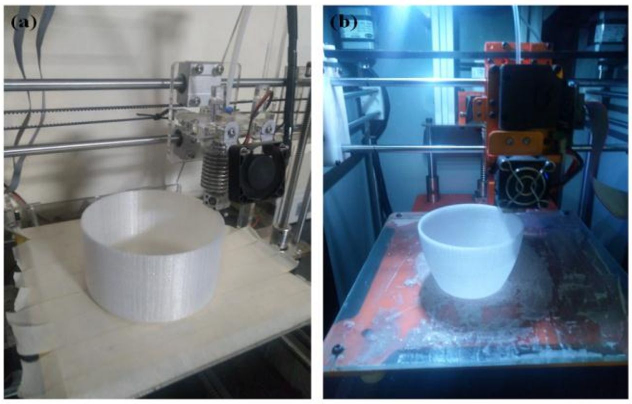

Figure 4: 3D printing **(a)** Prusa i3 and **(b)** Indie.

The printed parts are shown in Figure 5. The bottom case top side diameter is 60 mm and open bottom side diameter is 90 mm. The thickness of the case is 3 mm as shown in Figure 5. Bottom case has sufficient height of 72 mm and comfortable space for fixing a motor. The top case is printed with 110 mm diameter as shown in Figure 4(b) and 5(b).

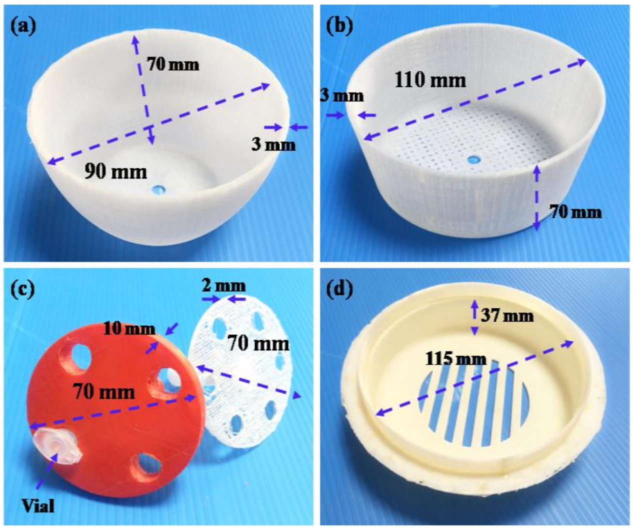

Figure 5: 3D printed files of pellet mixer parts **(a)** bottom case, **(b)** top case, **(c)** sample holders and **(d)** top case cap.

The top case is designed for different kind of sample holders. The wall thickness of bottom case and top case is maintained at 3 mm. The sample holder is designed for four and six vial capacity as shown in Figure 5(c). The thickness of sample holder-1 is 10 mm and sample holder-2 is 3 mm. And diameter of vial holder is 70 mm. The top cap is designed with 115 mm diameter with 5 mm mesh. The thickness of top case wall is same 3 mm as shown in Figure 5(d).

C. Assembly of printing parts

The assembly includes all 3D printed parts with embedded control system to form a fully functional pellet mixer. A direct current motor (DC motor) is fixed to bottom and top case with screws shown in Figure 6. Conventionally available mixers employ AC motor. This increases the weight of the system but also requires constant power supply. But by using a DC motor the requirement for AC power supply is negated. And the mixer can be operated with battery or Photo voltaic power generator. This makes the system a portable mixer.

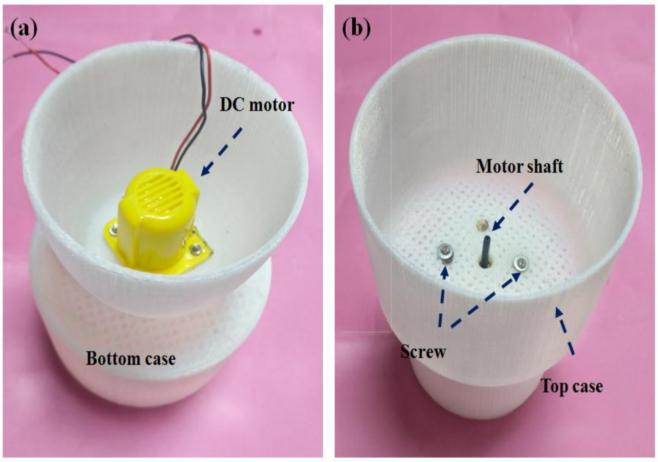

Figure 6: Assembly of motor.

The DC motor provides the rotatory energy to the sample holder in clockwise and anti clockwise direction as per the time period to be provided by the user. This is an important parameter which is normally fixed in commercially available mixers using potentiometer. This embed control along with mobile interface which is explained in Section III. The bottom case and top case is joined together with same screws including the DC motor. The sample holder is connected through the motor shaft. The top cap is for preventing any kind of spillover during the motor rotation. This prevents user from chemical hazard.

III. EMBEDDED SYSTEM DESIGN

The pellet mixer functionality is controlled using a smart phone. Figure 7 shows the block diagram of the embedded control module. The open source internet of things (IoT) platform, nodeMCU is used for prototyping [14]. It is a firmware that runs on the ESP8266 Wi-Fi system on chip (SoC) from Espressif Systems, and its hardware is based on the ESP-12 module. ESP8266 has 32-bit microprocessor that runs at 80 MHz and It has 10-bit analog to digital converter and 16 general purpose input output pins [15].

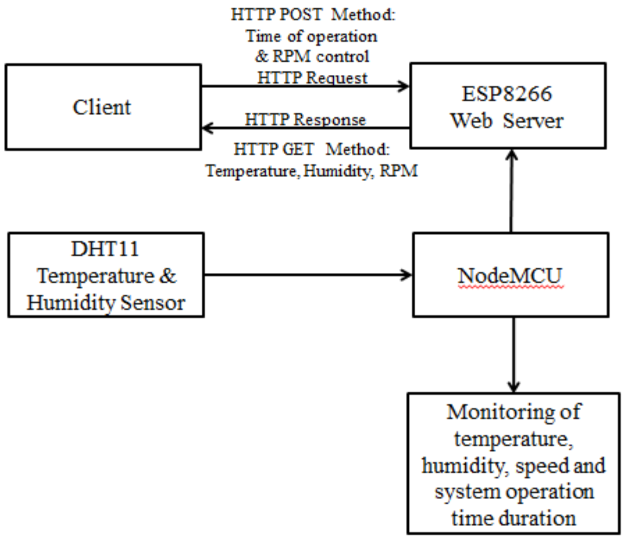

Figure 7: Block diagram of embedded system.

ESP8266 module is connected to the access point by providing required credentials. After the connection is established, the server starts at port 80. When the user enters the IP address 192.168.1.140 in browser, the page is served by ESP8266 to client using hypertext transfer protocol (HTTP). The page takes in the input i.e. the time of operation and the required revolution per minute (RPM) of motor using HTTP POST method. For selection of RPM, 12 choices are provided for user. The RPM varies from 0 to 6000 with equal step of 500. Thus, the user can select the required RPM and click on the start button to get system started.

After extracting the RPM and operation timing data, the processor on nodeMCU controls the motor speed. For the given duration of operation time, motor is rotated clockwise and anti-clockwise after every 180 degrees. To drive the motor, two motor driver ICs L293D are used in parallel [16]. It provides bidirectional high drive current up to 1 ampere. Along with motor speed control, the temperature and humidity of system is monitored using DHT11 sensor [17]. The real time system parameters are updated to user, through the web page served by ESP8266 using HTTP GET method. The page gets refreshed after every 2 seconds. The web page displays the entered duration of operation, current RPM, temperature and humidity of the system. Figure 8 shows the image of the page served by esp8266. It helps user to remotely monitor the system. The final implementation of circuit is shown in Figure 9.

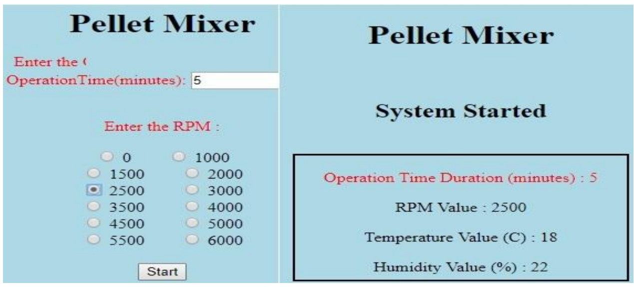

Figure 8: Web page display of mobile interface.

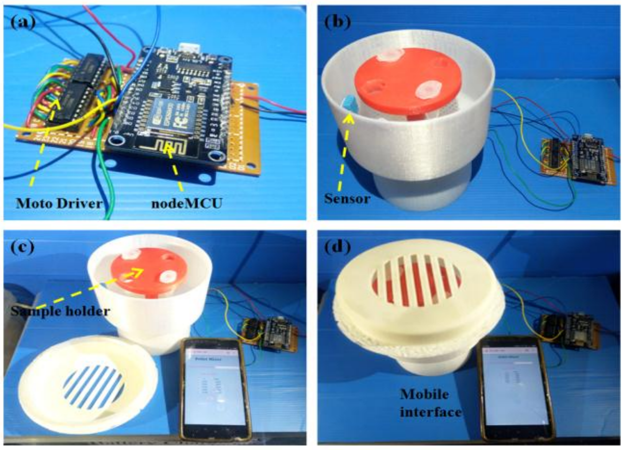

Figure 9: Mobile interfaced pellet mixer **(a)** control circuit. **(b)** sensor attachment, **(c)** sample attachment and **(d)** mobile interface system.

IV. RESULT AND DISCUSSION

The pellet mixer design includes 3D printing, development of IoT module and removes the requirement of constant power supply. This has been developed as part of the portable mini-laboratory for chemical and biological sample analysis.

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