Synthesis Of Variable Displacement Linkages and Application to Radial Piston Pump

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Abstract **- This paper attempts to acquire the synthesis of variable displacement linkages by overlay method using Auto-CAD software. This linkages are fabricated with design dimensions and applied to the radial piston pump. There are several types of positive displacement hydraulic pumps and motors including gear, screw, lobe and piston machines. Of these machines, there are three main architectures commonly used in variable displacement applications are axial piston, bent axis, and vane. But these pumps are very costly. This paper presents synthesis of variable displacement linkages, fabrication of linkages and application to radial piston pump to increase volumetric efficiency with minimizing the overall cost of pump. The prototype is prepared and experimental results are presented to validate the model. It will be shown that this linkage-based, variable, positive displacement pump shows promise as a highly efficient alternative to other variable displacement pumps.**

Index Terms **- Radial piston pump, Variable displacement linkages, Overlay method, Volumetric efficiency.**

I. INTRODUCTION

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps. Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes, from microscopic for use in medical applications to large industrial pumps. Mechanical pumps serve in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering and aeration, in the car industry for water-cooling and fuel injection, in the energy industry for pumping oil and natural gas or for operating cooling towers. In the medical industry, pumps are used for biochemical processes in developing and manufacturing medicine, and as artificial replacements. A positive displacement pump makes a fluid move by trapping a fixed amount and forcing (displacing) that trapped volume into the discharge pipe. Some positive displacement pumps use an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pump as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses.

There are three main architectures currently available for variable displacement pumps. An axial piston pump uses a variable angle swash plate to convert rotary motion into piston reciprocation resulting in fluid displacement. A bent axis piston pump uses a cylinder block, which is off-axis from the drive shaft. The bases of the pistons are mounted to a disk that is in line with the drive shaft while the piston heads are in line with the cylinder. All components rotate causing the pistons to reciprocate due to the bent axis. The angle between the input shaft and the cylinder determines the displacement. A vane pump has fluid chambers that are separated by vanes that are housed in a slotted rotor. The vanes contact a circular ring and the eccentricity between the ring and the rotor determines the fluid displacement. All of these architectures utilize planar joints that suffer from a trade-off between high mechanical friction and high leakage to maintain hydrodynamic bearings. Much work has been done on improving the efficiency of these variable machines [1]. An alternative approach to existing variable pump/motor architectures is to create an adjustable crank-slider linkage, which can vary its stroke and thus the displacement. Tao and Krishnamoorthy developed graphical synthesis technique for generating adjustable mechanisms with variable coupler curves [7].

II. OBJECTIVE

- ✓ Design and kinematic synthesis of a variable displacement linkage to give zero to maximum displacement , and point to point control of the displacement using manual linkage.
- ✓ To make variable discharge with increasing efficiency.
- ✓ To reduce the overall cost of pump.

III. PROBLEM DEFINITION

Axial piston pumps with constant pressure and variable flow have extraordinary possibilities for controlling the flow by change of pressure. But cost of the bent axis piston pump is extremely high over the radial piston pump. Hence, there is a need to develop a modification in the radial piston pump design that will offer a variable discharge configuration.

IV. METHODOLOGY

Variable displacement linkages are implemented for radial piston pump to get variable flow. These linkages consist fixed link (link 1), crank(link 2) , connecting rod(link 3), connecting link(link 4), output yoke(link 5), control link (link 6) .Therefore, this mechanism becomes six bar linkage mechanism. Variable displacement linkages are synthesized by overlay method by using Auto-cad software. While developing this mechanism some assumptions has been made to satisfy some conditions. The displacement of control lever is taken from 0 degree to 120 degree to get variable displacement of output link which results into variable flow. Then this linkages are applied to the radial piston pump and the different readings are taken at speed 100 rpm, 200 rpm, 300 rpm, 400 rpm, 500rpm, when control angle is 0 degree and 120 degree respectively. Then the actual flow rate is measured and theoretical flow rate is calculated by formula. By this two , the volumetric efficiency is calculated to validate the prototype.

Assumptions

a) Assume crank radius and three positions of cranks.

b) Assume fixed distances to minimize the size of mechanism

c) Assume connecting rod length, connecting link length ,control link length , output link length and we can obtained output displacement angle for 0 degree and 120 degree control angle.

Overlay Method

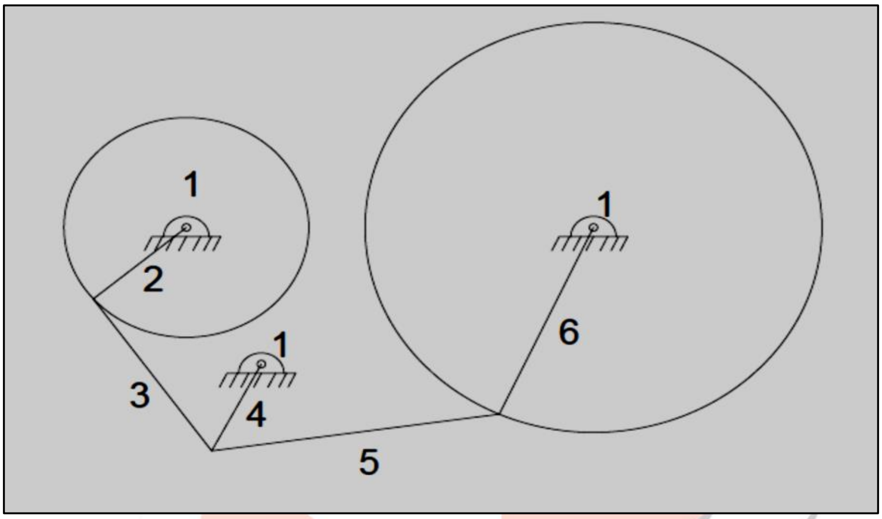

Figure 1 Schematic of mechanism

1.Fixed link 2. Crank 3. Connecting rod 4. Control link 5. Connecting link 6. Output link

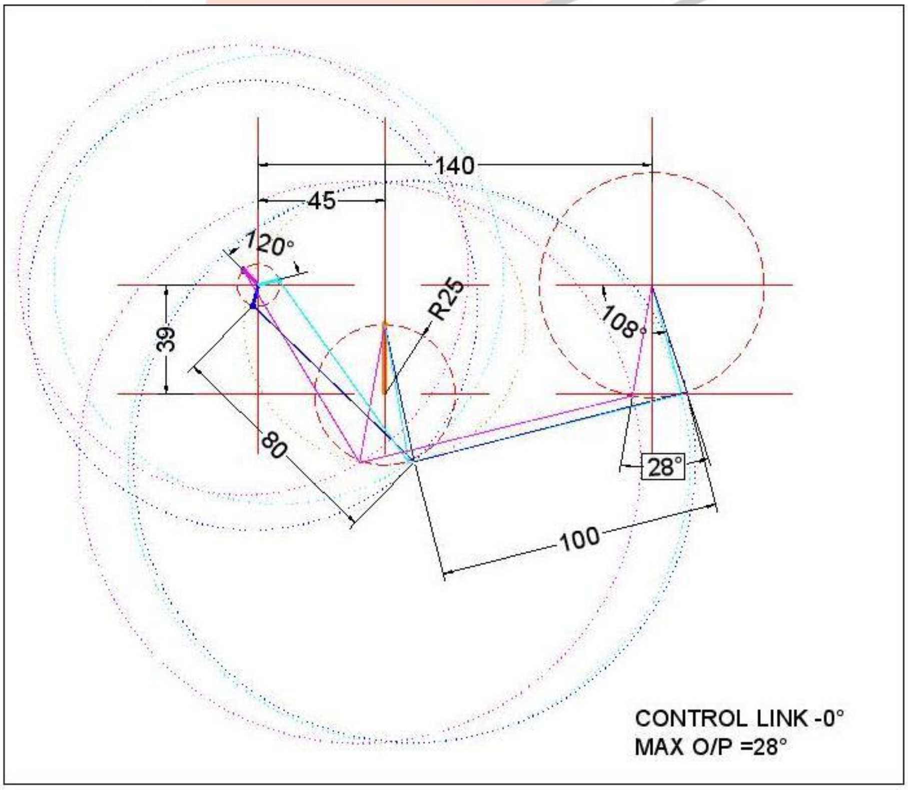

Figure 2 Synthesis of mechanism by overlay method when control link at 0 degree

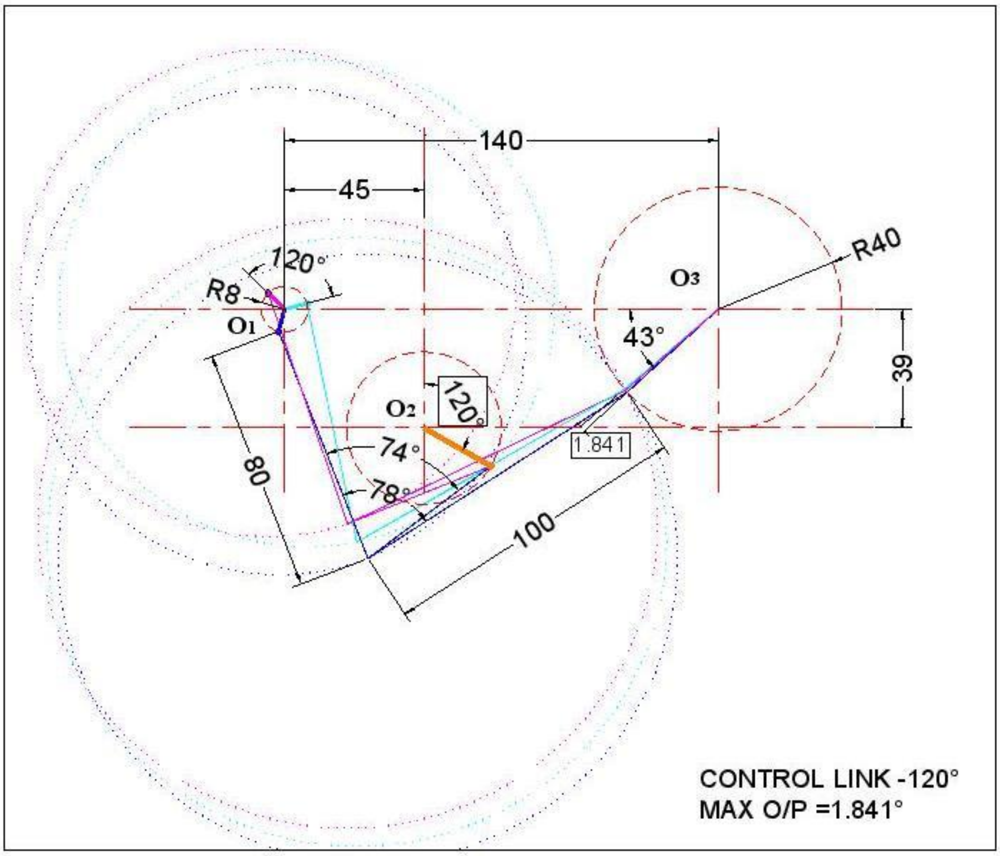

Figure 3 *Synthesis* of mechanism by overlay method when control link at 120 degree

Linkages values obtained by overlay method for prototype modeling

1-Fixed link-distance between i/p pivot & o/p pivot = 140 mm
2-crank- radius = 8 mm
3-connecting rod = 80 mm
4-control link = 50 mm
5-connecting link = 100 mm
6- Output yoke/link = 40 mm

Prototype

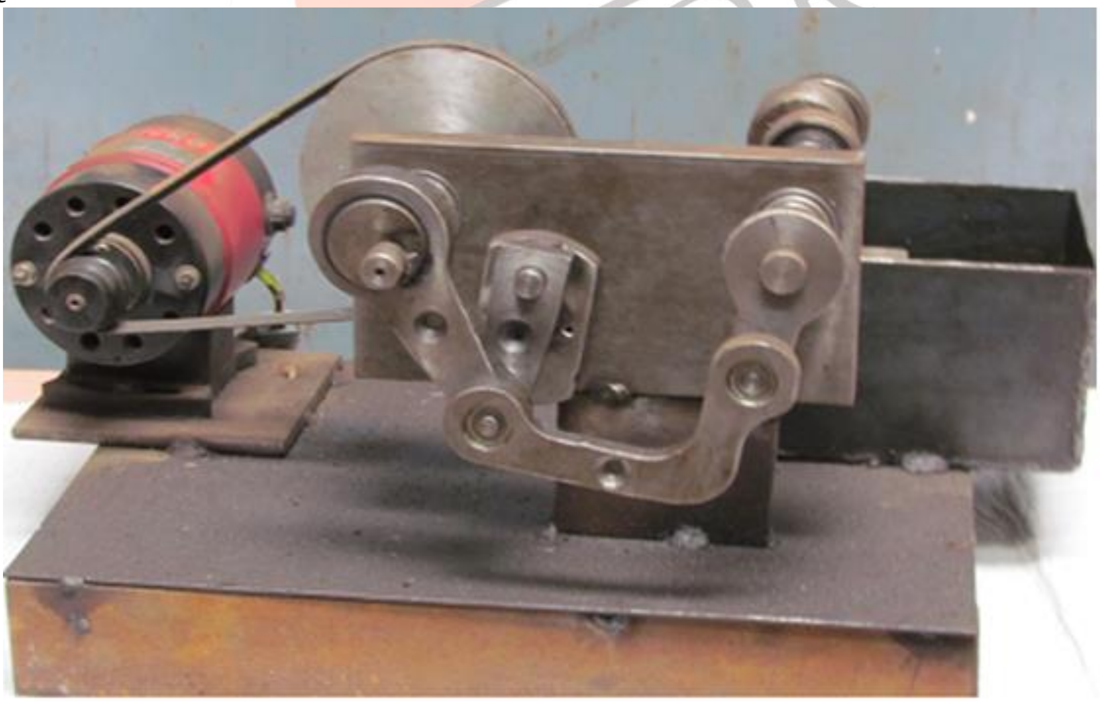

Figure 4 Kinematic linkage variable displacement pump

Volumetric Efficiency

Volumetric efficiency is defined as the ratio of actual flow rate to theoretical flow rate. It is given by,

$$\eta_v = \frac{Q_A}{Q_T}$$

Where,

η_v = Volumetric efficiency

Q_A= Actual flow rate

Q_T = Theoretical flow rate

V. EXPERIMENTAL RESULTS

Test & Trial on Variable Displacement Linkage Pump

Observation set-1 : Control link at 0^0 position

Procedure:

1. Position the control linkage at 0^0 position
2. Start pump motor
3. Maintain input speed at input =100 rpm
4. Collect 100 ml of oil in measuring beaker
5. Note time for collecting 100 ml of oil
6. Change input speed to 200 rpm
7. Repeat step 4 & 5
8. Repeat procedure for 300 rpm, 400rpm and 500 rpm

Table 1 Actual flow rate at 0 degree control angle

SR. NO.	SPEED (RPM)	VOLUME IN BEAKER (ml)	TIME (SECONDS)	FLOW RATE (LPM)
01	100	100	189	0.0317
02	200	100	94	0.063
03	300	100	65	0.092
04	400	100	49	0.122
05	500	100	40	0.15

Table 2 Volumetric at 0 degree control angle

SR. NO.	SPEED (RPM)	ACTUAL FLOW RATE (LPM)	THEORETICAL FLOW RATE	VOLUMETRIC EFFICIENCY
01	100	0.0317	0.036	86.35
02	200	0.063	0.073	86.82
03	300	0.092	0.11	83.7
04	400	0.122	0.147	83.2
05	500	0.15	0.183	81.65

Observation set-2 : control link at 120^0 position

Procedure :

1. Position the control linkage at 120^0 position
2. Start pump motor
3. Maintain input speed at input =100 rpm
4. Collect 100 ml of oil in measuring beaker
5. Note time for collecting 100 ml of oil
6. Change input speed to 200 rpm
7. Repeat step 4 & 5
8. Repeat procedure for 300 rpm, 400rpm and 500 rpm

Table 3 Actual flow rate at 120 degree control angle

SR. NO.	SPEED (RPM)	VOLUME IN BEAKER (ml)	TIME (SECONDS)	FLOW RATE (LPM)
01	100	100	2217	0.0024
02	200	100	1130	0.0053
03	300	100	769	0.007
04	400	100	575	0.01
05	500	100	473	0.012

Table 4 volumetric efficiency at 120 degree control angle

SR. NO.	SPEED (RPM)	ACTUAL FLOW RATE (LPM)	THEORETICAL FLOW RATE	VOLUMETRIC EFFICIENCY
01	100	0.0024	0.0033	86.78
02	200	0.0053	0.006	85.13
03	300	0.007	0.009	83.39
04	400	0.01	0.0124	83.65
05	500	0.012	0.015	81.35

VI. GRAPHICAL RESULTS

a)Graph of speed (on x-axis) and actual flow rate (on y-axis) at 0 degree control angle.
b)Graph of speed (on x-axis) and volumetric efficiency (on y-axis) at 0 degree control angle.
c) Graph of speed (on x-axis) and actual flow rate (on y-axis) at 120 degree control angle.
d) Graph of speed (on x-axis) and volumetric efficiency (on y-axis) at 120 degree control angle.

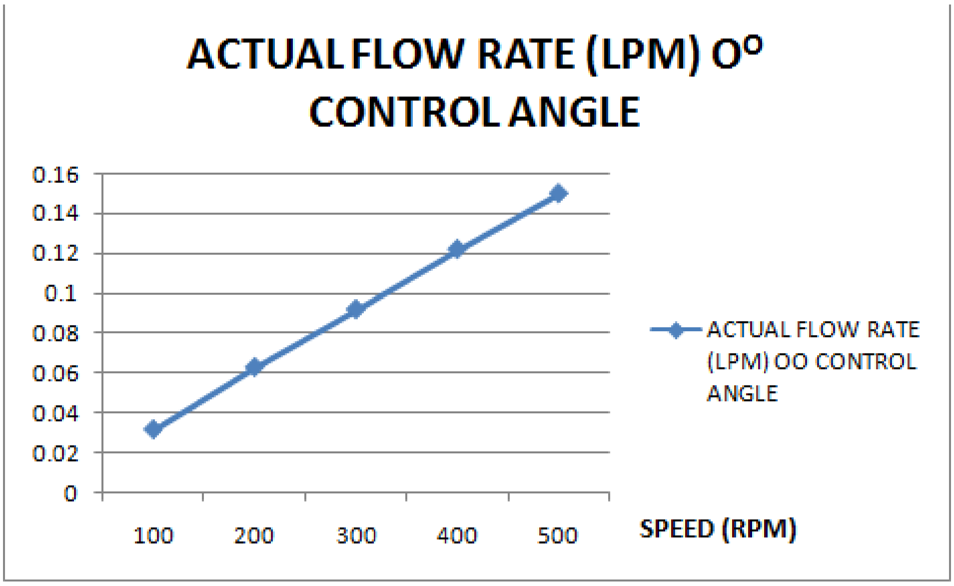

Figure 5 Variation of actual flow rate with the variable speed along x axis at 0 degree control angle

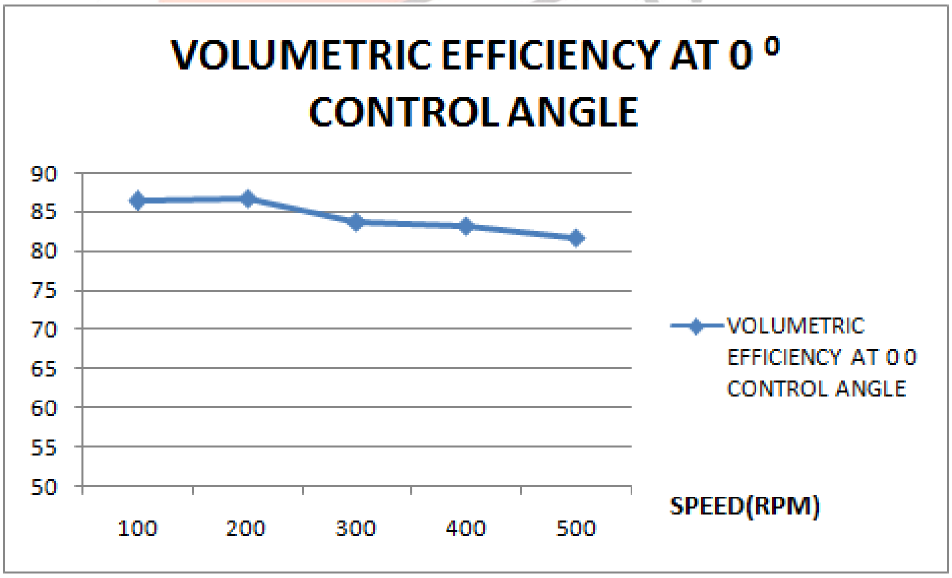

Figure 6 Variation of volumetric efficiency with the variable speed along x axis at 0 degree control angle

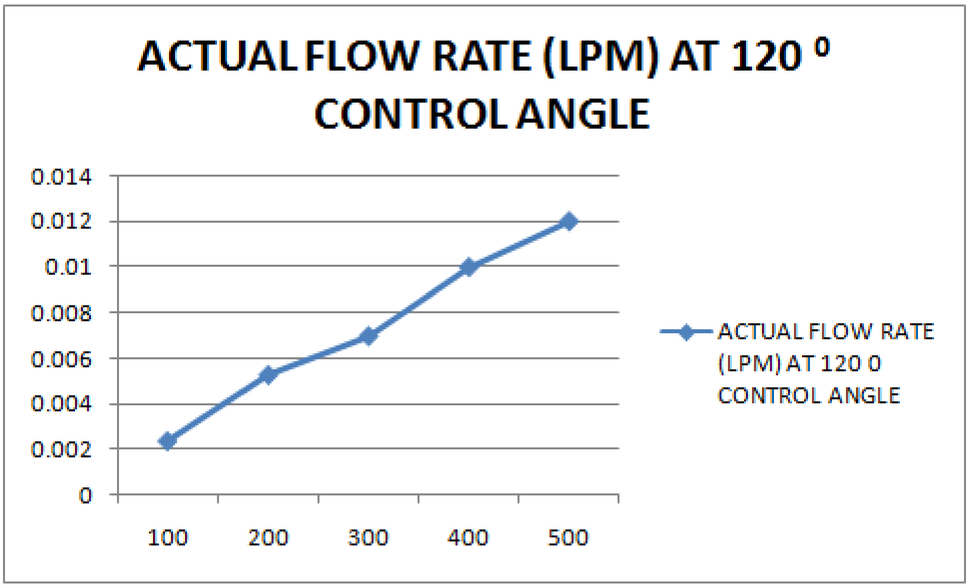

Figure 7 Variation of actual flow rate with the variable speed along x axis at 120 degree control angle

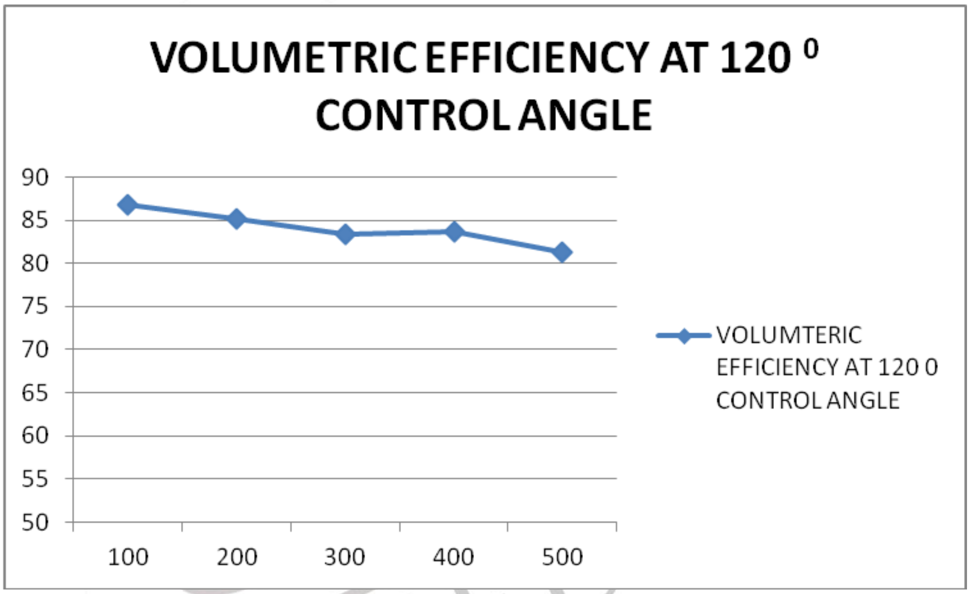

Figure 8 Variation of volumetric efficiency with the variable speed along x axis at 120 degree control angle

VII. CONCLUSION

It is seen that the discharge from the pump reduces at the control angle is changed from o degree to 120 degree. Volumetric efficiency drops slight as the speed in all cases of control angle, this is owing to the hysteresis of spring used in the pump and friction between the piston and cylinder. From the seen characteristic of flow in each control angle it can be safely assumed that the discharge of the pump increases with increase in pump speed for all control angles.

Precise control of the control angle will provide a wide range of flow rates, thereby the pump will find application in multiple industry.

VIII. ACKNOWLEDGMENT

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