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DESIGN DEVELOPMENT & ANALYSIS OF LINKAGE MOTION ADJUSTOR FOR VARIABLE DISPLACEMENT PUMP.

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Abstract: Axial piston pumps with constant pressure and variable flow have extraordinary possibilities for controlling the flow by change of pressure. Owing to pressure feedback, volumetric control of the pump provides a wide application of these pumps in complex hydraulic systems, particularly in aeronautics and space engineering. The major obstacle in application of the bent axis piston pump is extremely high cost (minimum Rs90000/)- over that of the radial piston pump , it ranges in the range of 5 to 6 times the cost of 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 in addition to the advantages of high efficiency and maximum pressure. Thus objective of 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. The solution offered is in form of the linkage motion adjuster pump where in 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. This mechanism is selected with the view that it offers maximum stability and vibration-less performance owing to nature of mounting of the pivot element which is mounted on a screw slide with precise adjustment of pivot position an there by permitting continuously variable position change of pivot and thereby stroke of the output. This enable precise control of the output discharge from the pump linkage .3-D modeling of set-up will be done using Unigraphics Nx-8.0 and CAE of critical component and meshing using Ansys Work-bench 14.5. The experimental validation part of the pump will be done using a test rig developed to evaluate the performance characteristics of the pump.

***Index Terms* – design, analysis, linkage motion adjuster, axial piston pump**

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.[1]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. The volume is constant through each cycle of operation

Positive Displacement Pumps has an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pumps as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant given each cycle of operation.

The positive displacement pumps can be divided in two main classes

- reciprocating
- rotary

Positive Displacement Pumps are "constant flow machines"

A Positive Displacement Pump must not be operated against a closed valve on the discharge side of the pump because it has no shut-off head like Centrifugal Pumps. A Positive Displacement Pump operating against a closed discharge valve, will continue to produce flow until the pressure in the discharge line are increased until the line bursts or the pump is severely damaged - or both.

A relief or safety valve on the discharge side of the Positive Displacement Pump is therefore absolute necessary. The relief valve can be internal or external. The pump manufacturer has normally the option to supply internal relief or safety valves. The internal valve should in general only be used as a safety precaution, an external relief valve installed in the discharge line with a return line back to the suction line or supply tank is recommended.

Reciprocating Pumps

Typical reciprocating pumps are

- plunger pumps
- diaphragm pumps

Plunger pumps comprise of a cylinder with a reciprocating plunger in it. In the head of the cylinder the suction and discharge valves are mounted. In the suction stroke the plunger retracts and the suction valves opens causing suction of fluid into the cylinder. In the forward stroke the plunger push the liquid out the discharge valve.

With only one cylinder the fluid flow varies between maximum flow when the plunger moves through the middle positions, and zero flow when the plunger is in the end positions. A lot of energy is wasted when the fluid is accelerated in the piping system. Vibration and "water hammers" may be a serious problem. In general the problems are compensated by using two or more cylinders not working in phase with each other.

In diaphragm pumps the plunger pressurizes hydraulic oil which is used to flex a diaphragm in the pumping cylinder. Diaphragm valves are used to pump hazardous and toxic fluids.

1.1 **Relevance of Piston Pumps**

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

The piston pump offers following features that make it outstanding as compared to other positive displacement pumps:

1.Pressure :Piston pumps have the highest pressure capabilities of the other technologies, up to 7250 psi (500 bar) for those in common use, and as high at 10,000 psi (690 bar) for certain specialized units. Vane and gear pumps are commonly limited to pressures up to about 4000 psi (275 bar).

2.Input Speed : Piston pumps have the highest input speed capabilities.

3.Power Density :Hydraulic power density is directly related to operating pressure; the higher the pressure the greater the power density. Piston pumps offer the highest power density with vane and gear types following in that order

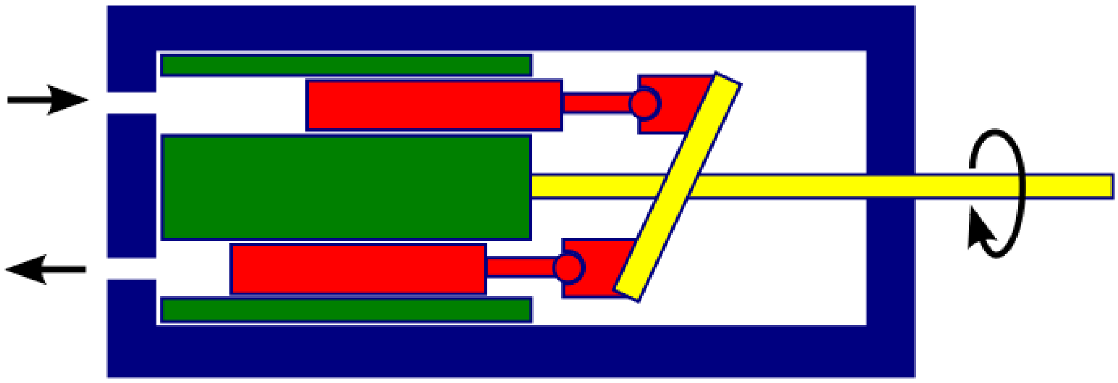
4.Conversion Efficiency :Like power density, the conversion ratio of input power to output power is directly related to operating pressure. Piston pumps offer the highest conversion ratio, followed by vane and gear pumps in that order. The ability of piston and vane pumps to be hydraulically balanced is also a factor in their greater conversion efficiency.

5.Inlet Vacuum Tolerance :Positive inlet pressure is always preferred in hydraulic pump applications to avoid wear and premature failure. Bent axis piston pumps offer good vacuum tolerant handling.

6.Fluid Compatibility : Piston pump tend to offer the greatest range of fluid compatibilities. Note that is it often necessary to de-rate a pump when it is used with non-petroleum fluids. Fluid compatibility depends on the type of seals, O-rings and materials used in the construction of a pump.

7.Life Expectancy and Repairability : Piston pumps offer longest service life of the other technologies and are repairable.

1.3 Axial Piston Or Swash Plate Piston Pump



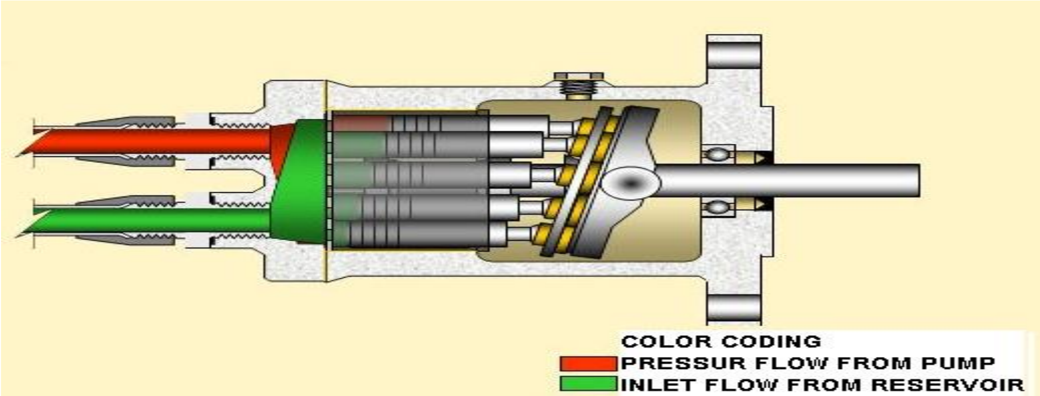


Fig.1 Swash-plate type axial-piston pumps

Swash-plate type axial-piston pumps are used as the fluid power-source for hydraulic circuitry. These devices are used to transmit power in many engineering applications such as aircrafts, earthmoving equipment, and shop tools. The advantages of these machines have been high effort and low inertia , flexible routing of power, and continuously-variable power transmission.

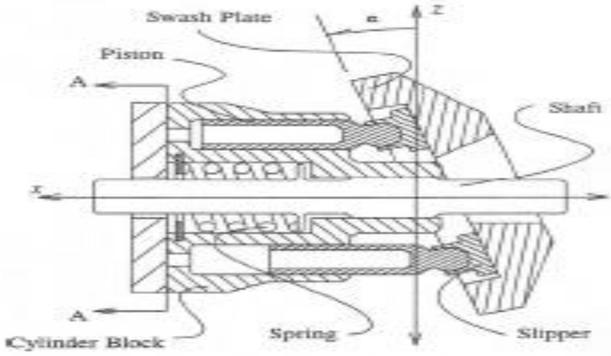


Fig.2 Varying the angle of swash plate

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.

Disadvantages of bent axis piston pumps have been fluid leaks, system flammability, contamination sensitivity, and lower operating efficiency. Though the advantages of these machines are gaining a strong presence in the marketplace, the disadvantages must be minimized if fluid power is to remain a strong alternative among the various choices of power transmission.

II. LITERATURE SURVEY

VIRAL MEHTA Dr. Noah [1] Manring, Dissertation Supervisor A critical challenge in fluid power industry is excessive noise generated by axial piston pumps. Chapter 1 begins with the discussion on motivation to reduce the pump noise from current level. Thorough background information is given detailing the understanding of this problem and mechanisms involved with it. Some of the standard and in-test methods to alleviate the problem and work in progress by different research groups are presented subsequently. At the end of this chapter, a theory highlighting a different origin of the problem is proposed that challenges the generally accepted view about the noise problem in axial piston pumps and sets foundation for the analysis described in this paper

Dipl.-Ing. M. Deeken Institute for Fluid Power Drives and Controls (IFAS), RWTH Aachen[2] Nowadays, the development of hydrostatic displacement units is concerned with improving efficiency and noise behavior. Here too, the use of software-based development tools is becoming increasingly important. Development of the specific computation algorithms required to solve the differential equations is being prevented by the use of existing software tools. One possible application for specialised simulation programs is the dimensioning of the control plate geometry in swashplate-type hydraulic displacement units. The kinematics of the pump or motor can be modelled in a mechanical simulation program while the hydraulic section is modelled using a hydraulic design tool. The pressure pulsations calculated with this tool also enable conclusions to be drawn regarding the load on the unit at a whole. The volume flow and pressure pulsations play a significant role with respect to the efficiency and noise behaviour of hydraulic drive units. Various papers have already been drawn up on this subject. M. Jarchow [1] draws attention to pulsation damping measures in his work. The effects of these measures were verified on the basis of measurements recorded for pumps and motors that operate according to the swash-plate principle. He also describes mathematical models for simulation of the various steering concepts. Other papers examine structural vibrations and their effects on noise.

Shawn Wilhelm, James D. Van de Ven University of Minnesota [3] 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. A variable displacement adjustable linkage pump has been developed which can achieve zero displacement and has a constant top dead center position of the pistons, regardless of displacement. This architecture employs roller element bearings in its pin joints, significantly reducing the mechanical losses at low displacements as compared to the hydrodynamic bearings of variable axial piston and bent axis machines. Previous work has described the experimentally validated efficiency model for a low-power single-cylinder pump. In this paper, the optimization and machine design of an 8.5 kW, high pressure, variable displacement, triplex prototype are presented and the potential applications are discussed. It will be shown that this architecture can achieve greater than 90% efficiency across the majority of the operating region. The pump can be applied to a wide range of applications with little compromise, compared with present variable displacement pump

Shawn R. Wilhelm James D. Van de Ven [4] A variable displacement hydraulic pump/motor with high efficiency at all operating conditions, including low displacement, is beneficial to multiple applications. Two major energy loss terms in conventional pumps are the friction and lubrication leakage in the kinematic joints. This paper presents the synthesis, analysis, and experimental validation of a variable displacement sixbar crank-rocker-slider mechanism that uses low friction pin joints instead of planar joints as seen in conventional variable pump/motor architectures. The novel linkage reaches true zero displacement with a constant top dead center position, further minimizing compressibility energy losses. The synthesis technique develops the range of motion for the base fourbar crank-rocker and creates a method of synthesizing the output slider dyad. It is shown that the mechanism can be optimized for minimum footprint and maximum stroke with a minimum base fourbar transmission angle of 30deg and a resultant slider transmission angle of 52deg. The synthesized linkage has a dimensionless stroke of 2.1 crank lengths with a variable timing ratio and velocity and acceleration profiles in the same order of magnitude as a comparable crank-slider mechanism. The kinematic and kinetic results from an experimental prototype linkage agree well with the model predictions

Vikrant Rajesh Suryawanshi [5] The study of this paper deals with discharge pumps. A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. 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. 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.

III. RESEARCH METHODOLOGY

A. Need Of The Project

Axial piston pumps with constant pressure and variable flow have extraordinary possibilities for controlling the flow by change of pressure. Owing to pressure feedback, volumetric control of the pump provides a wide application of these pumps in complex hydraulic systems, particularly in aeronautics and space engineering.

The major obstacle in application of the bent axis piston pump is extremely high cost (minimum Rs90000/)- over that of the radial piston pump , it ranges in the range of 5 to 6 times the cost of 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 in addition to the advantages of high efficiency and maximum pressure.

Thus objective of 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.

B. Objective

- Design and kinematic synthesis of mechanical linkage with point to point variable pivot position to give zero to maximum angular displacement of output link displacement , and point to point control of the displacement using manual screw slide mechanism for precise output control.
- Design & analysis of components of the mechanical linkage mechanism and the output displacement link for pump application.
- Design and selection of and single cylinder piston pump to which the adjustable stroke linkage will be applied to.
- 3. Testing of the single cylinder piston pump to plot the following characteristics of pump
- a) Discharge Vs Speed
- b) Pressure Vs Speed
- c) Volumetric efficiency Vs Speed
- 4. Comparative analysis of the actual results of discharge and cost in comparison to variable discharge pump of analogous configuration

IV. WORKING PRINCIPLE

The motor drives the spiral bevel gear box thus input speed of 9000 rpm is reduced to 3000 rpm at the output of gear box where the input pulley of 25 mm diameter is fitted . The Speed at the input shaft can be varied by moving the belt on the cone pulley with (100 , 80 , 60 , 40 mm) steps thus maximum speed at the input shaft will be 1875 rpm and minimum speed will be 750 rpm.

The input shaft drives the kinematic linkage which converts rotary motion of eccentric to oscillation of link-3 which in turn oscillates the cam . The oscillation of cam is converted to reciprocation of piston and thus pumping action takes place :

Working of Stroke changing mechanism

The 12 volt dc motor is operated using a push button , thus the rotation of motor will rotate the worm which will further rotate the worm gear and thus the coupler shaft will rotate the control link . The control link position when changed will change the oscillation angle of the link-3 and thereby the stroke of cam and thus discharge from pump is changed.

V. DESIGN CONSTRUCTION

A. Design Methodology

In our attempt to design a special purpose machine we have adopted a very a very careful approach, the total design work has been divided into two parts mainly;

- System design
- Mechanical design

System design mainly concerns with the various physical constraints and ergonomics, space requirements, arrangement of various components on the main frame of machine no of controls position of these controls ease of maintenance scope of further improvement; height of m/c from ground etc.

In Mechanical design the components are categoriesed in two parts.

- Design parts
- Parts to be purchased.

For design parts detail design is done and dimensions thus obtained are compared to next highest dimension which are readily available in market this simplifies the assembly as well as post production servicing work.

The various tolerances on work pieces are specified in the manufacturing drawings. The process charts are prepared & passed on to the manufacturing stage .The parts are to be purchased directly are specified &selected from standard catalogues.

B. System Design

The system design comprises of development of the mechanism so that the given concept can perform the desired operation. The mechanism is basically an inversion of four bar kinematic linkage , hence the mechanism is suitably designed using Grashoff's law and the final outcome is shown in the figure below.

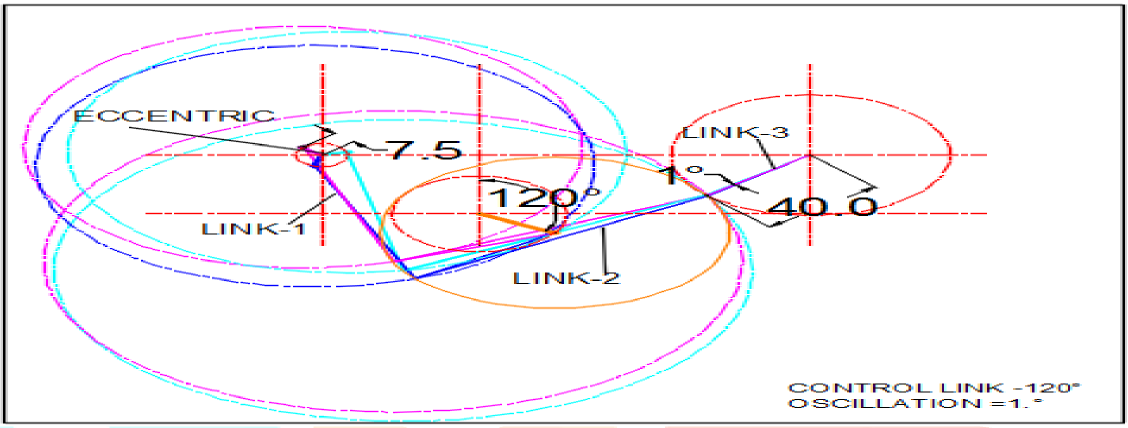


Fig. 3 kinematic linkage design using 2-d Autocad

Figure above shows the kinematic linkage design using 2-d Autocad where in the locus of each end point of the linkage are used to the response of the output link for given control link position .Here it is clear for the maximum control link position of 120 degree the output link oscillates through an angle of 1 degree indication almost zero motion of the cam thus the expected output from the pump will be zero even if motor is running.

VI. TEST & TRIAL ON LINKAGE MOTION ADJUSTER PUMP

A. 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 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 for other speed settings

Table-1 Observation Table: 0 Degree

SR. NO.	SPEED (RPM)	VOLUME IN BEAKER (ml)	TIME (SECONDS)	Actual FLOW RATE (LPM)	Th. Flow rate (lpm)	Volumetric Efficiency
01	300	100	64	0.09375	0.1085184	86.39087933
02	500	100	37	0.162162162	0.180864	89.65972342
03	700	100	27	0.222222222	0.2532096	87.76216313
04	900	100	22	0.272727273	0.3255552	83.7729739
05	1100	100	18	0.333333333	0.3979008	83.7729739
06	1300	100	16	0.375	0.4702464	79.74542708

1. **Graph of Actual flow rate Vs Speed**

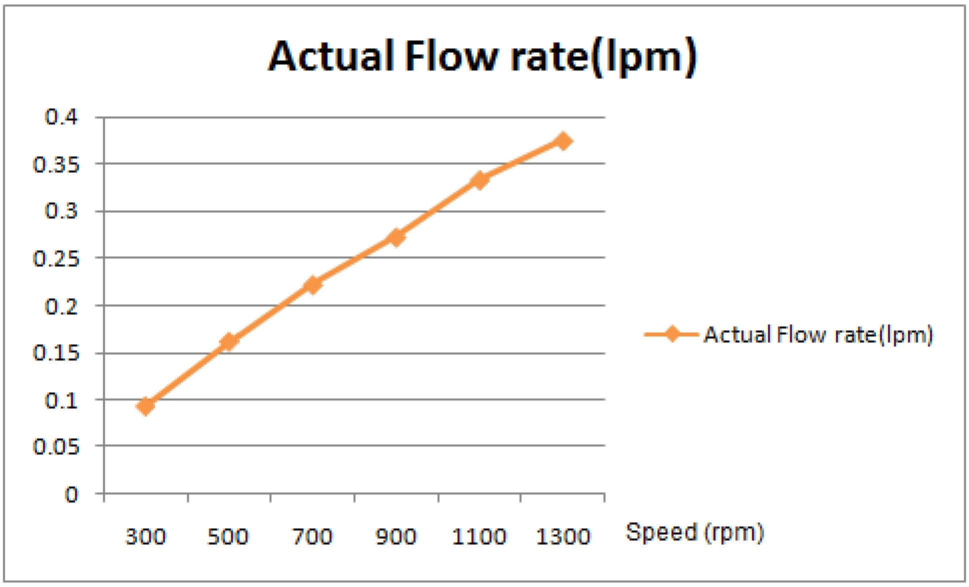


Fig.4 Graph of Actual flow rate Vs Speed

The actual flow rate is seen to increase with the increase in speed of linkage motion adjeuster pump.

2. Graph of Theoretical flow rate Vs Speed

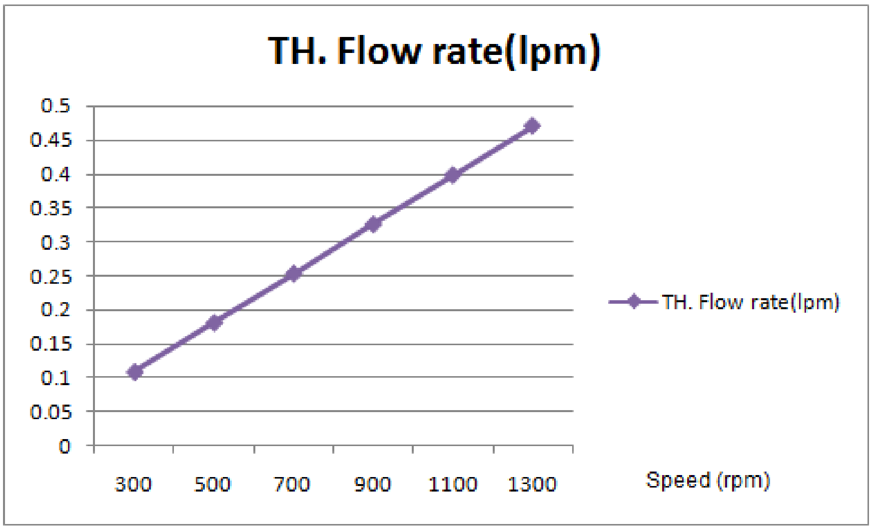


Fig.5 Graph of Theoretical flow rate Vs Speed

The theoretical flow rate is seen to increase with the increase in speed of linkage motion adjeuster pump.

3. Comparison Graph of Th & Actual Flow rate Vs speed

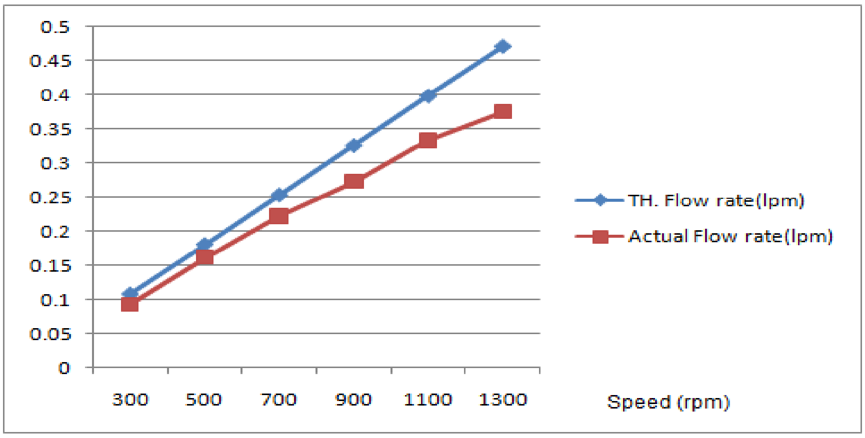


Fig.6 Comparison Graph of Th & Actual Flow rate Vs speed

The theoretical flow rate is seen to be higher than the actual flow rate although both show a rising trend with increase in speed

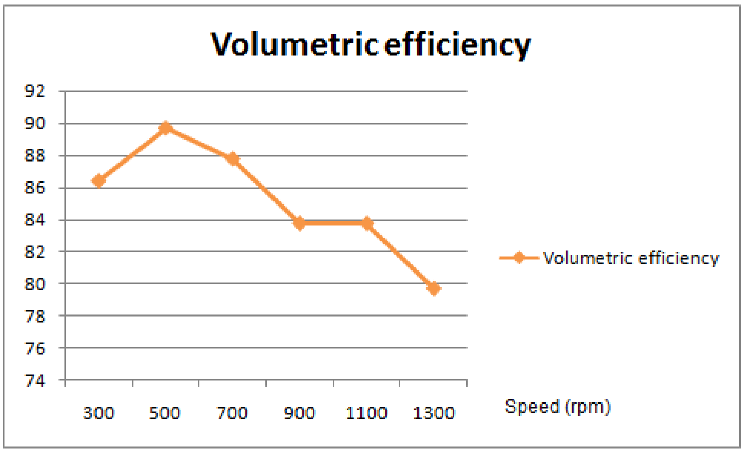


Fig.7 Volumetric efficiency

The volumetric efficiency is seen to drop at higher speed although the highest efficiency is observed at 500 rpm thus the recomended range of speed is 300 to 900 rpm

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 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 for other speed settings

Table- 2 Observation Table:120 degree

SR. NO.	SPEED (RPM)	VOLUME IN BEAKER (ml)	TIME (SECONDS)	Actual FLOW RATE (LPM)	Th. Flow rate (lpm)	Volumetric Efficiency
01	300	100	248	0.024193548	0.0271296	89.17768189
02	500	100	146	0.04109589	0.045216	90.88793881
03	700	100	103	0.058252427	0.0633024	92.02246231
04	900	100	82	0.073170732	0.0813888	89.9027037
05	1100	100	71	0.084507042	0.0994752	84.95287494
06	1300	100	63	0.095238095	0.1175616	81.01122751

1.Graph of Actual flow rate Vs Speed

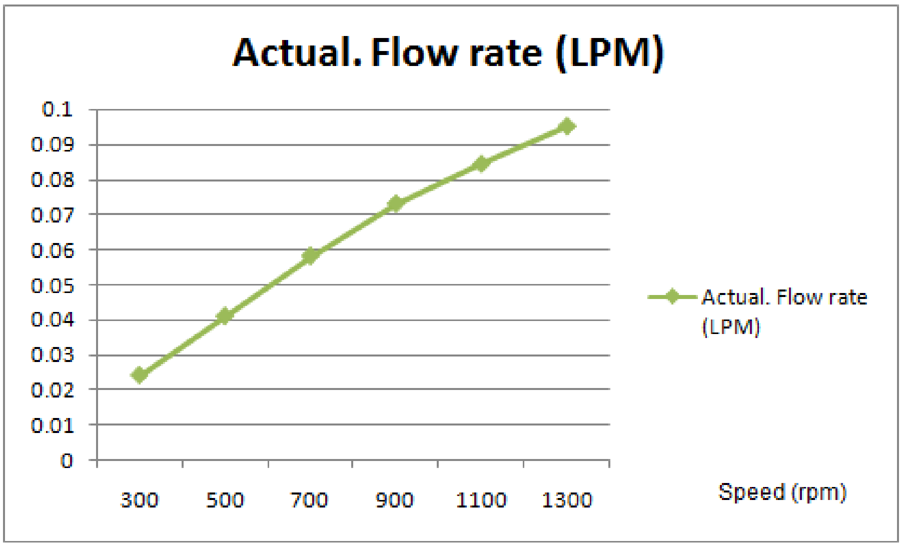


Fig. 8 Graph of Actual flow rate Vs Speed

The actual flow rate is seen to increase with the increase in speed of linkage motion adjeuster pump.

2.**Graph of Theoretical flow rate Vs Speed**

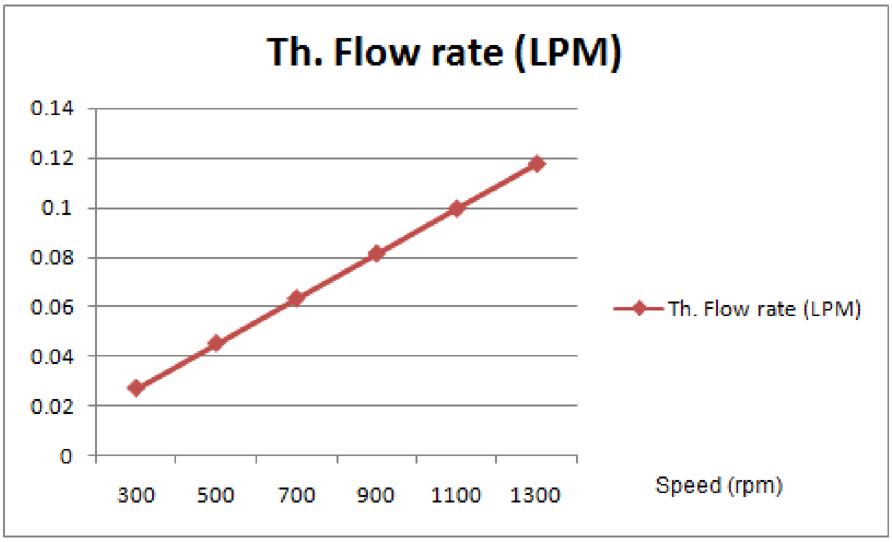


Fig.9 Graph of Theoretical flow rate Vs Speed

The theoretical flow rate is seen to increase with the increase in speed of linkage motion adjeuster pump.

3.Comparison Graph of Th & Actual Flow rate Vs speed

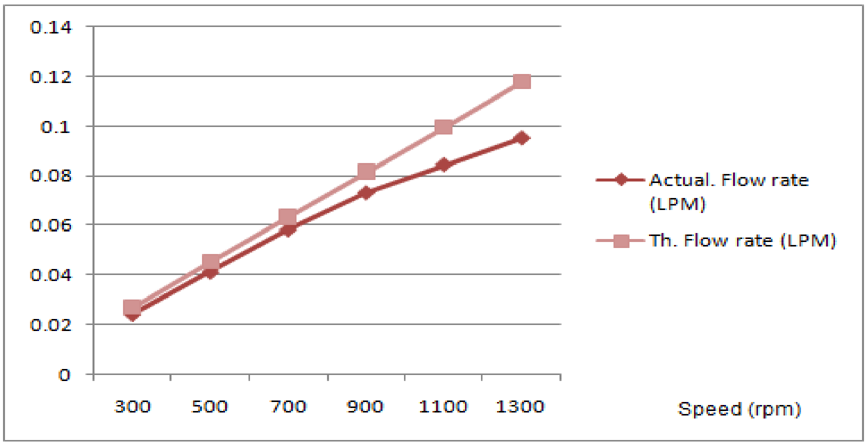


Fig.10 Comparison Graph of Th & Actual Flow rate Vs speed

The theoretical flow rate is seen to be higher than the actual flow rate although both show a rising trend with increase in speed

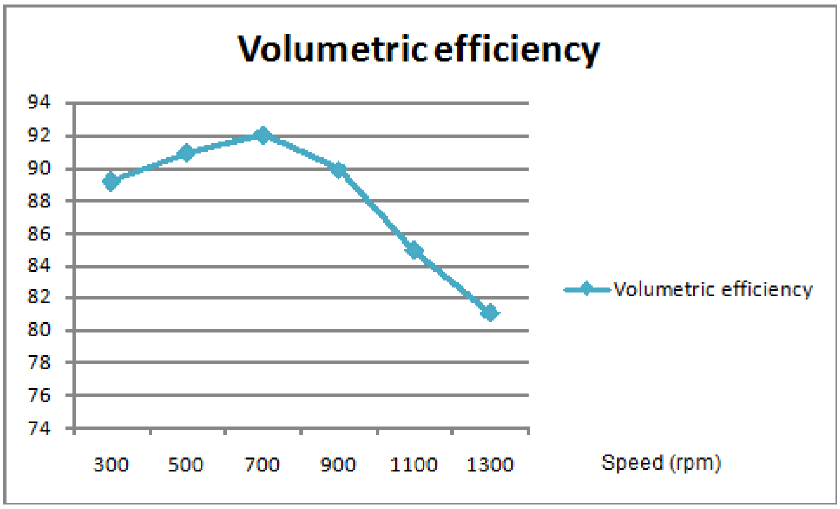


Fig.11 Comparison Graph of Th & Actual Flow rate Vs speed

The volumetric efficiency is seen to drop at higher speed although the highest efficiency is observed at 700 rpm thus the recomended range of speed is 300 to 900 rpm

VII CONCLUSION.

1] The Linkage motion adjuster pump kinematic linkage was designed using Auto-cad to find the minimum and maximum oscillation angle for the o degree and 120 degree position of the control link.
2] The critical part of the Linkage motion adjuster pump were deigned and analysis was also done using Ansys-workbench 16.0 the parts were found to be safe.
3] The testing was done for 0 degree configuration and The theoretical flow rate is seen to be higher than the actual flow rate although both show a rising trend with increase in speed The volumetric efficiency is seen to drop at higher speed although the highest efficiency is observed at 500 rpm thus the recommended range of speed is 300 to 900 rpm
4] The testing was done for 120 degree configuration and The theoretical flow rate is seen to be higher than the actual flow rate although both show a rising trend with increase in speed The volumetric efficiency is seen to drop at higher speed although the highest efficiency is observed at 700 rpm thus the recomended range of speed is 300 to 900 rpm

ACKNOLEDGEMENT.

I would like to express my gratitude, sincere thanks and deep sense of appreciation to my project guide **Dr. S. S. Patil**, Head Of The Department, Department of Mechanical Engineering, SVPM's College of Engineering, Malegaon (Bk.) for continuously assessing my work, providing great and valuable guidance.

REFERENCE.

1) *Design, Development & Analysis Of Variable Displacement Pump By Application Of Linkage Motion Adjuster Neelam M. Kamthe, M. M. Bhoomkar International Engineering Research Journal (IERJ) Special Issue 2 Page 4075-4080, 2015, ISSN 2395-162.*
2) *Modeling, Analysis, And Experimental Investigation Of A Variable Displacement Linkage Pump A Dissertation Submitted To The Faculty Of University Of Minnesota By Shawn Wilhelm In Partial Fulfillment Of The Requirements For The Degree Of Doctor Of Philosophy Advisor James D. Van De Ven, Phd July 2015.*
3) *Simulation Analysis and Experiment of Variable-Displacement Asymmetric Axial Piston Pump Youshan Gao 1,2, Jie Cheng 1, Jiahai Huang 2,* and Long Quan 2 1 December 2016; Accepted: 22 March 2017; Published: 27 March 2017.*
4) *Design, Development & Analysis of Variable Displacement Pump R.R.Kolhe, Prof.S.S.Pimpale International Engineering Research Journal (IERJ), Volume 2 Issue 6 Page 2214-2218, 2016 ISSN 2395-1621.*
5) *Design, Development and Analysis of Variable Displacement Pump by Application of Linkage Motion Adjuster Neelam M. Kamthe, Manmohan M. Bhoomkar, Ganesh E. Kondhalkar International Journal of Engineering Trends and Technology (IJETT) – Volume 32 Number 3- February 2016.*
6) *Design, Development and Testing of Bent Axis Piston Pump Vijay V. Doijad 1 Amol B. Rabade 2, A.S. Todkar 3 International Journal of Application or Innovation in Engineering & Management (IJAIEM) Web Site: www.ijaiem.org Email: editor@ijaiem.org, editorijaiem@gmail.com Volume 2, Issue 12, December 2013 ISSN 2319 – 4847.*
7) *Design, Construction And Working Of A Variable Flow Radial Piston Pump Using Variable Displacement Linkages Vikrant Rajesh Suryawanshi. B.E. (Mechanical) Research Student, D.I.E.M.S, Maharashtra, India. International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 02 Issue: 07 | Oct-2015 p-ISSN: 2395-0072.*
8) *Adaptive Control Of Variable Displacement Pumps A Thesis Presented To The Academic Faculty By Longke Wang In Partial Fulfillment Of The Requirements For The Degree Doctor Of Philosophy In The School Of Mechanical Engineering Georgia Institute Of Technology May 2011.*