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Design and Fabrication of Low Cost Vortex Mixer Using Additive Manufacturing

Ashish Kumar Patel[1], Asmita Jha[2], Amit Patwardhan[3], Jayant Pawar[4], Rabinder Henry[5],
Email: ashi12790@gmail.com, asmita.pcity@gmail.com, amitpatwardhan8@gmail.com, jayantpawar26@gmail.com, henrysal2008@gmail.com,

Abstract-This paper outlines the methodology and fabrication process involved in the design of a vortex mixture. The parts of the mixer are designed in CAD/CAM tool and additively printed with 3D printer. A microcontroller based control system is designed for controlling the rotator speed.

Keywords- additive manufacturing1, analytical instrumentation2, chemical laboratory3, vortex mixer4.

1. INTRODUCTION

In chemical laboratories for mixing reagents different types of instruments are used. Traditionally, simple mixing technique using stirrers were common. With advent of electronics and motors, vortex mixers evolved as one of the most preferred instrument for mixing and stirring reagents.

Traditional methods are time consuming to mix manually. This is a tedious process especially with regard to small quantities of reagents. The mixing of solid state pellets or amorphous materials in liquid state solvents resulted in inhomogeneous solutions [1].

To overcome this limitations mechanical mixers using hand driven gear systems evolved during early 1900s. With miniaturization of electrically driven motors and evolution of power & control electronics mixers like magnetic stirrers and centrifuges evolved in early 1950s. With the development of small dimensional Alternating Current (AC) motors in the early 1960s and 1970s, new types of shakers, mixers, stirrers and temperature controlled equipment and instruments evolved specifically for usage in chemical and biological laboratories. This rapid growth led to the evolution of new kind of industry called scientific instrumentation manufacturers. Many companies and industries like Fishcer, Cambridge Instruments, were setup from university laboratories and this marked the move from academic to industries [2, 3].

In this paper the main focus is on design and development of vortex mixer using 3D printed structural parts and embedded system for control. The commercially available Vortex mixtures on average cost about 100$ to 150 $. To design and fabricate with customizable functionality a low cost vortex mixer is reported in this paper.

1.1. *Vortex Mixer*

Vortex mixer is an instrument used for reagent mixing in the laboratories especially where there is requirement for chemical or material analysis. The basic operation principle of a vortex mixer is the centrifugal force. This allows for mixing of different reagents at different speeds [4, 5]. This kind of mixer which uses rotator force reduces the time required for mixing and gives the results instantly. The block diagram of a vortex mixer is shown in Fig. 1. The system includes embedded control unit. This provides the facility for programming to control functionality of the mixer. The rotator force is normally provided by a DC motor. The motor is interfaced with microcontroller of the embedded system. The mixer includes a sample holder for mixing the reagents using the centrifugal energy provided through the DC motor. Rest of the structure provides mechanical support to increase the stability during the rotator motion.

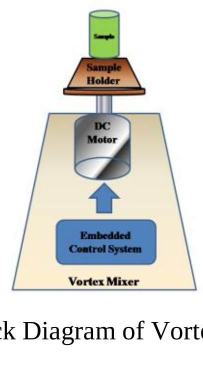

Fig 1: Block Diagram of Vortex Mixer.

1.2. *Additive manufacturing technology*

Additive manufacturing technology is known as 3D printing technology. This is used to develop a 3D model of the vortex structure. Additive manufacturing technology prints the model in layer by layer fashion known as Fused Deposition modeling (FDM) technique [6]. This technology replaces the traditional method of manufacturing technique like molding, bending, welding, and cutting etc. 3D printed models are designed in CAD/CAM tools like "Fusion 360". This is an open source cloud based tool. 3D printing allows for printing complex 3D geometrical structure thereby negating the requirement of moulds (dies's) required in the traditional process of making solid state structures. [7, 8].

2. MATERIAL AND METHODS

2.1. *Design and Printing parts*

Vortex mixer's parts are designed in Autodesk Fusion 360 software. A 3D model is designed based on solid modeling technique. Designed models are converted to Stereo Lithographic File (STL) format. The STL files provide co-ordinates for each layer to be printed. Sliced models are converted to "G-code file" format which is readable by the 3D printer [6]. The designed 3D model of the parts is shown in Fig. 2 in STL file format.

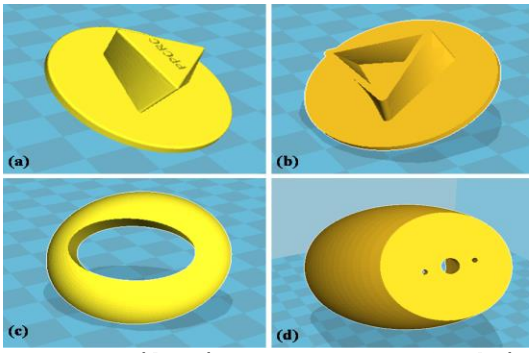

Fig 2: STL files of Vortex Mixer parts **(a)** Shaft connector **(b)** Sample holder connector **(c)**

2.2. *Fabrication of Vortex mixer parts*

Vortex mixer's parts have been printed by 3D printer supplied by Indie [9]. The printed parts are sample holder, shaft connector and body case of the system. These are shown in Fig. 3.

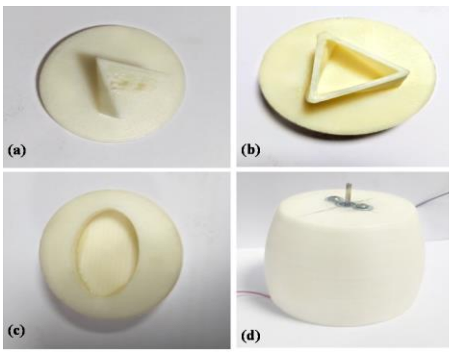

Fig 3: 3D Printed Parts of Vortex Mixer **(a)** Shaft connector **(b)** Sample holder connector **(c)** Sample holder **(d)** Body case.

The material used for printing the parts as shown Fig. 3 is Acrylonitrile Butadiene Styrene (ABS). ABS has ability to give the flexibility, durability and heat resistance to the printing object [7. 8]. This material suitable for mechanicals parts like Gear, part is exposed to UV and car cup holder etc. The temperature during the printing was maintained at 250 ºC The bed temperature of the 3D printer is maintained at 80 ºC. A uniform thickness of 1.6 mm is maintained for all the parts for easy integration. The casing dimensions are shown in Fig. 4.

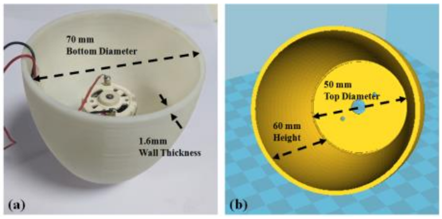

Fig 4: 3D printed and STL file of case.

The bottom side of the body case has a diameter of 70 mm. This allows the structure to be stable when the mixer's motor is on. The top side of the body case has a diameter of 50 mm. the height of the case is 60 mm. The motor is screwed to the top side within the hollow structure of the case as shown in Fig. 4.

2.3. *Assembly of Vortex Mixer*

The Vortex mixer is assembled using the 3D printed parts as shown in Fig. 3. The prototype includes a DC motor. The shaft of the motor is mm. This shaft is glued using PVC (Poly Vinyl Chloride) glue [10] to the casing as shown in Fig. 4. This casing houses the DC motor and also provides mechanical stability as described in the introduction. The motor is fixed inside the hollow area of the casing using screws as shown in Fig. 4. The end of the motor shaft is connected to the sample holder. The shaft length of the DC motor is 7 mm. The sample holder is attached to the casing. It has 3 parts. The dimensions of the different parts of the sample holder are shown in Fig. 5.

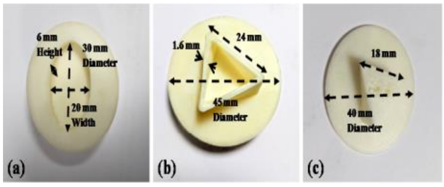

Fig 5: 3D printed sample holder.

The shaft connector has a diameter of 40 mm. The sample holder diameter is 45 mm. Both are locked using simple lock-key mechanism using triangular structure as shown in Fig. 5. The sample holder lock as shown in Fig. 5b has triangle with side length of 24 mm. The sample holder as shown in Fig. 5c has triangle key with side length of 18 mm. The actual sample holder is attached to the top side of the sample holder connector as shown in Fig. 5a. The thickness of this structure is 6 mm and it has cavity in the shape of ellipse. The major axis of the ellipse is 30 mm and the minor axis is 20 mm. The depth of the hollow ellipsoid for holding Vial is 6 mm. The assembled vortex mixer is interfaced with an embedded system as shown in Fig. 9.

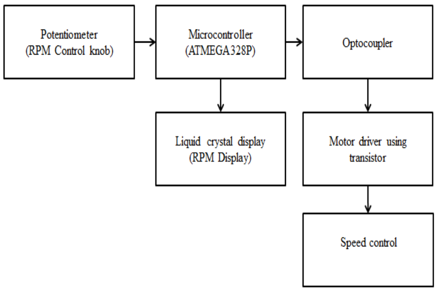

Fig 6: Embedded system block diagram.

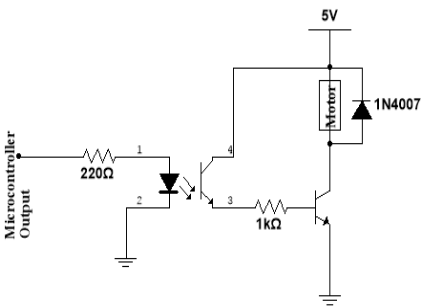

Fig 7: Motor driver circuit interface with microcontroller using Optoisolator.

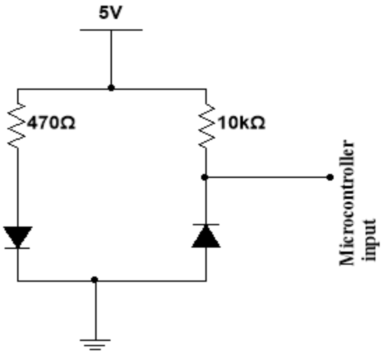

Fig 8: Tachometer circuit design.

2.4. *Interface of Embedded system control*

Embedded system control has been designed for vortex mixer to control the speed of motor to mix reagents. The block diagram of the electronic control system is shown in Fig. 6. It has a microcontroller Atmega328P (Arduino nano) [11]. Microcontroller receives input from potentiometer (knob). Depending on the position of knob, controller sends the corresponding pulse width modulated (PWM) signal to motor driver. The motor driver is built using KSP2222A NPN transistors [12]. As per datasheet the maximum output current of this transistor is 600 mA. The current required to drive the motor is 330 mA, hence this transistor was selected. In order to protect the controller pin, it is isolated from the driver circuit using optoisolator [13]. The circuit diagram of driver interfacing circuit through optoisolator is shown in Fig. 7. Hence, the controller controls the speed of the motor. A tachometer circuit as shown in Fig. is designed to measure the motor revolution per minute (RPM). Tachometer circuit as shown in Fig. 8 is designed using LED (Light Emitting Diode) and photoreceiver placed in the line of sight at a distance of 2 cm. The controller receives the signal from receiver and computes the time (in milliseconds) required to calculate one cycle of signal. This computes the time required to complete one revolution of motor. Final computation is done to find the total number of revolutions covered in one minute. Thus, the RPM of motor is calculated and displayed. In vortex mixture circuit, the pulse width of PWM signal required to control the speed of dc motor is set as per the required speed. To make the system user friendly, potentiometer is connected as knob so that user can control the motor speed by just rotating the knob. The system is calibrated for 8 different RPM of motor from 0 to 7000 RPM with equal step of 1000 RPM. The system is controlled on these RPM depending on the corresponding position of knob. RPM is displayed in a LCD panel as shown in Fig. 9.

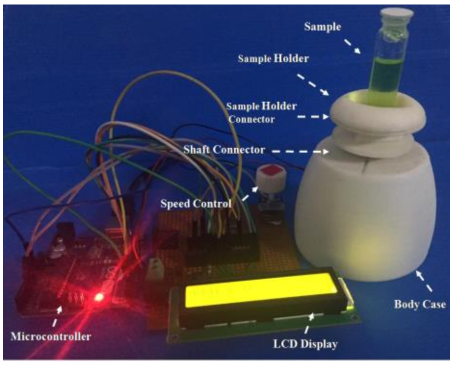

Fig 9: 3D printed Vortex mixer.

3. RESULT AND DISCUSSION

Initial experimentations showed that the Vortex mixer rotating speed, control mechanism and the display system are working properly. But the vibration generated by the motor spin is to be compensated with heavier base. Holding the vial manually on the printed holder is not smooth and the vibrations are not being transmitted to the reagents. This has been overcome by coating the cap with rubber paint a shown in Fig. 10.

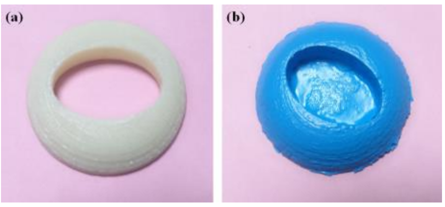

Fig 10: a) Without rubber coating b) with rubber coating.

4. CONCLUSION

The experimentation with development of the porotype is a continuous process and currently in the middle stage of product development and testing.

5. ACKNOWLEDGMENT

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