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Design and Analysis of Variable Displacement Pump with Kinematic Linkage

[#1]Gourav Jadhav, [#2]Aditya Ghorpade, [#3]Sandeep Hadke, [#4]Vaibhav Gorade

[1]jadhavgourav.95@gmail.com
[2]adityaghorpade5@gmail.com
[3]sandeep.hadke1995@gmail.com
[4]vaibhavgorade1995@gmail.com

[#1234]Student, Mechanical Department,

Sinhgad Institute of Technology and Science,
Narhe, Savitribai Phule Pune University.

ABSTRACT

Variable displacement hydraulic pump with high efficiency at all operating conditions from zero to maximum output is beneficial to multiple applications. There is number of architectures currently available for variable displacement pump. But variable displacement pump is 5 to 6 times costly with compared to fixed displacement pump. Thus objective of this project is defined to develop a kinematic linkage to varying the displacement of pump. Kinematic link is joined at one end of connecting link. By controlling the position of control link can vary the output without changing the input. When control link at 120˚, zero max mechanics is at zero speed condition. When control link is at 0˚, zero max mechanism at maximum speed condition. Thus from this mechanism get variable flow rate as per requirement between 0-120 degree control link position. Modal analysis of this link gives behavior of kinematic link at different frequencies. Result of this project shown in various position of control link related flow rate and related volumetric efficiency which shows that when speed increases flow rate is going to increase at all position of control link and volumetric efficiency is slightly decreases still resultant volumetric efficiency is more beneficial. From this project tried to improve power, energy loss with cost reduction.

Keywords— Kinematic linkage, Displacement pump, Design , Analysis.

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I. INTRODUCTION

Variable displacement piston pump offers variable discharge option, and hence it is used in multiple of application such as automobile (JCB, Man lift, Dozer etc) and CNC machines hydraulic feed drive.(3-6) Conservative 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, by connecting the system of linkage stroke control piston to the sump or drain. Budget of such variable displacement pump is very high as compared to fixed displacement axial piston pumps. (11)

Axial piston pumps with constant pressure and variable flow have astonishing possibilities for controlling the flow by change of pressure. Because of pressure feedback, volumetric control of the pump provides a comprehensive application of these pumps in multifarious hydraulic systems, particularly in aeronautics and space engineering. The major complication in application of the variable displacement piston pump is enormously high cost over that of the fixed displacement piston pump, it ranges in the range of 5 to 6 times the cost of radial piston pump(11). Hence there is a need to improve a modification in the fixed displacement piston pump design that will propose 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 Fixed displacement piston pump , thereby offering to vary the discharge of the pump using manual control.

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 . 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.

II. DESIGN AND DEVELOPMENT OF LINKAGE

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. Here four links with one control link arranged for variable output without changing input. The speed changing mechanism is simple in construction.(10)

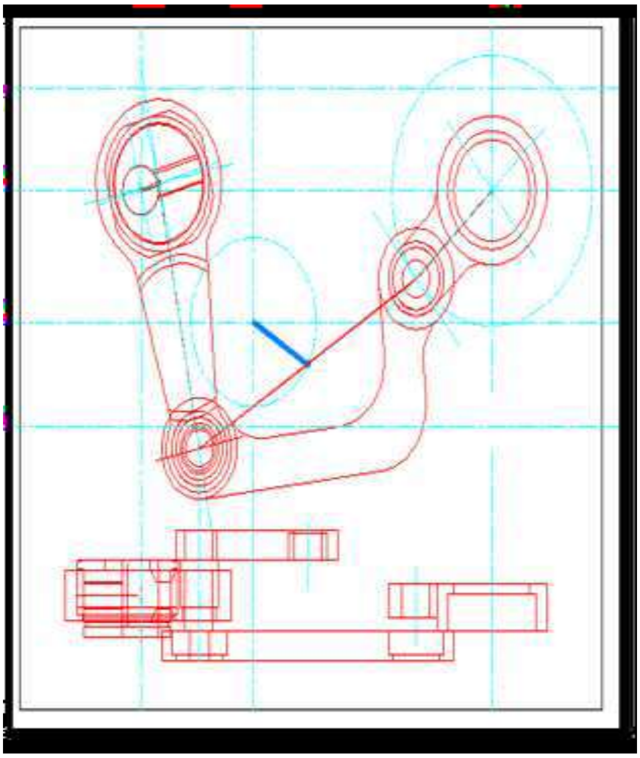

Figure 1. Linkage Overview

It consists of a control shaft that is mounted on two cranks that are hinged to the frame. The control shaft carries a handle. Turning the handle changes the position of the connecting link connecting rod joint which will lead to change in the degree of oscillation of the output yoke thereby speed change of the output shaft. It consist of base four bar crank rocker mechanism which includes the input crank, coupler link, and control link. The position of ground pivot of the control link can be adjusted through the dashed arc centered at the adjusted point. The connecting rod joints the oscillating link to the base four bar at the coupler point. When the adjusted ground pivot collinear with axis of oscillation, then oscillating link will exhibit no oscillation when crank is rotated.(3) As the adjustable ground pivot moves away from the axis, the oscillating link translate. An additional benefit of this linkage is that the slider returns to the same top dead centre position independent of displacement setting. This means that all the working fluid, can be ejected on every stroke to minimize compressibility losses. This four bar chain is constructed as shown in figure 1. This construction is attached to output shaft. The motion of shaft is oscillatory. Attach one cam on output shaft. This cam lift is adjusted as lift of cam is equal to stroke of piston pump. This assembly work as radial piston pump. Change in position of control link we produce different stroke length. Using this adjustable stoke length find out varying flow rate through radial piston pump.

III. EXPERIMENTAL SET-UP

Appropriate engineering methods will be engaged to fabricate the components and then accumulate the test set – up for design of variable displacement piston pump using variable displacement linkage. The speeds are instantaneously changed by turning the handle. On the drive shaft A is mounted a series of eccentrics B. These eccentrics are connected to connecting links C by connecting rod D.
As the drive shaft rotates , the eccentrics convey an oscillating movement to the left hand ends of the connecting links ‘C’ and as these are hinged to the output yoke E they impart oscillatory movement to the roller clutches within yokes ‘E’ .Each reciprocating movement of clutch will cause the drive shaft to rotate a fraction of a revolution , and as the eccentrics are spaced uniformly about the drive shaft , the impulse given to the driven shaft will be successive and over lapping .In this way a uniform rotary movement of the driven shaft is obtained. The fluctuating movement of the right hand end of the output link concludes the amount the driven shaft turns throughout each impulse, and this oscillating movement hinge on the position of joint known as control point along the path. An complete range of speeds is covered effortlessly, empowering the mechanism to glide from one speed to another. Using VDLP , some observation take place as speed constant and varying control angle.

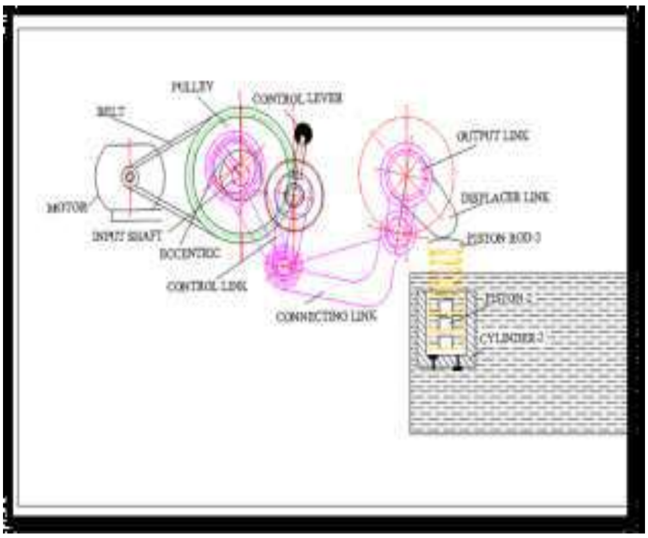

Figure 2. Experimental Set-up

IV. ANALYSIS OF KINEMATIC LINKAGE

There are various types of analysis can be done on kinematic linkage modal analysis, structural analysis, thermal analysis .

Modal analysis results behaviour of kinematic link at different vibrational conditions.

Structural analysis is used for calculating different types of stress like tensile stress ,bending stress, compression stress etc.

Thermal analysis gives information about behaviour of link at different temperature conditions.

In this paper we are calculating deflection of kinematic linkage at different frequencies using modal analysis which is on ansys software.

Modal analysis gives frequency of kinematic linkage at each calculated mode.

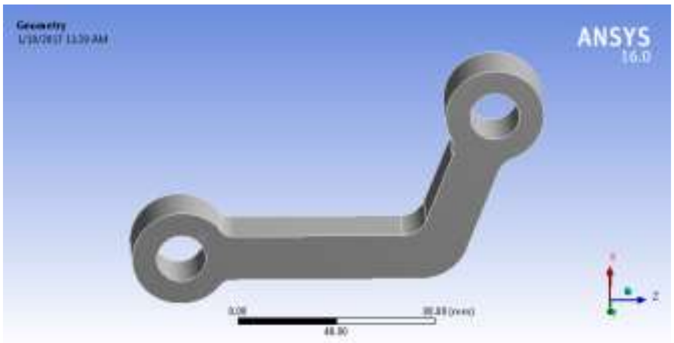

Figure 3. CAD model of linkage

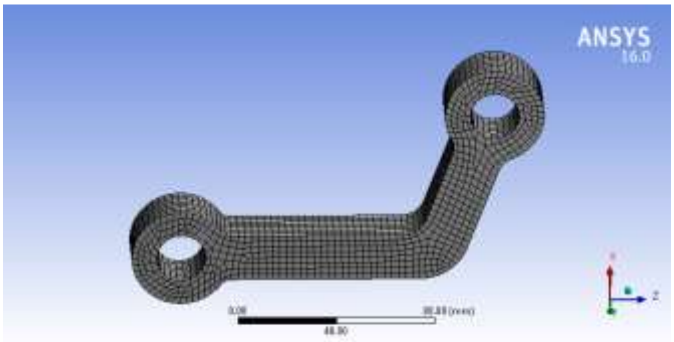

Figure 4. Meshing of linkage

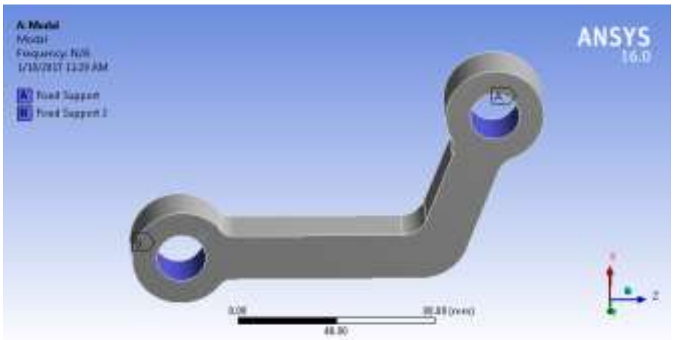

Figure 5. Fix ends of linkage

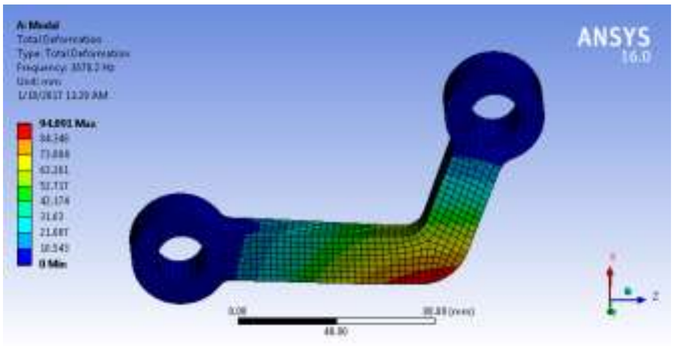

Figure 6. Deformation of linkage at frequency 3670 Hz

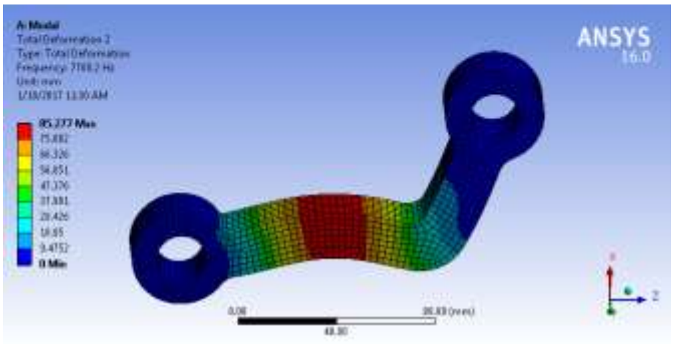

Figure 7. Deformation of linkage at frequency 7768 Hz

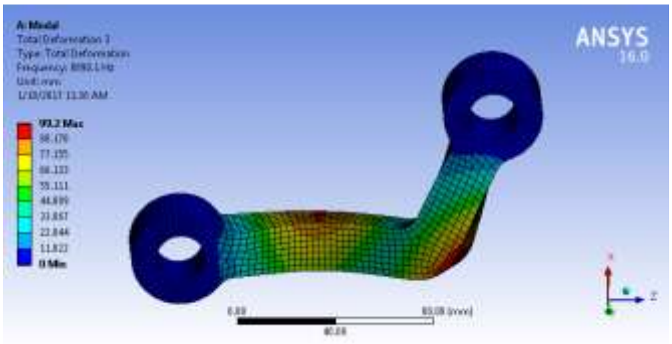

Figure 8. Deformation of linkage at frequency 8890 Hz

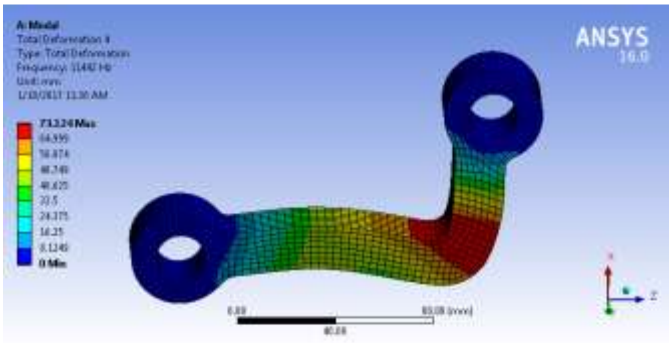

Figure 9. Deformation of linkage at frequency 11442 Hz

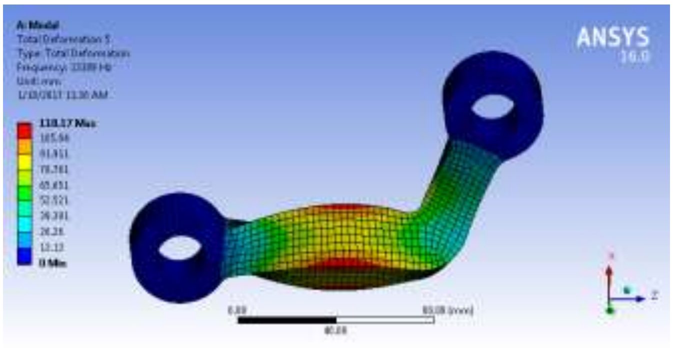

Figure10. Deformation of linkage at frequency 13389 Hz

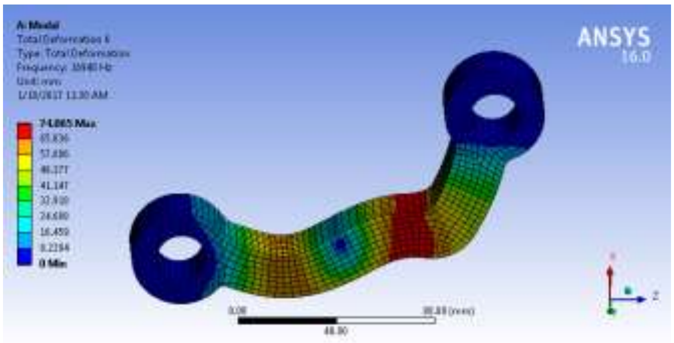

Figure 11. Deformation of linkage at frequency 16948 Hz

V. RESULTS AND TABLE

1. It is seen that the discharge from the pump reduces at the control angle is changed from 0 degree to 120 degree.
2. 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.
3. 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.
4. Precise control of the control angle will provide a wide range of flow rates thereby the pump will find application in multiple industry.
5. At the position of control link 0 degree increasing speed from 100rpm to 500rpm and measured the amount of lubricating oil collected in beaker to calculate flow rate. Same procedure repeated 20, 40, 60, 80, 100 and 120 degree angular position of control link.

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	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 2. Actual flow rate 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. CONCLUSION

Fixed displacement pump is converted into variable displacement pump by using kinematic linkage. 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. Hence the variable flow radial piston pump using variable displacement linkages was successfully designed and manufactured for perfectly economical and efficient applications.

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