Design and Development of Floating Fulcrum Based Variable Discharge Radial Piston Pump For Mql System

Shubham Landge[1], Vishnu Aher[2], Varhade Vishal G.[3]
[1, 2, 3]Dept of Mechanical Engg
[1, 2, 3] A.V.C.O.E, Sangamner, India

Abstract- *Conventionally the flood lubrication system is used for cooling the tool and work interface to attain maximum surface finish. Minimum quantity lubrication (MQL) has increasingly found its way into the area of metal cutting machining. Heart of the Variable displacement pump applied to the automatic lubrication system is the variable displacement linkage as applied to the pump.[2] The conventional pumps used are of fixed displacement type, thus the volume flow cannot be controlled hence they are not useful for the automatic lubrication systems In contrast to flood lubrication, minimum quantity lubrication uses only a few drops of lubrication (approx. 5 ml to 50 ml per hour) in machining. The floating fulcrum variable displacement pump is an innovative kinematic link base stroke changing mechanism that is controlled using a floating fulcrum or pivot mounted on the linear slide controlled using an adjuster screw. Project work include the kinematic linkage design, analysis and performance evaluation of flow parameters for pump. The strength analysis of the kinematic linkage parts done using ANSYS workbench 16.0,whereas the actual model that l be developed & tested to determine the performance characteristics of the pump and there by determine the maximum and minimum volume flow rate of the system, volumetric efficiency and precision of flow control. The pump tested for three different control angle ($0^{0,}$ $40^{0,}$ $80^{0)}$ positions & different speeds (1875,1250,938 rpm).*

Keywords- Piston Pump, MQL, Surface Roughness Floating fulcrum, Kinematic link pump,Precise control

I. INTRODUCTION

Minimum Quantity Lubrication (MQL) consists of a mixture of pressurized air and oil micro-droplets applied directly into the interface between the tool and chips. However, the question of how the lubricants can decrease the friction under very high temperature and loads is still not answered especially for long engagements times. MQL decreased the contact length compared to dry cutting for both short and long engagement time. Minimum quantity lubrication (MQL) has increasingly found its way into the area of metal cutting machining and, In contrast to flood lubrication, minimum quantity lubrication uses only a few drops of lubrication in machining.[1] Today, the enormous cost-saving potential resulting from doing almost entirely without metalworking fluids in machining production is recognized and implemented by many companies, primarily in the automotive industry. While in the early 1990s small applications (sawing, drilling) were done ―dry‖, today we are able to produce cylinder heads, crankcases, camshafts and numerous other components made of common materials – such as steel, cast iron and aluminium – using MQL in the framework of highly automated large volume production.

1.2 Lubricant Properties for Minimum Quantity Lubrication

Minimum quantity lubrication is total-loss lubrication. The lubricant in use is often subject to high thermal and mechanical loads and is applied to the work zone in the form of mists and aerosols. The user should therefore ensure that only toxicologically harmless lubricants are used. For fault-free, low-emission metal machining when using minimum quantity lubrication, lubricants with very good lubricity and a high thermal rating are best. In industrial manufacturing, synthetic ester oils and fatty alcohols with favourable, vaporization behaviour and a high flash point are used.

Synthetic esters are preferable for all machining processes in which the lubricating effect between tool, the work piece and separation from the chips is of prime importance.(Prevention of abrasive wear) Examples of this are threading, drilling, reaming and turning). Synthetic esters have the advantage that, despite low viscosity, they have a high boiling point and flash point. This means that much less vapour is emitted in the workspace compared to conventional mineral oils. In addition to these properties, ester oils exhibit verygood biodegradability, and owing to their low toxicity are rated as Water Pollution Category or —non-hazardous to water.

Compared to ester oils, fatty alcohols have a lower flash point at the same viscosity. In contrast to ester oils, they offer less lubricity.

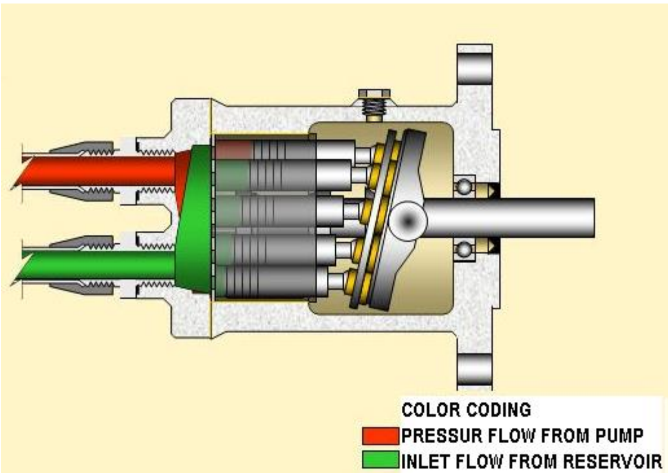


Fig 1.Axial piston pump

1.3 RELEVANCE OF PISTON PUMP

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 .[3]The displacement varying mechanism and power to weight ratio of variable displacement piston pump makes them most suitable for control of high power levels.

II. LITERATURE SURVEY

Kekare H.T et al. (2015) This paper presented variable displacement linkage which use for desired position displacement. Using this particular displacement run a radial piston pump for variable discharge. 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 .[1] Positive Displacement Pumps are "constant flow machines" Thus objective of research is defined to develop a variable displacement linkage that will enable to vary the stroke of an two cylinder radial piston pump, thereby offering to vary the discharge of the pump using manual control.

Shawn Wilhelm et al. (2012) Studied that The Conventional variable displacement hydraulic pumps and motors suffer from poor efficiency at low displacements, primarily due to the friction and leakage associated with hydrodynamic bearings, which do not scale with output power.[2] A variable displacement adjustable linkage pump has been developed which can achieve zero displacement.

Vikrant Suryawanshi (2015) The study of this paper deals with discharge pumps. Positive Displacement Pumps are "constant flow machines" The bent axis piston pump can perform this work precisely but it is economically costlier. Thus objective of research is defined to develop a variable displacement linkage that will enable to vary the stroke of a two cylinder radial piston pump, thereby offering to vary the discharge of the pump using manual control and perform the same work as bent axis piston pump in an economical way.

James D. Van de Ven et al. (2011) A hydraulic pump/motor with high efficiency at low displacements is required for a compressed air energy storage system that utilizes a liquid piston for near-isothermal compression. To meet this requirement, a variable displacement six-bar crank-rocker-slider mechanism, which goes to zero displacement with a constant top dead center position, has been designed.[6] The synthesis technique presented in the paper develops the range of motion for the base four-bar crankrocker, creates a method of synthesizing the output slider dyad, and analyzes the mechanisms performance in terms of transmission angles, slider stroke, mechanism footprint, and timing ratio. It is shown that slider transmission angles can be kept above 60 degrees and the base four-bar transmission angles can be controlled in order to improve overall efficiency.

Shital R. Deokar et al. (2016) A meter mixing machine is a machine used to mix different components with a specific ratio. The metering pump moves a precise volume of liquid in a specified time with accurate flow rate. There are various pumps used for this application. A piston pump is one of the useful metering pump because it gives comparatively steady flow rate. Flow rates for metering pumps are usually quite low due to the nature of the application. Metering pumps are used wherever the flow rate of a liquid needs to be regularly measured and adjusted to precise level.[5] They're most commonly used to pump treatment chemicals in industries.

Patil P.R et al. (2014) The effect of cutting tool geometry has long been an issue in understanding mechanics of turning. Tool geometry has significant influence on chip formation. This article presents a survey on variation in tool geometry i.e. tool nose radius, rake angle, groove on the rake face, variable edge geometry, wiper geometry and curvilinear edge tools and their effect on tool wear. Component turning using these conventional inserts has shown moderate to low production rates, lower surface finish and dimensional inaccuracies while machining components. Earlier method of lubrication uses the coolant pump to circulate cooling fluid using coolant pump this method proved costly and so also the machine environment conditions were affected namely floor becoming slippery etc, hence it was decided to implement the minimum quantity lubrication on the machine.

Shawn R. Wilhelm et al. (2013) The power density of hydraulic drive trains make variable displacement machines appealing to a wide range of applications such as mobile hybrid systems, heavy machinery, and hydrostatic transmissions for wind power. In this paper, the linkage kinematics and dynamics are discussed, an energy loss model is presented and used to drive design decisions of a first generation prototype, and experimental results are presented to validate the model.[7] A piston pump is one of the useful metering pump because it gives comparatively steady flow rate. They're most commonly used to pump treatment chemicals in industries.

III. NEED OF RADIAL PISTON PUMP

1. Axial piston pumps with constant pressure and variable flow have extraordinary possibilities for controlling the flow by change of pressure.
2. The major obstacle in application of the bent axis piston pump is extremely high cost (minimum Rs 90000/)- over that of the radial piston pump , it ranges in the range of 5 to 6 times the cost of radial piston pump[1].
3. Variable stroke linkage developed using compact kinematic linkage.
4. Simple and easy point to point control. .
5. Precision control , so accura te discharge control.
6. Low cost (nearly 60% less) than the conventional pump mechanism,
7. Low maintenance cost
8. Easy adaptability to automatic control

IV. OBJECTIVE

The project is defined to develop a variable displacement linkage that will enable to vary the stroke of an single cylinder axial piston pump, thereby offering to vary the discharge of the pump using manual control.

V. METHODOLOGY

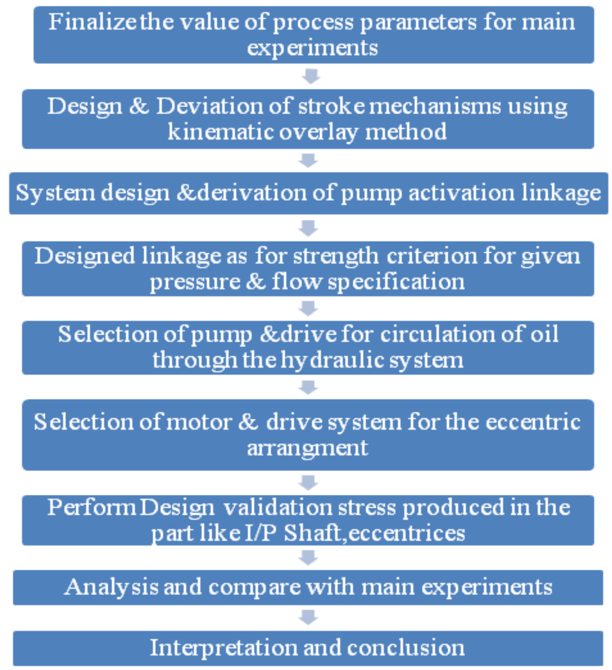


Fig2 Methodology description.

VI. EXPERIMENTAL WORK

TABLE I: MECHANICAL PROPERTIES OF BASE PARTS

Parts name	Designation(Types of material)	Ultimate tensile strength(N/mm^2)	Yield strength(N/mm^2)
I/P Shaft	EN 24	800	680
I/P Crank	EN 9	600	480
Conn. Rod	AL 7075	400	320
O/P Link	EN9	600	480

TABLE II: CALCULATION OF PARTS

Parts name	Torque (Nm)	Fs (allowable) N/mm^2	Fs (Actual) N/mm^2	Result
I/P Shaft	0.475	144	0.55	Fsact<Fs all
I/P crank	0.475	144	0.88	Fsact<Fs all
Conn rod	0.475	144	0.21	Fsact<Fs all
O/P Link	0.475	144	0.07	Fsact<Fs all

1 CONSTRUCTION

Development of test rig in order to conduct the experiment. This mechanism shown above is to convert rotary motion of crank element into oscillatory output of the output element. The angle of oscillation of the output is a function of the position of pivot element. The pivot element position can be varied as it is placed on a slide . Thus adjustment of the stroke can be done by varying the position of the pivot element.

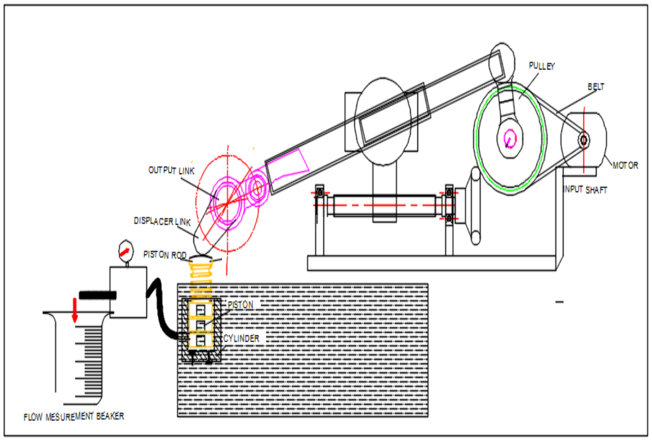


Fig 2. Experimental Setup

1.1. ELECTRIC MOTOR

Electric motor is the source of energy in this stepless drive. It has the following specifications.

SINGLE PHASE AC MOTOR
230 volt, 50 Hz , 0.5 amp
Power = 50 watt. (1/15 Hp)
Speed = 0 to 9000
TEFC CONSTRUCTION
COMMUTATOR MOTOR.

1.2. REDUCTION PULLEY

This arrangement is for transmitting the power from the motor shaft to the input shaft , the power is transmitted by means of an v-belt.

1.3 INPUT SHAFT

Input shaft is an high grade steel (EN 24) construction coupled to the motor by coupling at one end . Input shaft is held in ball bearings at either end of the shaft . Shaft carries the reduction pulley at one end and the crank at its centre

1.4 CRANK

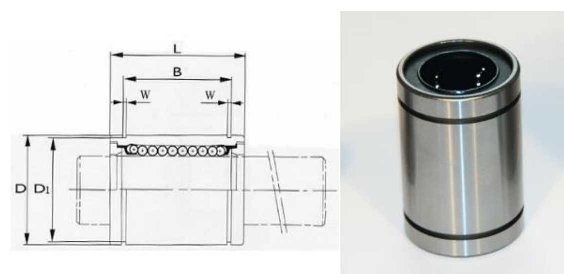
Crank is an high grade steel (EN 09) held on the input shaft at the centre. It transfers motion to the connecting rod.

1.5 CONNECTING ROD

Connecting rod is an element which is imparted oscillating motion by the input shaft .Connecting rod is connected to the input shaft by the Connecting pin at the other end , The connecting rod is made of two components, 12mm hard chrome bar held in the holder that is connected to the crank via the connecting pin.

1.6 CONNECTING LINK

Connecting link is the member that connects the connecting rod to the output yoke. The connecting link carries a linear ball bearing LM-12 at its one end . At one end the connecting rod is connected and at the other end it is connected to the output yoke. Specifications of the linear bearing LM-12.



Part Number	d	D	L	B	W	Circuits	C	Co	Weight (g)
LM 12 UU	12	21	30	23	1.3	4	42	61	32

1.7 CONTROL LINK

The control link is the speed governing member , it changes the position of the joint of the connecting link with connecting rod pivot . This pivot mechanism has a ball bearing housing mounted on a slide. The slide is connected to the linear slide mechanism of the adjuster linkage. The adjuster linkage has screw of M16 threads 2 mm pitch.

1.8 OUTPUT YOKE

Output yoke is connected to the connecting link which oscillates it about the output shaft.

1.9 MEASUREMENT BEAKER :

The measurement beaker is used to measure the flow rate.

Fig.3.Actual model

2 WORKING

- The motor is started and the speed of the motor can be set using a electronic speed regulator. The motor supplies the power to the input shaft using a open belt drive.
- The belt drive is a v-belt drive and the ratio is 1:5 reduction. The input shaft rotates the crank which makes the output shaft to oscillate using the connecting rod and output link .
- The oscillator motion of the output eccentric is transferred to the pump as linear motion .
- The piston of the piston pump moves up and down to cause the pumping action. The discharge of the pump depends upon the stroke of the pump which is controlled by the angle of oscillation of the linkage.
- The angle of oscillation is controlled by adjusting the position of the pivot hence the handle when rotated will change the location or position of the pivot and thus stroke will change and so will the discharge from the pump .
- The measurement beaker is used capture the flow of oil in given time (t) seconds to find the discharge from the pump.

3. Experimental analysis

Testing of the Single cylinder axial piston pump to plot the following characteristics of pump

a) Discharge Vs Speed
b) Pressure Vs Speed
c) Volumetric efficiency Vs Speed

VII. OBSERVATION

1) OBSERVATION SET-1_ : Control link at **0^0** position

Speed for Test = 1875 /1250 /938 rpm ---as per steps on cone pulley.

PROCEDURE **:**

1. Position the control linkage at 0^0 position
2. Start pump motor
3. Maintain input speed at input rpm
4. Collect 100 ml of oil in measuring beaker
5. Note time for collecting 100 ml of oil
6. Change input speed to given rpm
7. Repeat step 4 & 5
8. Repeat procedure for 1875 rpm, 1250 rpm and 938 rpm

TABLE III –CRANK AT **0^0** DEGREE POSITION

SR. NO.	SPEED (RPM)	VOLUME IN BEAKER (ml)	TIME (SECONDS)	FLOW RATE (LPM)
01	1875	100	40	0.15
02	1250	100	49	0.122
03	938	100	65	0.1

2) OBSERVATION SET-2_ : Control link at **40^0** position

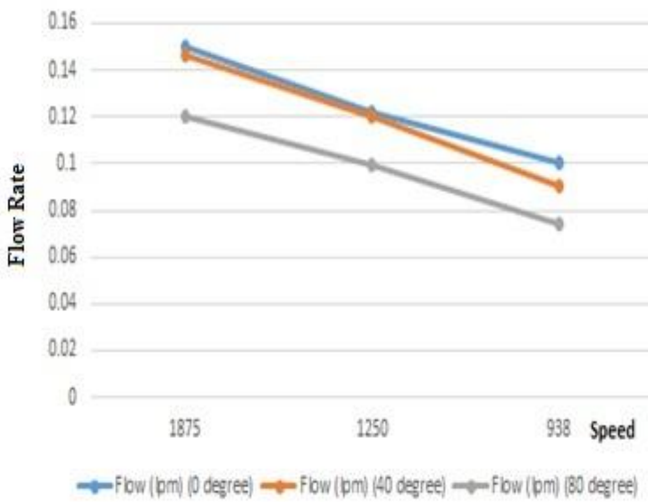
TABLE IV –CRANK AT **40^0** DEGREE POSITION

SR. NO.	SPEED (RPM)	VOLUME IN BEAKER (ml)	TIME (SECONDS)	FLOW RATE (LPM)
01	1875	100	51	0.146
02	1250	100	50	0.12
03	938	100	67	0.09

3) OBSERVATION SET-3_ : Control link at **80^0** position

TABLE V –CRANK AT **80^0** DEGREE POSITION

SR. NO.	SPEED (RPM)	VOLUME IN BEAKER (ml)	TIME (SECONDS)	FLOW RATE (LPM)
01	1875	100	60	0.12
02	1250	100	61	0.0983
03	938	100	81	0.074



GRAPH I: Comparison graph of Speed Vs Flow rate.

Discussion –

- Speed is always directly proportional to Flow Rate.
- When Control angle increases then Flow Rate decreases.

VIII. OUTCOME OF VARIABLE DISPLACEMENT PUMP

1. Configuration of a variable displacement linkage for multiple industrial application
2. Discharge abilities of the variable displacement axial piston pump at variable displacement conditions
3. Pressure characteristics of the pump at variable displacement conditions
4. Data sheet generation for given device to help decide probable application areas,& discharge from pump at various eccentric positions.
5. Comparative (theoretical) analysis as to space and power and cost requirements of the device as compared to conventional pump.

IX. CONCLUSION

1. The parts of the system were designed by theoretical and analytical method, it was found that the maximum stress induced in the parts was well below the permissible limits indicating that the parts designed are safe.
2. Test and trial on the pump setup indicated that with increase in speed of the pump the flow rate was found to increase, this is owing to increase in number of strokes per minute increase. The maximum discharge in all three cases was found to be maximum at 1875 rpm.
3. Test and trial on the pump setup indicated that with decrease in control angle of the pump the flow rate was found to increase , this is owing to increase in angle of oscillation of crank , and thereby the stroke length increasing. The maximum discharge in all three cases was found to be maximum with 0 degree crank angle where the mechanism exhibits maximum stroke.

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