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DESIGN IMPROVEMENTS OF VARIABLE DISPLACEMENT PUMPS-A REVIEW

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ABSTRACT
In Variable displacement pump the displacement or amount of fluid pumped per revolution of pump's input shaft can be varied as per requirement. This paper investigate the different improvements achieved for increase the efficiency of variable displacement pump .This paper also discussed about the alternative mechanisms for variable displacement pump to improve efficiency and cost reduction of pump.

INTRODUCTION
In industry the variable discharge of pump is required for different functions and controls. Variable displacement pumps are used for getting variable discharge in economical manner. This paper briefs about variable displacement pumps in market, and the review on research have done to improve the performance of variable displacement pump followed by conclusion.

VARIABLE DISPLACEMENT PUMPS
Volumetric control of the pump provides a wide application of these pumps in complex hydraulic systems, particularly in aeronautics and space engineering. The variable displacement pump to control hydraulic circuits gives more energy saving than throttling valve control. [1] There are three designs are available currently for variable displacement pump. Figure1 shows Swash-plate type axial-piston pump, which is 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. 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 [2]

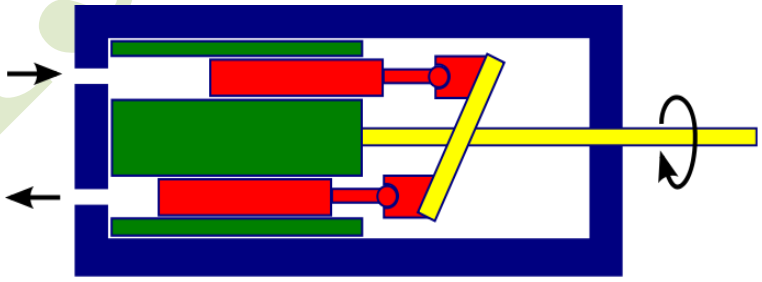

Figure 1: Swash-plate type axial-piston pumps

Bent axis pump shown in figure.3 consist of cylinder block which is inclined to the drive shaft. The disk connected inline to the drive shaft on which the piston bases are mounted and heads of pistons are inline with cylinders. When drive shaft start to rotate the pistons reciprocates in cylinders because of bent axis.[2]

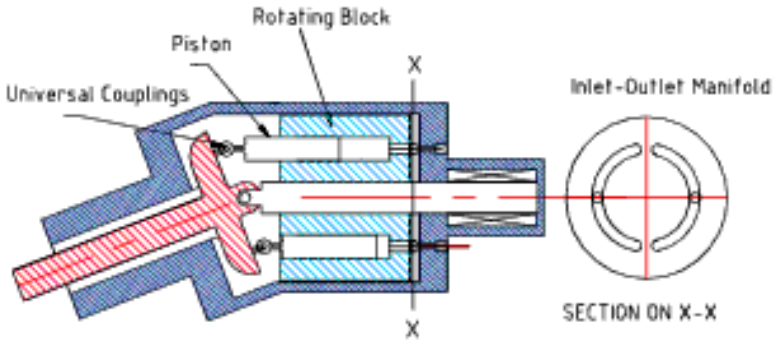

Figure 2: Bent axis piston pumps

Vane Pump Figure3 consists of rotor having vanes which rotates inside ring. Rotor is eccentric with ring. Vanes tensioned to keep the contact with walls of ring. Vanes are slide into ring and creates the chambers, volume of these chamber decreases due to eccentricity. Due to which the fluid from chambers forces out the pump. Eccentricity between rotor and ring decides the displacement. [2]

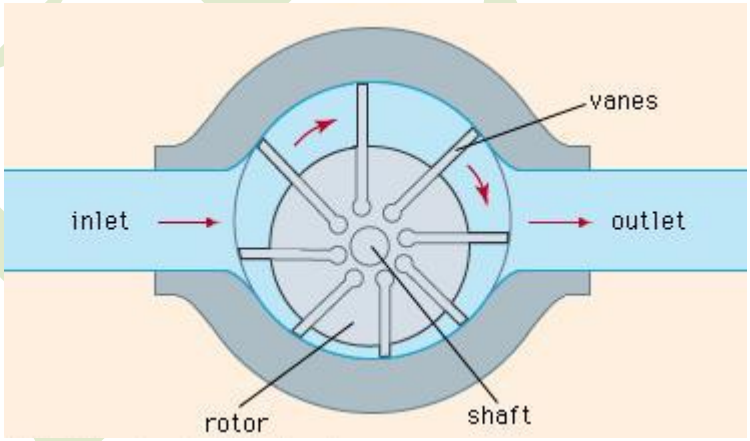

Figure 3: Vane Pump

ADVANTAGES OF VARIABLE DISPLACEMENT PUMP

- It allows fine control on operation.
- It saves power.
- Operation is economical.
- It can be used in heavy duty close circuit.
- It is used in complex hydraulic systems, particularly in aeronautics and space engineering

REVIEW ON RESEARCH OF IMPROVEMENT EFFICIENCY OF PUMP

Noah D. Manring [3] has investigate the advantages of axial piston pump by using various valve plate slot geometry, He considered three types of geometry - a constant area slot geometry, a linearly varying slot geometry, and a quadratically varying slot geometry. By analyzing the pressure transients that are associated with each design at low pump displacements, it is shown that the magnitude of the pressure transition itself and the maximum pressure time rate-of change may be specified for each design. He concludes that constant area slot design gives the advantage of minimizing the discharge area of the slot which is required. The linearly varying slot design has advantage of shortest slot utilization and the quadratically varying slot has no advantage over the above two designs. So Result of his work suggests that third design is not offer any improvement in performance.

Shu Wang[4] has research on improving the volumetric efficiency of axial piston pump. In the design of piston pump most important parameter of system is volumetric efficiency. Main obstacles in optimization the design are the geometric complexities of valve plate and its multiple interactions with pump. He uses the concept of pressure carryover to develop mathematical relationship between geometry of the valve plate and volumetric efficiency of the piston pump. He presented theoretical consideration of design of valve plate, axial piston pump efficiency, and the conditions of fluid operation. This study provides guidelines for geometries required for an efficient design, mainly valve plate timings. Under various operating conditions multiple valve plates was tested and simulated for theoretical result validation.

David Rossing Grandall[5] has research work of predicting the efficiency and performance of pumps and motor by experimentation and modeling. He constructed the pump and motor test stand to measure the efficiency of swash plate an axial piston pump. He used the regenerative loop hydraulic system to minimize the power requirement. The main test conditions are low displacement and low speed regimes. Efficiency values ranged from 0% to 82%. An existing efficiency model in the literature is fit to the data. He suggested improvement in model. He suggest displacement sensor in the pump/motor units which will be tested to avoid the uncertainty with calculating the derived volume based on the data.

Seeniraj, G. K., and Ivantysynova, M[6] discussed about design of axial piston pump, he focused on design of valve plate. Both flow pulsation and oscillating forces on the swash plate can minimize by using well designed valve plate. He used 'CASPAR' computational tool to investigate the effect of design of valve plate on flow ripple, oscillating forces and volumetric efficiency. He presented the simulation results from CASPAR on impact of various valve plate design parameters. He specified the reason of relation of pressurization and decompression inside the displacement chamber to the flow ripple, forces applied on swash plate and the control effort needed to stroke the swash plate.He presented the simulated results of effect of noise reduction techniques on volumetric efficiency.

All designs which are discussed above utilizes planar joints which having high mechanical friction and high leakage to maintain hydrodynamic bearings. In [3-6] work has been done to enhance the efficiency of these machines. But this work is for maximize efficiency only for high displacement; they have not improve poor efficiency at low displacement. So it is necessary to consider other methods to improve efficiency at lower displacement.

D. C. Tsot and S. Kdshnamoorthy [7] have presented his work to point out the versatility of adjustable 4-bar linkages for a tough-to-design task. The coupler curve with double point(s) is merely one example. Basic geometric concepts of the 4-bar linkage and the creative imagination of the designer can lead to the "invention" of many useful mechanisms.
D. C. Tsot and S. Kdshnamoorthy [8] gave result that if coupler curve with double points or cusp(s) generated by linkages then it usually consist some geometric properties which are useful for synthesis. Also Symmetrical coupler curves are generated by linkages with fewer parameters of link lengths, thus leading to simpler analysis and synthesis. He conclude that if simple adjustment is done with length of link , different curves of same nature but having different sizes can be achieved with same hardware. The variety of mechanism is achieved.
In [7-8] alternative mechanisms suggested to create adjustable crank slider linkage, which are able to vary the stroke and so the displacement. They developed the graphical synthesis technique for generating adjustable mechanisms with variable coupler curves.

Zhou, H., and Ting, K.-L discussed [9] Adjustable slider–crank linkages for multiple path generation by making simple changes in the position of the slider guider. For continuous path generation he did the synthesis of adjustable four-bar linkages, mainly for adjustable slider–crank linkages. He analyzed the path flexibility of adjustable slider–crank linkages. He set up the optimized synthesis model which is based on position structural error of the slider guider, which reflects difference between desired path and generated path, avoid the difficulty of selecting corresponding comparison points on the two paths, and can be calculated easily. He used genetic algorithm to find the global optimal solution. The results of an optimal synthesis example find the effectiveness of the proposed method.

Soong, R.-C., and Chang [10] has discussed methodology of Functional synthesis of mechanisms which is based on kinematic state, he also considered cost factor also. After a general functional representation model based on the kinematic state pair is proposed with a result of the kinematic state space, an exhaustive functional synthesis of the kinematic state pair with the lowest cost algorithm is then proposed to produce solutions with K-lowest cost.
He considered example of feeding mechanism device for cold heading machine which proves that the method which discussed is helpful to produce valuable functional chain solutions with low cost. Mechanism has presented which vary the length of moving link to change the coupler curve.

Shoup, T. E. [11] presented an idea of design of an adjustable spatial slider crank mechanism which is used as a variable displacement pump. Velocity fluctuation, force transmission effectiveness and mechanism geometric proportions are considered for design. He also mentions the example. He stated that RSSP mechanism having ability an adjustable pump mechanism.He also suggests that the use of adjustable three-dimensional linkages may useful further study for applications requiring sliding input and sliding output or for applications requiring rotary input and rotary output.

Wilhelm, S., and Van de Ven, J. DD. [12] have discussed that Compressed air energy storage system which uses a liquid piston for near -isothermal compression, this requirement is full fill by a pump having high efficiency at low discharge. So the variable displacement six-bar crank-rocker-slider mechanism, which gives zero displacement along with a constant top dead center position, has been designed. They also presented the synthesis process which develops the range for four bar crank-rocker motion. Also they synthesized the output slider dyad and analyzes the mechanisms performance in terms of transmission angles, slider stroke,

mechanism footprint, and timing ratio and proves that, It is shown that slider transmission angles can be kept above 60 degrees and the base four-bar transmission angles can be controlled to improve overall efficiency. This synthesis procedure develops a crank-rocker-slider mechanism for a variable displacement pump that can be efficient for all displacements.

Wilhelm, S., and Van de Ven, J. DD [13] have also investigate that a variable displacement pump is beneficial to multiple applications with high efficiency at all operating conditions, including low displacement. Two disadvantages in conventional pumps are the friction and lubrication leakage in the kinematic joints. Similar to conventional pump/motor architectures this paper presents synthesis, analysis, and experimental validation of a variable displacement six bar crank-rocker-slider mechanism that uses low friction pin joints instead of planar joints .The compressibility energy losses reduced due to the novel linkage reaches true zero displacement with a constant top dead center position. The synthesis method develops the range of motion for the base four bar 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 four bar transmission angle of 30 deg and a resultant slider transmission angle of 52 deg. 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

CONCLUSION

Variable displacement pump is suitable for very fine control economically. Based on the literature review, this paper reviews the various improvements have done to improve the performance of Variable displacement of pump. But most of the work have resulted to increase efficiency, but not focused on lower efficiency at low volumetric displacement.

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