ISSN 2395-1621

Design, Development & Analysis Of Variable Displacement Pump By Application Of Linkage Motion Adjuster

[#1]Neelam M. Kamthe, [#2]M. M. Bhoomkar

[1]neelam.kamthe007@gmail.com
[2]manmohan_bhoomkar@yahoo.co.in

[#12]Mechanical Engineering Department, SavitribaiPhule Pune University,
ABMSP's AnantraoPawar College of Engineering and Research, Parvati, Pune

ABSTRACT

This 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 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. 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 a 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 Unigraphix 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

Keywords- a Piston Pump,Linkages,Pivot,motion adjuster.

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

This 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. 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

© 2015, IERJ All Rights Reserved

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 classesareReciprocating, 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.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. 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 preffered 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.

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).

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

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

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.

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.

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.

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

II.LITERATURE REVIEW

Shawn R. Wilhelm and James D. Van de Venhave studied on the 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 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 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 degree 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

© 2015, IERJ All Rights Reserved

experimental prototype linkage agree well with the model predictions.[1]

Williamson, C., Zimmerman, J., and Ivantysynovastudied Utilizing variable displacement hydraulic pumps and motors to control a hydraulic circuit offers significant energy savings over throttling valve control.[2]

Li, P. Y., Loth, E., Simon, T. W., Van de Ven, J. D., and Crane, S. E. studied
the efficiency of variable displacement machines decreases significantly at low displacement.This results in poor efficiency for applications that require operating at partial load for the majority of the cycle such as hydraulic hybrid vehicles, hydrostatic transmissions for wind power, and the unique application of compressed air energy storage using a liquid piston.[3].

Ivantysyn, J., and Ivantysynova, M.,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 inline with the drive shaft while the piston heads are inline 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 [4].

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 [5–10].

Tao and Krishnamoorthy,For the most part, previous efforts have resulted in an increase in the maximum efficiency, but they have not addressed poor efficiency at low volumetric displacement. It is, therefore, reasonable to consider other methods of varying displacement. 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 so they developed graphical synthesis technique for generating adjustable mechanisms with variable coupler curves [11,12].

McGovern and Sandor presented a method using complex numbers to analytically synthesize adjustable mechanisms for variable function and path generation [13,14].

Handra- Luca outlined a design procedure for sixbar mechanisms with adjustable oscillation angles [15].

Zhou and Ting presented a method of generating adjustable slider-crank mechanisms for multiple paths by adjusting the distance between the slideraxis and the crank.Adjustable slider–crank linkages are capable of generating multiple paths with a simple adjustment ofthe position of the slider guider. Little work has been done in the area of synthesis of adjustable four-barlinkages for continuous path generation, especially of adjustable slider–crank linkages. The path flexibilityof adjustable slider–crank linkages is analyzed. The optimal synthesis model is set up based on the positionstructural error of the slider guider introduced in this paper, which can effectively reflect the overall differencebetween the desired and the generated paths, avoid the difficulty of selecting corresponding comparisonpoints on the two paths, and can be calculated conveniently. A genetic algorithm is employed toseek the global optimal solution. The results of an optimal synthesis example verify the effectiveness of theproposed method. [16].

A number of adjustable four- and sixbar mechanisms have been presented, which vary the length of a moving link to change a coupler curve[17–23].

Adjustable linkage mechanisms for controlling piston displacement have been previously described and patented for internal combustions engines to vary the compression ratio to meet the power demand [24–29].

Shoup,Adjustable linkage mechanisms for controlling piston displacement have been previously described but these engine linkages, however, do not go to zero displacement Shoupdeveloped a technique for the design of an adjustable spatial slider-crank mechanism for use in pumps or compressors [30].

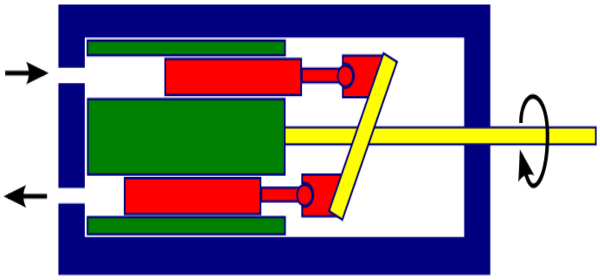
Wilhelm, S., and Van de VenA hydraulic pump/motor with high efficiency at low displacements is required for a compressed air energy storage system that utilizes a liquid piston for near-isothermal compression. To meet this requirement, a variable displacement six-bar crank-rocker-slider mechanism, which goes to zero displacement with a constant top dead center position, has been designed. 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. This synthesis procedure constructs a crank-rocker-slider mechanism for a variable displacement pump/motor that can be efficient throughout all displacementsSpatial mechanism requires the repositioning of the axis of slide relative to the crank. None of these mentioned techniques and examples provides both a constant top dead center (TDC) regardless of displacement and the ability to reach zero displacement. Apreliminary kinematic synthesis technique was previously described by the authors [31]

III. PROBLEM STATEMENT

Swash-plate type axial-piston pumps are used as the fluid power-source for hydraulic circuitry. These devices are used

© 2015, IERJ All Rights Reserved

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.



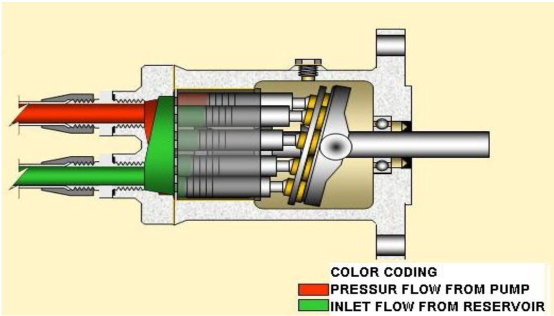


Figure 1Axial Piston pump/Swash plate type Piston pump.

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.

NEED FOR 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

IV.METHODOLOGY

In this mechanism shown 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 .

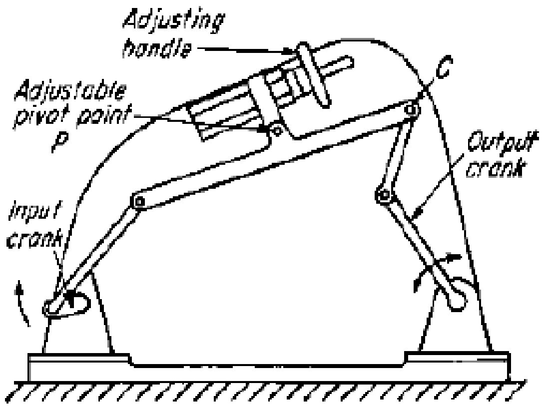


Figure 3.Adjustable Stroke Mechanism Using Adjustable Pivot Drive

V.PROPOSED METHODOLOGY

- Design and Development

System design as to and theoretical derivation of dimensions of the adjustable stroke mechanism kinematic linkage using' Kinematic overlay method' using Auto –Cad software.System Design and theoretical derivation of dimensions of the pump activation linkage for the above derived kinematic linkage system.System Design and theoretical derivations of linkage as for strength criterion for given pressure and flow specifications.Selection of pump and drive for circulation of oil through the hydraulic system to get desired flow rates .Selection of motor and drive system for the eccentric arrangement to deliver desired power to pump system.Development of PID diagram for the circuit of hydraulic oil from the modules to the system and flow from the system back to the oil tank.Design validation of the stress produced in the parts like input shaft , eccentrics , connecting link , output link , control link , piston rod , displacer link , using ANSYS software.

- Fabrication

© 2015, IERJ All Rights Reserved

Suitable manufacturing methods will be employed to fabricate the components and then assemble the test set –up

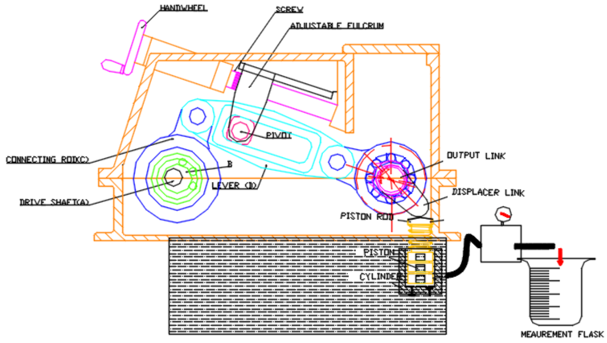


Figure 2.Assembled test set –up.

- 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

ACKNOWLEDGEMENT

Thanks to Dr. M.M.Bhoomkar and Prof. G. E. Kondhalkarfor there valuable contribution in carrying out this project..

REFERENCE

[1] Shawn R. Wilhelm, James D. Van de Ven , “Design and Testing of an Adjustable Linkage for a Variable Displacement Pump”, Journal of Mechanisms and Robotics, NOVEMBER 2013, Vol.5.

[2] Williamson, C., Zimmerman, J., and Ivantysynova, M., 2008, “Efficiency Study of an Excavator Hydraulic System Based on Displacement-Controlled Actuators,” Proceedings of the Bath/ASME Symposium on Fluid Power and Motion Control.

[3] Li, P. Y., Loth, E., Simon, T. W., Van de Ven, J. D., and Crane, S. E., 2011, “Compressed Air Energy Storage for Offshore Wind Turbines,” International Fluid Power Exposition, Las Vegas, NV.

[4] Ivantysyn, J., and Ivantysynova, M., 2001, Hydrostatic Pumps and Motors, Academic Books International, New Delhi.

[5] Wieczorek, U., and Ivantysynova, M., 2002, “Computer Aided Optimization of Bearing and Sealing Gaps in Hydrostatic Machines—The Simulation Tool CASPAR,” Int. J. Fluid Power, 3(1), pp. 7–20.

[6] Manring, N. D., 2003, “Valve-Plate Design for an Axial Piston Pump Operating at Low Displacements,” ASME J. Mech. Des., 125(1), pp. 200–205.

[7] Inaguma, Y., and Hibi, A., 2007, “Reduction of Friction Torque in Vane Pump by Smoothing Cam Ring Surface,” Proc. Inst. Mech. Eng., Part C: J. Mech. Eng. Sci., 221(5), pp. 527–534.

[8] Wang, S., 2012, “Improving the Volumetric Efficiency of the Axial Piston Pump,” ASME J. Mech. Des., 134, p. 111001.

[9] Grandall, D. R., 2010, “The Performance and Efficiency of Hydraulic Pumps and Motors,” MSc. thesis, The University of Minnesota, Minneapolis, MN.

[10] Seeniraj, G. K., and Ivantysynova, M., “Impact of Valve Plate Design on Noise, Volumetric Efficiency and Control Effort in an Axial Piston Pump,” ASME 2006 International Mechanical Engineering Congress and Exposition, Fluid Power Systems and Technology, Chicago, IL, ASME Paper No. IMECE2006- 15001, Nov. 5–10, New York, pp. 77–84.

[11] Tao, D. C., and Krishnamoorthy, S., 1978, “Linkage Mechanism Adjustable for Variable Symmetrical Coupler Curves With a Double Point,” Mech. Mach. Theory, 13(6), pp. 585–591.

[12] Tao, D. C., and Krishnamoorthy, S., 1978, “LinkageMechanism Adjustable for Variable Coupler Curves With Cusps,” Mech. Mach.Theory, 13(6), pp. 577–583.

[13] McGovern, J. F., and Sandor, G. N., 1973, “Kinematic Synthesis of Adjustable Mechanisms (Part 1: Function Generation),” ASME J. Eng. Ind., 95(2), pp. 417–422.

[14] McGovern, J. F., and Sandor, G. N., 1973, “Kinematic Synthesis of Adjustable Mechanisms (Part 2: Path Generation),” ASME J. Eng. Ind., 95(2), pp. 423–429.

[15] Handra-Luca, V., 1973, “The Study of Adjustable Oscillating Mechanisms,” ASME J. Eng. Ind., 95(3), pp. 677–680.

[16] Zhou, H., and Ting, K.-L., 2002, “Adjustable Slider-Crank Linkages for Multiple Path Generation,” Mech. Mach. Theory, 37(5), pp. 499–509.

[17] Xu, W., Lewis, D., Bronlund, J., and Morgenstern, M., 2008, “Mechanism, Design and Motion Control of a Linkage Chewing Device for Food Evaluation,” Mech. Mach. Theory, 43(3), pp. 376–389.

[18] Grenier, M., and Gosselin, C., “Kinematic Optimization of a Robotic Joint With Continuously Variable Transmission Ratio,” Proceedings of the ASME 2011 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Washington, DC, Aug. 28–31, ASME, New York, pp. 513–521.

[19] Patel, S. R., and Patel, D., 2013, “Dynamic Analysis of Quick Return Mechanism Using MATLAB,” Int. J. Eng. Sci. Innovative Technol., 2(3), pp. 346–350.

[20] Shyu, J. H., Chen, C. K., Yu, C. C., and Luo, Y. J., 2011, “Research and Development of an Adjustable Elliptical Exerciser,” Adv. Mater. Res., 308, pp. 2078–2083.

© 2015, IERJ All Rights Reserved

[21] Bai, L., Ge, W.-j., Chen, X.-h., and Meng, X.-y., "Hopping Capabilities of a Bio-Inspired and Mininally Actuated Hopping Robot," 2011 International Conference on Proceedings of the Electronics, Communications and Control (ICECC), Zhejiang, China, Sept. 9–11, IEEE, New York, pp. 1485–1489.

[22] Soong, R.-C., and Chang, S.-B., 2011, "Synthesis of Function-Generation Mechanisms Using Variable Length Driving Links," Mech. Mach. Theory, 46(11), pp. 1696–1706.

[23] Anirban, G., and Amarnath, C., 2011, "Adjustable Mechanism for Walking RobotsWith Minimum Number of Actuators," Chin. J. Mech. Eng., 24(5), p. 760.

[24] Nelson, C. D., 1985, Variable Stroke Engine, U.S. Patent 4,517,931.

[25] Pierce, J., 1914, Variable Stroke Mechanism, U.S. Patent 1,112,832.

[26] Pouliot, H. N., Delameter, W. R., and Robinson, C. W., 1977, "A Variable Displacment Spark-Ignition Engine," SAE Technical Paper No. 770114, SAE International.

[27] Yamin, J. A. A., and Dado, M. H., 2004, "Performance Simulation of a Four- Stroke Engine With Variable Stroke-Length and Compression Ratio," Appl. Energy, 77(4), pp. 447–463.

[28] Freudenstein, F., and Maki, E. R., 1981, "Variable Displacement Piston Engine," U.S. Patent 4,270,495.

[29] Freudenstein, F., and Maki, E., 1983 "Development of an Optimum Variable- Stroke Internal-Combustion Engine Mechanism From the Viewpoint of Kinematic Structure," ASME J. Mech., Trans, and Automation, 105(2), pp. 259–266.

[30] Shoup, T. E., 1984, "The Design of an Adjustable, Three Dimensional Slider Crank Mechanism," Mech. Mach. Theory, 19(1), pp. 107–111.

[31] Wilhelm, S., and Van de Ven, J. D., 2011, "Synthesis of a Variable Displacement Linkage for a Hydraulic Transformer," Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, IDETC/CIE 2011, August 28–31, 2011, Washington, DC, ASME, New York, p. 8.

© 2015, IERJ All Rights Reserved