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Investigation on Adjustable Stroke Mechanism In Conversion Of Axial Piston Pump For Variable Discharge

[#1]Nisha R.Patil, [#2]Atul P. Kulkarni, [#3]Abhijeet R.Deshpande, [#4]Kiran S.Wangikar

[1]nisha09patil@gmail.com
[2]apk_31173@rediffmail.com
[3]abhijit.deshpande32@gmail.com
[4]wangikarkirans@gmail.com

[#1234] Mechanical Department, VIIT College, Savitribai Phule Pune University

ABSTRACT

Variable discharge piston pump offers variable discharge option, and hence it is used in variety of application such as automobile (JCB, Man lift, Dozer etc) and CNC machines hydraulic feed drive. Conventional variable displacement hydraulic pumps have a rotating cylinder block with an axially movable piston, which engages a tiltable swash plate for varying the stroke of the piston. In these conventional axial piston pumps, destroking is achieved by connecting the swash plate or stroke control piston to the sump or drain. Cost of such variable displacement pump is very high as compared to fixed displacement axial piston pumps. In this work, conversion of fixed displacement pump into variable displacement is done by introducing the innovative kinematic linkage to the pump operating mechanism. It will make the discharge continuously variable from zero to maximum and vice a versa. Linkage synthesis is done in this work, which will help for optimization of the linkage. Stroke length of piston is found out by experimental set up and results are validated with CAD software and relation between linkage angle with stroke length, flow rate and time is found out.

Keywords- Kinematic Linkages, Linkage Synthesis, Stroke Length, Flow Rate.

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I. INTRODUCTION

In hydraulic power systems, variable displacement pumps save power, increase the productivity or control the motion of a load precisely, safely and in an economical manner .The displacement varying mechanism and power to weight ratio of variable displacement piston pump makes them most suitable for control of high power levels. The bent axis piston pump is preferred in most hydraulic power systems because of its high performance and efficiency. It is also capable of operating at variable conditions of flow, pressure, speed and torque. Swash plate piston pump is another variable displacement pump in which by varying the angle of swash plate it is possible to vary the stroke of the pistons hence the discharge can be varied in this configuration of pump. But cost of such type of pump is very high as compared to fixed displacement axial piston pump. By adjusting stroke of the piston it is possible to vary discharge of the pump.Frudenstein et al [1]disclosed a fixed geometry rocker mechanism driving oscillating links which are adjustable to provide control of the piston displacement and compression ratio.Myers et al [2] provided a manual displacement control for varying a displacement of hydraulic pump in whicha displacement control linkages has a nonlinear coupling element and a resilient override spring serially connected between the input lever and the valve spool.Tuan-Jie Li et al [3] presented a general approach to the kinematic analysis of planar geared linkage mechanisms in which the kinematic equations and the analytic solutions for the kinematic units are derived.Georges E.M. Vael et al [4] presented a design for a variable displacement open circuit Floating Cup Pump. Richard B. Willi et al [5] have made invention which is related to the variable stroke reciprocating mechanism operated by a constant displacement actuating means.Volkan Parlaktaş et al [6] presents an analysis and synthesis method for a certain type of geared four-bar mechanism (GFBM) for which the input and output shafts are collinear.Shawn R. Wilhelm et al [7] proposed a variable displacement six-bar crank-rocker-slider mechanism, which goes to zero displacement with a constant top dead center position. This paper describes a synthesis technique to design a, linkage for a variable displacement piston pump/motor that cango to zero displacement and has a constant top dead center.Volkan Parlaktaş et al [8] presented a novel study on the analysis of the “single piece” compliant spatial slider–crank mechanism in which there was no ball joint in the structure of the mechanism.

II.METHOD

Fix displacement pump gives fixed discharge. By changing stroke of the piston it is possible to change the discharge of the pump. 7 bar double crank slider mechanism is used in this work which convert rotary motion of two cranks into reciprocating motion of slider. Motion of the slider is directly given to the plunger of the axial piston pump. So the reciprocating motion is directly transferred to the plunger.

Stroke of the piston can be changed by simply changing angle between two cranks. When two cranks are parallel to each other slider gives maximum displacement so plunger performs maximum stroke. At this position pump gives maximum discharge. In the experimental set up (Fig 1(a)-Fig 1(e)) arrangement is provided for different angles like 0˚,45˚,90˚,135˚,180˚. When angle between two cranks is 45˚ stroke of the piston decreased slightly. So discharge of the pump is also reduced. When angle between two cranks is 90˚ stroke of the piston further decreased as compared to stroke of the piston at 45˚. So discharge of the pump is also reduced as compared to discharge at 45˚.When angle between two cranks is 135˚ stroke of the piston further decreased as compared to stroke of the piston at 90˚. So discharge of the pump is also reduced as compared to discharge at 90˚. When angle between two cranks is 180˚ the stroke of the piston is zero. So pump gives zero discharge. In this way fixed discharge pump is converted into variable discharge by using manually operated seven bar double crank slider mechanism.

Static and dynamic balancing of linkages are not considered in proposed work.

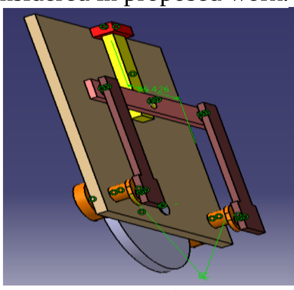
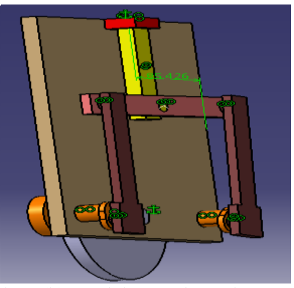

Fig.1(a) Model 1- 0˚ Angle Fig. 1(b) Model 2 - 45˚ Angle

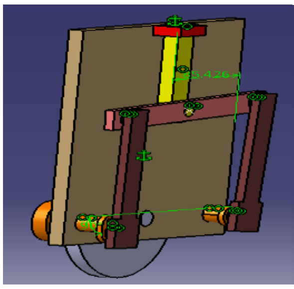
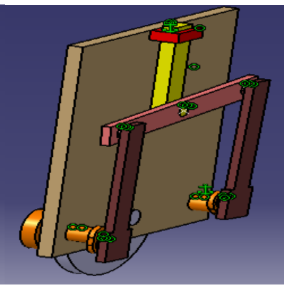

Fig. 1(c) Model 3 - 90˚ Angle Fig. 1(d) Model 4 - 135˚ Angle

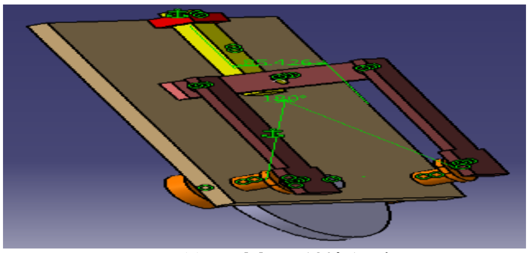

Fig. 1(e) Model 5 – 180˚ Angle

A.Experimental Setup

Actual experimental setup is run on different speeds like 100, 200, 300, 400, 500 RPM to measure flow rate of oil from pump. Polyhydron oil immersed type, face mounting, fixed delivery pump is used to change its discharge from zero to maximum. In this setup 50W and 6000 RPM variable motor is used. 1:5 reduction ratio of speed is used to reduce speed using belt n pulley arrangement. For further speed reduction pinion and gear arrangement is used. Out speed of large pulley is given to pinion as a input speed. Output speed of gear is given to one of the input crank. Motion of one input crank to another is transferred by using chain and sprocket. And reciprocating motion of slider is transferred to the plunger of the pump. So flow rate of the oil is measured at different speed. To trace the path of particular point pens are attached to that points (lower point and upper of two connecting links, point at slider and connecting rod, slider).

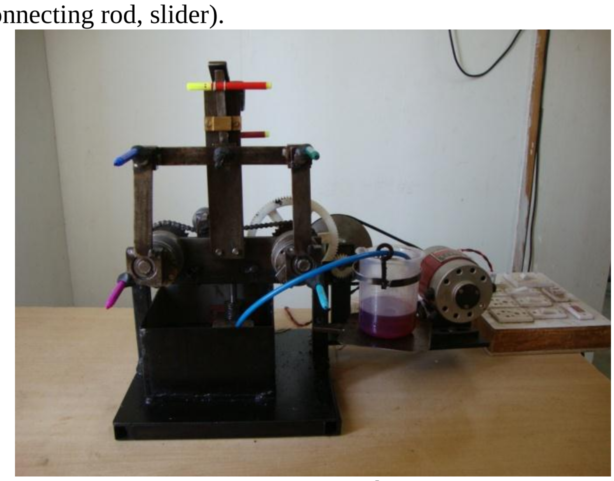

Fig. 2 Experimental setup

III.LINKAGE SYNTEHESIS

By attaching pens to the particular point paths which are followed by that point are recorded on A4 size paper. Stroke length of slider in experimental setup (Fig 2) is also recorded on paper attaching scale to that. Simulation of CAD model is done to find out stroke length of the slider. Same points are marked on CAD model to find their trace. These CAD results (trace of points and stroke length) are validated with experimental results of trace of points and stroke length.

A. Analysis of Stroke Length

Maximum stroke length obtained when two cranks are parallel to each other which is 16 mm as shown in (Fig 3a).

As angle between two cranks increased stroke length decreases (Fig 3a-Fig 3e).

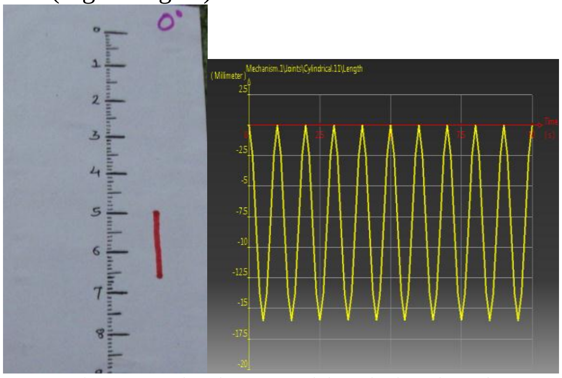

Fig.3a Actual and CAD model stroke length at 0˚

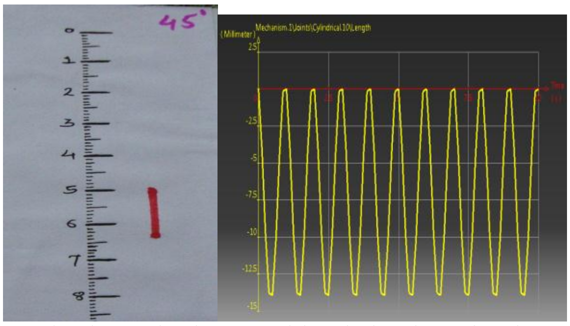

Fig. 3b Actual and CAD model stroke length at 45˚ angle

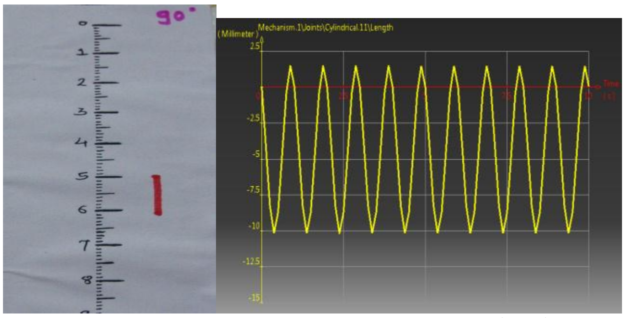

Fig. 3c Actual and CAD model stroke length at 90˚ angle

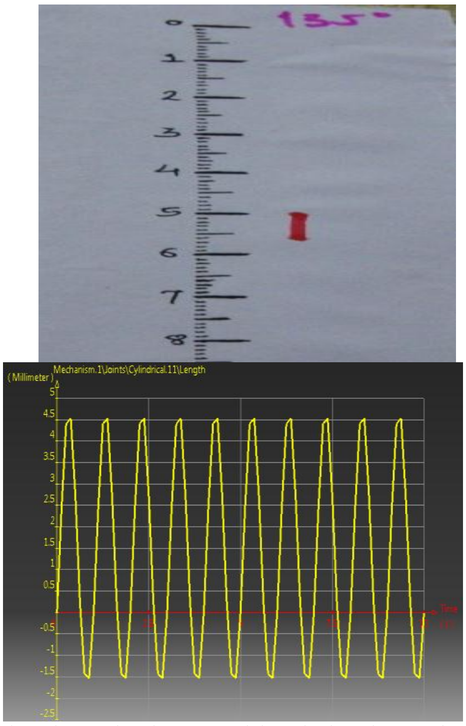

Fig. 3d Actual and CAD model stroke length at 135˚ angle

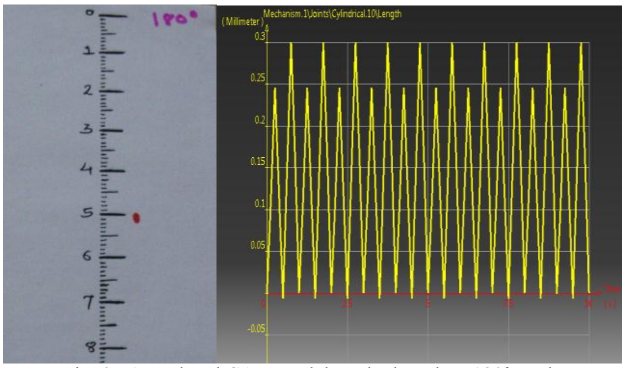

Fig. 3e Actual and CAD model stroke length at 180˚ angle

B. *Analysis of Trace*

Two points of the crank perform oval shape trace for every change in angle. There is no change in their shape. But upper points of connecting links perform different shape trace for different angle. Joint of slider and connecting rod perform same length trace as slider. Different points are located in fig.2. Traces of same points are performed on CAD software by taking different angles between two cranks and results are validated with experimental results.

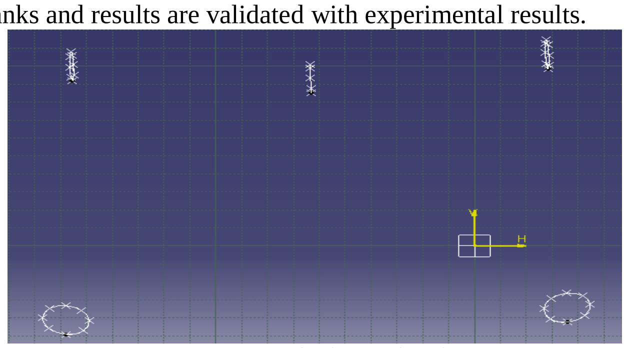

Fig.4a Trace of points at 0˚ angle

Fig. 4b Experimental trace of points at 0˚ angle

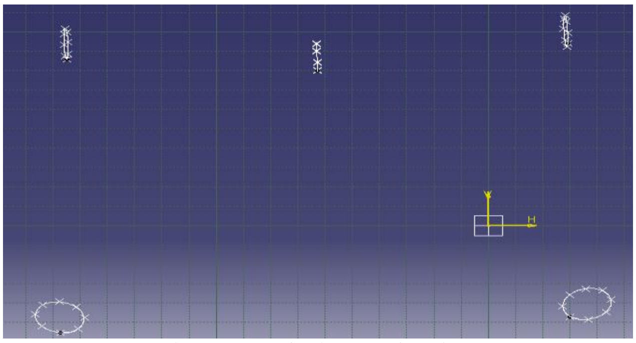

Fig.4c Trace of points at 45˚ angle

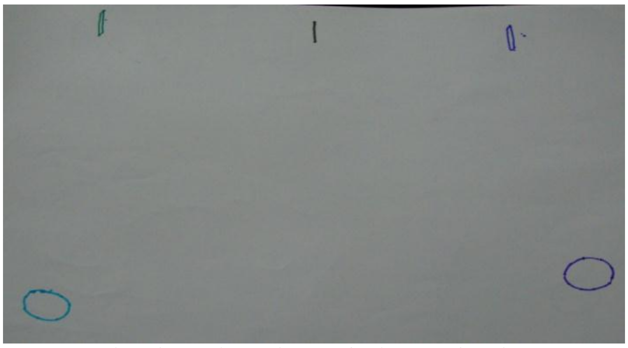

Fig. 4d Experimental trace of points at 45˚ angle

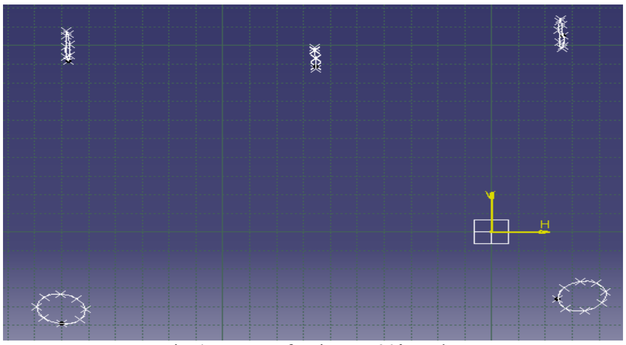

Fig.4e Trace of points at 90˚ angle

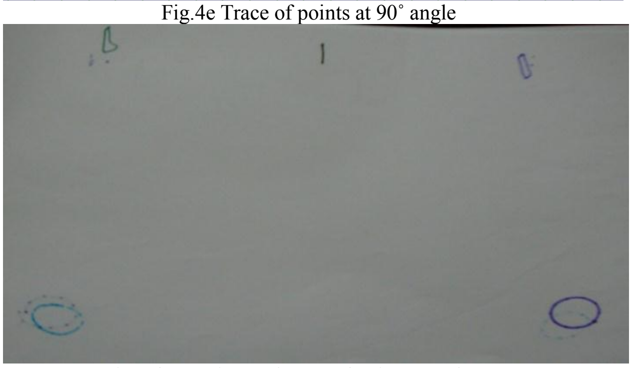

Fig. 4f Experimental trace of points at 90˚ angle

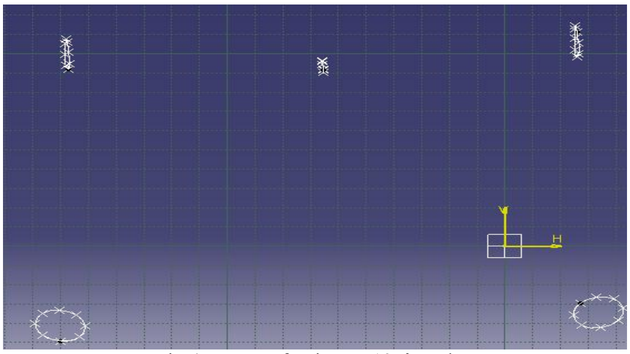

Fig.4g Trace of points at 135˚ angle

Fig. 4h Experimental trace of points at 135˚ angle

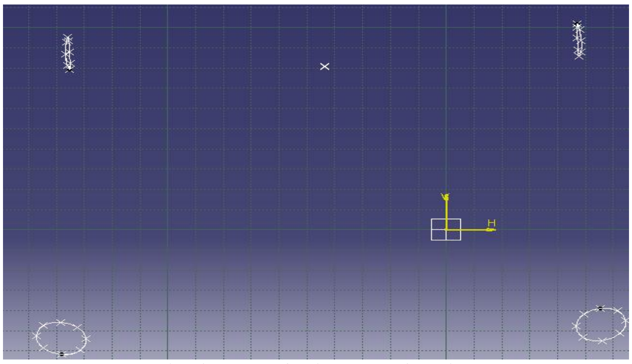

Fig.4h Trace of points at 180˚ angle

Fig. 4i Experimental trace of points at 180˚ angle

IV.EXPERIMENTAL TSTING & RESULTS

Set up is run at 100, 200, 300, 400, 500 RPM and time is measured to fill 100 ml oil in beaker. This procedure is repeated for 0˚,45˚,90˚,135˚,180˚ angles. Flow rate is calculated for every running speed and for every angle reading. Following charts (Fig 5-Fig 9) show time required to fill 100 ml oil in beaker at speed 100, 200, 300, 400, 500 RPM for every change in angle of input cranks. Following results show that as angle between two input links increases time required to fill 100 ml oil in beaker also increases but stroke length decreases so flow rate is also decreases.

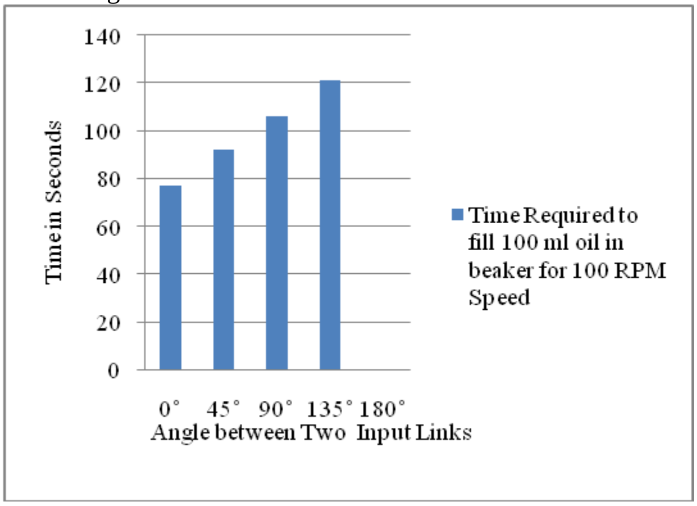

Fig. 5 Time Required to Fill 100 ml Oil in Beaker at 100 RPM Speed

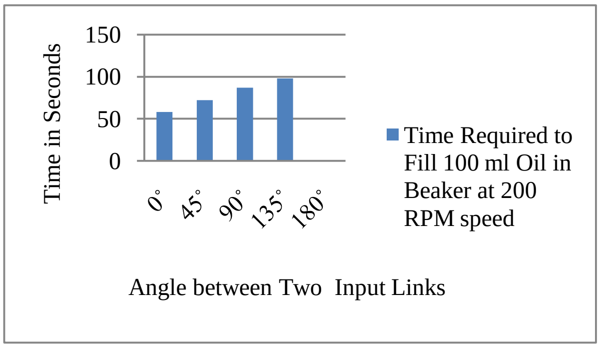

Fig. 6 Time Required to Fill 100 ml Oil in Beaker at 200 RPM Speed

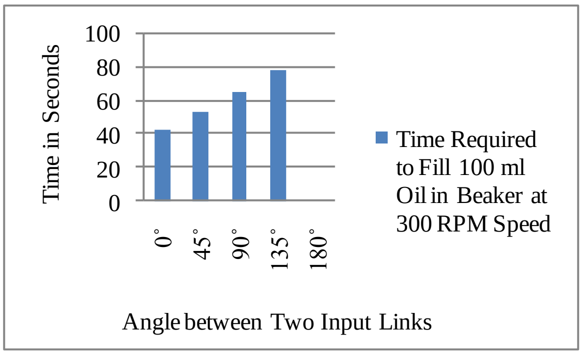

Fig. 7 Time Required to Fill 100 ml Oil in Beaker at 300 RPM Speed

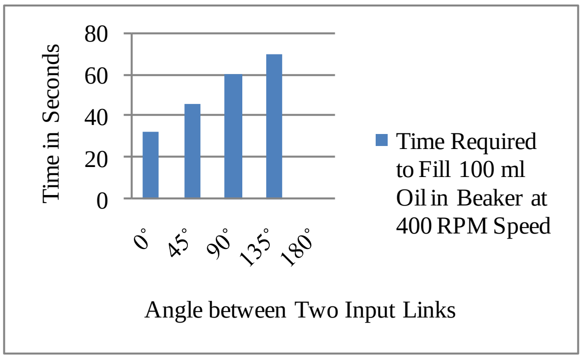

Fig. 8 Time Required to Fill 100 ml Oil in Beaker at 400 RPM Speed

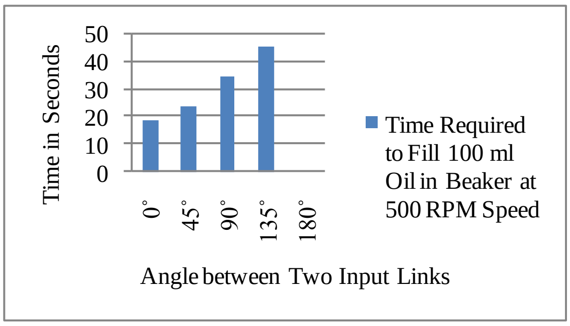

Fig. 9 Time Required to Fill 100 ml Oil in Beaker at 500 RPM Speed

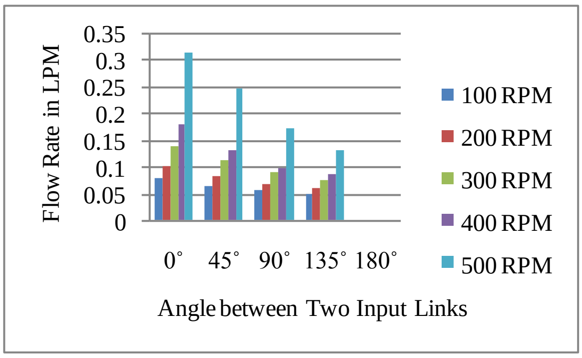

Fig. 10 Comparison of actual flow rate

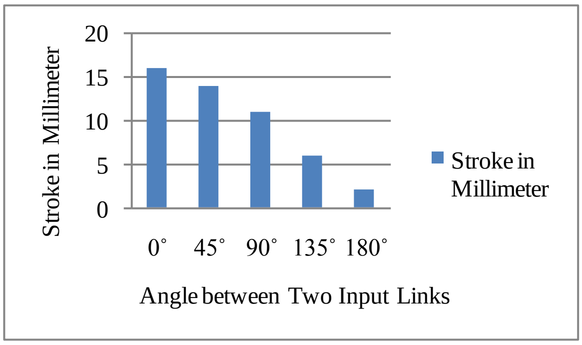

Fig. 11 Comparison of actual stroke length

V.CONCLUSION

Fixed discharge pump is converted into variable discharge pump by using seven bar double crank slider mechanism and by changing angle between two cranks, stroke of the piston is changed. Discharge of the pump is varied from zero to maximum by manual control. As angle between two cranks increased stroke of the piston decreased so discharge is also decreased proportionately. As angle between two input cranks increased flow rate is decreased for every given speed. This type of linkage can be used to vary stroke of any type reciprocating piston pump. Cost of such type of attachment is very low as compared to commercially available variable discharge pump. So this type of attachment can be preferred for medium speed application.

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