DESIGN AND DEVELOPMENT OF ADVANCED ROTARY PERISTALTIC PUMP

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ABSTRACT

This paper presents an advance in design and development of rotary peristaltic Pump. The basic working principle and construction of peristaltic pump is provided. In this design considered four rollers 90 degrees a part of roller ram with 9.5 mm internal diameter tube for illustrating fluid flow characteristics are considered. Experiments have been conducted on Newtonian fluid and theoretical calculations are carried out for the flow rate of pump are presented. This prototype consists of Peristaltic pump, coupling with speed reduction gears, rotating disc, and 1/4 HP 1440 rpm motor. Design calculations, selection of materials and fabrication are carried out by author. Author will carry out sundry tests on the pump to know its flow characteristics by using diverse Viscosity fluids, keeping number of rollers, tube diameter and other parts of pump is unchanged.

Key words: Peristaltic Pump, Rollers, Tubes, flow characteristics, pump design and development.


http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=8&IType=6

1. INTRODUCTION

A Peristaltic Pump is a type of a Positive Displacement used for pumping variety of fluids, may run continuously or when needed to pump the required volume of fluids. The operating principles of (PD) pumps differ from other pumps. The principle of positive displacement uses a mechanism to frequently expand a cavity so as to allow fluids to flow into the cavity, and then seal that cavity. The fluid then moves forward. The only pumping element of
peristaltic pump is a flexible tube. The pump works by squeezing the tube with rollers or shoes. This means that pump can run dry, self-prime and handle viscous or abrasive liquids, plus, as the tube is one complete unit, there are no seals. This makes the pump leak free and clean. Peristaltic pump has sundry domestic usages such as in medical sector, food processes, chemical industries and handling of critical fluid. Thus, a study is needed to systematically be conducted in order design and analysed the principle operation of such device.

2. LITERATURE REVIEW

Mohd Firdaus Bin Mansor [1] focused on the basic principle of peristaltic pump and its purpose which is helpful to develop new peristaltic pump. Marion H. Bobo, Michael M Brown [2] addresses about the implementation of casing to receive a flexible tube. The casing has curved wall and clamped. The roller assembly contains at least to a compression roller assembly and at least one guide roller. The guide rollers are peripherally spaced between compression rollers whose race of them comes into contact with the flexible tube during rotation of the roller assembly. The use of gear system for rotating the roller from the above can understand the operation of roller and tube. Robert B. Clay and William A. Dorering [3] designed the pump by squeezing the roller pressing and elastic tube supported by side a semi cylindrical chamber. The collapsed tube responded by travelling side roller which press the tube transversely. David B. Parker [4] illustrated the importance of the positive displacement (PD) pump over the centrifugal pump. Here they have presented how the system response of the PD pumps. PD pumps are capable of moving a wide range of fluids. Entrained gasses, solids, low viscosity to high viscosity and low net positive inlet pressure available can all be designed for. The flow is nearly constant, without pulsation and does not impart high shear to the fluid. The high mechanical efficiency offers energy savings. PD pumps come in many designs and operating ranges, but they all work on the same principle. An increasing volume is opened to suction, filled, closed, moved to discharge, and displaced. The delivered capacity is nearly constant throughout the discharge pressure range. This constant capacity will intersect a system curve at a defined point, allowing a high degree of system control. Curtis Phillips, [5] explained that, Peristalsis is the progressive constriction and relaxation of a tube, or canal, so that the resulting wavelike motion moves the contents of the tube forward much in the way toothpaste is squeezed out of a tube. A peristaltic pump achieves this by using rotor inside a semi-circular loop of flexible tubing to squeeze the tube. As the rotor turns, the “pinch” moves around the loop and displaces the fluid through the pump. Since the fluid is displaced by the contraction of the tube, it doesn’t experience shear or cavitations. Latham, T.W [6] has created the idea of fluid transport by means of peristaltic wave in mechanical and physiological studies. Jaffrin and Shapiro [7] presented the detailed study on basic mechanism of peristaltic pump in the work. There are several devices have been proposed in the past for pumping viscous and slurries. As these slurries are very corrosive and abrasive for pumping and machinery operations, many problems come across the nature of the suspended solids it contains. The slurry normally contains a crystalized liquid media in which solid particles are suspended. These viscous materials have corrosive and abrasive action on the pump parts, hence it is necessary to separate pump moving parts from the slurry to avoid obstacle, corrosion and wear of the parts. Some typical and continuous problems of the pump is observed in the past literature on the pump as follows. Pump losses as a result of Leaks from oil seal, Inconsistencies in the checking and diagnosis of the operating status of an industrial pump Provision times and maintenance intervals [8]. In general for all peristaltic pump tubing is fixed between the tube-bed and the rotor at each roller location the tubing is squeezed at different positions. The tubing is continuously squeezed by the rollers which push the liquid in the direction of the revolving rotor. The rollers on the revolving rotor move across the tubing. The tubing behind the rollers recovers its shape, creates a vacuum and draws liquid in
behind it. The pillow is the pump chamber and determines the volume per roller step and, hence, the flow rate. The pillow volume not only depends on the inner diameter of the tubing, but also on the tubing properties, the drive and pump-head specifications as well as the liquid and the physical application conditions [9]. It explained that the various types of tube used in peristaltic pumps are Polyvinyl chloride (PVC), Silicone rubber and Fluoropolymer [10]. It described that the various kinds of tube materials, with standing temperature range, chemical compatibility, chemical resistance, medical bio-compatibility, wear resistance when long tube life is required [11]. It addresses about a few applications of peristaltic pump such as Perfusion flow across tissue or cells, Pump in and out with balanced flow, Transfer bulk liquids i.e. controlled animal feeding, Aggressive chemicals and slurries, Pumping fluids without contamination, e.g. water for drinking purpose, Volume pumping such as pharmaceutical, food, chemical, and waste water [12]. P. Srinivasa Rao and G. Bhanodaya Reddy, [13]. Explained about PMCs preparation and test for mechanical properties also fabricated peristaltic pump rollers, which is apart of this work.

3. DESIGN AND FABRICATION OF PERISTALTIC PUMP

An advanced rotary peristaltic pump is designed with Solid works (Figure 1.(a),(b)) and Fabricated (Figure 2). It consists of pump case, rotating disc, rollers, Silicon tube, Speed reduction gears, and motor. The maximum speed of the motor is 1440 rpm, and reduced to 9 rpm with speed reduction gears. The rotary peristaltic pump is different from the linear peristaltic pump. In rotary peristaltic pump motor is used to rotate the shaft whereas in case of linear peristaltic pump cam is used to control the motion of shaft. The rotor shaft is attached to the speed reduction gears then that connected to the motor. The Pump case has rotor that lay down at shaft that support by its bearing. Normally two shoes will put at rotary peristaltic pump have two flange. This flange will be connecting input fluid and output. Tube is a part of the peristaltic pump, which is squeezed and released by the rollers to create vacuum for drawing the fluid enter into the tube.

![2D Diagram of An advanced rotary Peristaltic Pump](http://www.iaeme.com/IJMET/index.asp)

(a) With Dimension  
(b) Without Dimension

**Figure 1** 2D Diagram of An advanced rotary Peristaltic Pump
3.1. Basic operation and working Principle
The basic operation for an advanced rotary peristaltic pump as shown in figure (2). Working Principle and operation is very easy. It has variable speed reduction gears, AC motor and adjustable roller arm with same roller diameter leads to operate different diameter of the tubes up to 24 mm of ID. When rotor is rotate, fluid is enter the tube because of attraction force from vacuum produce after tube is fully pressed by rotor along the tube and flow to the output. This operation stay repeatedly until the power of motor is off.

![Image](http://www.iaeme.com/IJMET/index.asp)

**Figure 2** Schematic arrangement of experimental setup of rotary peristaltic pump.

3.2. Design and performance specifications of peristaltic pump
Some important peristaltic pump specifications either related to design or performance. A number of design parameters should be considered when selecting peristaltic pumps.

**Tubing size:** The diameter and wall thickness of the casing used to house the media, typically given in inches (in) or millimetres (mm). It affects the discharge and the size of tubing needed for replacement. Pumps may be designed to allow multiple sizes of tubing.

**Number of rollers:** The number of rollers or shoes used in the drive mechanism. More rollers reduce pulsation and provide a smoother flow.

**Number of channels:** The number of separate tubes in the pump which operate simultaneously.

The following are performance specifications to be considered while selecting peristaltic pumps are flowrate, pressure, horsepower, power rating, outlet diameter, and operating temperature.

**Flow rate:** Defines the rate of volume of discharge through the pump, usually given in gallons per minute (gpm) for industrial applications and gallons per hour (gph) or millilitres per minute (ml/min) for low-flow applications.

**Pressure:** It is resistance of the force per unit area handled by the pump. It is usually given in pounds per square inch (psi) or bar.

**Horsepower:** Denotes that the output power of the pump, measured in units of horsepower (hp). This determines the type of motor or power source needed to operate the pump.

**Power rating:** It indicates the power required to operate the pump, measured in Watts (W) or horsepower (hp).

**Outlet diameter:** It is the size of the discharge or outlet connection of the pump. It determines the size of connections made between the pump and the system.
Operating temperature: Defines the range of temperatures at which the pump can operate or the temperature limit of the tubing within the pump.

4. THEORETICAL APPROACH ON FLUID FLOW CHARACTERISTICS

In this section, a mathematical model for a study uniform flow in and out of a control volume through the flexible tube of the peristaltic pump is to be derived as follows, let’s consider a frictionless one dimensional flow through a flexible tube. It is assumed that the average velocity of fluid is to be equal to the speed of the roller, without leakage between two adjacent rollers. The volume flow rate is more commonly known as discharge. (It is also commonly, but inaccurately, simply called flow rate). The symbol normally used for discharge is Q. The discharge is the volume of fluid flowing per unit time. Multiplying this by the density of the fluid gives us the mass flow rate. The volume flow rate is given by

\[ Q = A v \]  

Where Q is flow rate of the fluid, A is cross sectional area normal to the flow direction, v is average fluid velocity normal to . The cross sectional area and the diameter of the flexible tube are related by

\[ A = \frac{\pi d^2}{4} \]  

where d is the diameter of the flexible tube. The relation between the average velocity and the speed of the rotation are related by

\[ Q = 0.5 * \pi * d^2 * N * r \]

Where N is the speed of the rotation (rpm) and r is the radius of the rotation which is measured from the rotor axis to the centre of the roller. The volume flow rate of the peristaltic pump can be expressed in terms of the parametric factors of the peristaltic pump.

From Eq.(3), It can be stated that for a given size of flexible tube in the peristaltic pump, the volume flow rate is dependent upon not only the speed of the rotation, but also the radius of the rotation.

Experiments have been conducted on Newtonian fluid (Ex.water) and theoretical calculations also carried out for discharge and tabulated. The diameter of the tube 0.0095 meters, distance between the centre of the rotor

![Graph](speed_vs_discharge.png)

**Figure 3** Theoretical and Experimental Discharge of pump
Table 1 Theoretical and Experimental results

<table>
<thead>
<tr>
<th>S.No</th>
<th>Speed of rotor (rpm)</th>
<th>Theoretical Discharge (ml/min)</th>
<th>Experimental Discharge (ml/min)</th>
<th>Percentage of error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>641.084</td>
<td>560</td>
<td>12.648</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>854.779</td>
<td>745</td>
<td>12.843</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>1068.474</td>
<td>1005</td>
<td>5.940</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>1282.169</td>
<td>1210</td>
<td>5.628</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>1780.791</td>
<td>1710</td>
<td>3.975</td>
</tr>
<tr>
<td>6</td>
<td>27</td>
<td>1923.254</td>
<td>1880</td>
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</tr>
<tr>
<td>7</td>
<td>30</td>
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<td>2030</td>
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<td>8</td>
<td>38</td>
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<tr>
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<td>10</td>
<td>50</td>
<td>3561.583</td>
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<td>7.063</td>
</tr>
</tbody>
</table>

The figure 3. shows that with increasing speed discharge increases. Series 1 plotted line shows the experimental results of the speed and discharge. Series 2 plotted line shows the theoretical calculation of speed and discharge. The percentage of error(%) is calculated between experimental and theoretical discharge by using the following relation. Percentage of error(%) = \( \frac{Q_{\text{Exp}} - Q_{\text{theo}}}{Q_{\text{theo}}} \times 100 \)

The maximum percentage of error for experimental and theoretical discharge is 12.843 plotted on figure 4

![Figure 4 Theoretical and Experimental Discharge vs percentage of error](http://www.iaeme.com/IJMET/index.asp)
5. CLASSIFICATION OF PERISTALTIC PUMPS BASED ON PRESSURE

Peristaltic Pumps are classified into two types based on the kind of pressure they use. They are:

5.1. High Pressure Peristaltic Pumps or Hose Pumps

These pumps are generally used in high pressure environment (up to 16 bar) and use shoes (rollers only used on low pressure types). They have casings which are filled with lubricants to help avoid damage caused by abrasion to the peripheral of the pump and to help dissipate the heat and hose pump are typically reinforced resulting in a very thick wall. For a given ID the hoses have much bigger OD than tubing for the roller pump. So that the liquids do not leak out of the tube due to the high pressures used while pumping. These reinforced tubes, often called "hoses". This class of pump is often called a "hose pump". This thicker wall, combined with a stiffer material typically used in the hoses make the forces necessary to occlude the hose much greater than for the tubing. This results in a bigger and slower pump (up to 50/60 RPM) and motor for a given flow rate with the hose pump than the roller pump, consuming more energy to run. The biggest advantage with the hose pumps over the roller pumps is the high operating pressure of up to 16 bars. With rollers max pressure can arrive up to 12 Bar without any problem. If the high operating pressure is not required, a tubing pump is a better option than a hose pump if the pumped media is not abrasive. With recent advances made in the tubing technology for pressure, life and chemical compatibility, as well as the higher flow rate ranges, the advantages that hose pumps had over roller pumps continues to erode.

5.2. Low Pressure Peristaltic Pumps or Tube Pumps

These pumps usually have dry casings and use rollers. Nonreinforced tubes are also used in these pumps because the pressure on the tubes is not very high. This class of pump is sometimes called a "tube pump" or "tubing pump". These pumps employ rollers to squeeze the tube. Except for the 360 degree eccentric pump design as described below, these pumps have a minimum of 2 rollers 180 degrees apart, and may have 8 or even 12 rollers. Increasing the number of rollers increase the frequency of the pumped fluid at the outlet, thereby decreasing the amplitude of pulsing. The downside to increasing number of rollers it proportionately increases number of squeezes, or occlusions, on the tubing for a given cumulative flow through that tube, thereby reducing the tubing life.

![Figure 5 Silicon tubes](http://www.iaeme.com/IJMET/index.asp)
6. TUBE MATERIALS USED FOR PERISTALTIC PUMP

A few tube materials include:

**Silicone:** A translucent medical/food grade tubing which is odourless, non-toxic, and has FDA and USP Class VI approvals. It is auto cleavable and has a temperature range up to 220°C. Used in most general applications.

**Autoprene:** This is an opaque thermo-plastic rubber with unmatched wear resistance when long tube life is required. This material has FDA food grade approval, and has been further enhanced to meet the requirements and approval standards of USP Class VI criteria for medical bio-compatibility.

**Viton:** A black, shiny, synthetic rubber with resistance to concentrated acids, solvents, ozone, radiation and temperatures up to 200°C. Viton is expensive, and while it has excellent chemical compatibility, Viton is not renowned for durability and will have a limited service life.

**Tygon:** This tube has excellent chemical resistance, handles virtually any inorganic chemical, and is one of the families of non-toxic tubes. Tygon has a clear finish and is available in a limited size range.

**Prothane II:** A transparent blue polyester polyurethane tubing which is resistant to ozone, diesel fuel, kerosene, motor oil, mild solvents, aromatic hydrocarbons, petrol and concentrated acid and alkaline solutions.

**Vinyl:** The least expensive of any pump tubing type, but is not widely chemically compatible and has a below average service life. It cannot be autoclaved and cannot handle temperatures above 80°C.

**Fluor polymer:** The most chemically inert tubing material, but with an extremely short service life. It is auto clavable.

7. CONCLUSIONS

This paper presents an advances in design and development of rotary peristaltic pump. Author has designed and fabricated also performed the experiments on peristaltic pump. By using Newtonian fluid discharge is obtained in the collecting tank by controlling the speed of certain period of time with the stop watch. Theoretical calculations have been carried out to calculate the discharge, plotted graph between speed and discharge for both theoretical and experimental values. By this concluded that with increasing speed discharge increases. keeping the diameter of the tube is unchanged. Experimentally obtained discharge is less than theoretical discharge. And it is observed that the maximum percentage of error between theoretical and experimental discharge is very less by this concluded that discharge point of view the fabricated advanced peristaltic pump is good. As a part of future study, Author will carry out several tests on the pump to know its flow characteristics by using different Viscosity fluids, different tube diameters keeping diameter roller and other parts of pump is unchanged.

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