# Design and Development of Stepless Variable Speed Kinematic Linkage Drive

**Avinash A. Kawale**, **Dr. F.B.Sayyad**

*Abstract*— **This paper presents the synthesis, analysis, and experimental validation of a variable displacement four-bar crank-rocker-slider mechanism that uses low friction pin joints instead of planar joints. The synthesis technique develops the range of motion for the base four-bar crank-rocker and creates a method of synthesizing the output slider. Kinematic Linkage Transmission is a mechanical adjustable speed drive .The speed range is infinitely adjustable from 0 to ¼ of input speed under full rated load. Speed Adjustments are easily made by moving a lever control through an arc. Precise speed control settings are possible.**

**Index Terms — Cam, Continuously Variable Transmission, Link Mechanism, Quadric Crank Chain, Ratchet**

## I. Introduction

There are many machines and mechanical units that under varying circumstances make it desirable to be able to drive at an barely perceptible speed , an inter mediate speed or a high speed. Thus a infinitely variable (or step-less speed variation in which it is possible to get any desirable speed. Some mechanical hydraulic and electrical devices serve as such step-less drives .However the torque Vs speed characteristics of these drives do not match that of step-less drives at increased driving torque at low speeds.

Hence the need of an step-less drive with the following characteristics

- Step-less or infinitely variable speed.
- Wide range of speed variation i.e. (N-max to N-min).
- Shifting form one speed to another should be Shockless.
- Minimum number of controls for speed changing.
- Ease of operation.
- Compact construction.

Worked on examines and compares the five basic principles that can be used in continuously variable transmission design (CVT). It describe commercially available CVTs suitable for motor vehicles. Basic terms used in this report are defined in this section. A CVT is a transmission having a speed ratio that can be varied continuously over its allowable range. Its speed ratio may take on any value between its operational limits, i.e., an infinite number of ratios are possible.

A gearbox transmission, on the other hand, has a discrete number of fixed speed ratios. One important disadvantage of the ratchet type CVT is that it does not allow reverse torque. The only way to get regenerative braking is to put two such CVTs in parallel, but reversed with respect to each other. One would then be used for positive torque and the other for regenerative braking [1]. Have carried out work on, An automatically and smoothly continuously variable transmission, for transmitting input mechanical energy from a crank to the drive wheel. A ratchet have oscillatory alternating motion member and a continuous rotary motion member, connected to the driven wheel. More particularly the invention is an entirely mechanical transmission mechanism, which automatically and continuously varies the transmission ratio in a Stepless manner as a function input and output torque and speed although the transmission is particularly suitable for bicycles, it also has properties which are advantages for other vehicles and other machines [2]. The purpose of this research has been to investigate the family of positive engagement, continuously variable transmissions, which have the possibility for higher efficiency and torque capabilities than the friction dependent CVTs that are currently in use. The analysis of the positive engagement CVT family reveals that all published embodiments belonging to this family must overcome a problem called the non-integer tooth problem. This research has described this problem as it exists in three published embodiments. This has been done to show several ways in which this problem can be manifest [3]. Have carried out work on, this paper describes the continuously variable transmission (CVT) generally CVTs, are classified as belt-type or toroidal CVTs, and each CVT is basically composed of two parts such as the V-belt and pulley. or friction wheel. In the belt-type CVT, the pulley is driven by a belt placed between two circle boards in the pulley, while in the toroidal CVT, We have proposed an L-CVT in which the link of the quadric crank chain, the cam mechanism and the ratchet mechanism were mounted. Since the proposed method is not based on friction conduction, it provides a mechanism that creates no noise and no slip [14], is durable, and offers high transmission efficiency [4]. In the current automotive industry, there is a strong emphasis being placed on the fuel efficiency of a vehicle. This demand for efficiency is driven primarily by fluctuating fuel costs and a desire to reduce emissions. In response to this demand, hybrid vehicle sales have increased. These vehicles have proven to be efficient because they draw their power from an internal combustion engine coupled with an auxiliary power source capable of energy recovery [5]. It has been found in the past that contact stress is limiting factor for torque capacity of a cam based continuously variable transmission. While other high stressed component can we resized in order to somewhat accommodate high load such as sprig clutches, the input shaft and the planetary gear system. It has found herein that the cam and roller system have greater system on transmission size. Although the variable transmission system has a uniform output velocity given a constant input. The result of the heavy follower return spring storing and releasing energy as they

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held the followers to the cam [6]. A variable displacement hydraulic pump/motor with high efficiency at all operating conditions, including low displacement, is beneficial to multiple applications. This paper presented 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. 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 [7].

## II. Objective

Design & drawing of kinematic linkage to deliver 1:4 reduced output in step-less way.
Development & manufacturing of drive
Testing of drive to derive the performance.
Plot Performance Characteristic Curves ;
Kinematic Synthesis of kinematic linkage mechanism for optimized output.

## III. Method

Type Synthesis and Task Specifications.
The concept of the linkage is to vary one of the links such that there is a change in the displacement or stroke of a slider (the piston). Several requirements must be defined to guide the synthesis process. For simplicity, variability will be achieved by moving a ground pivot rather than changing the length of a moving link. The axis of slide of the piston and the ground pivot of the crank will remain fixed to simplify the pump/motor block. Therefore, a third movable ground pivot is required for a functioning variable linkage. A minimal number of links is favorable as it limits the linkage's complexity, moving mass, and overall size.[7]

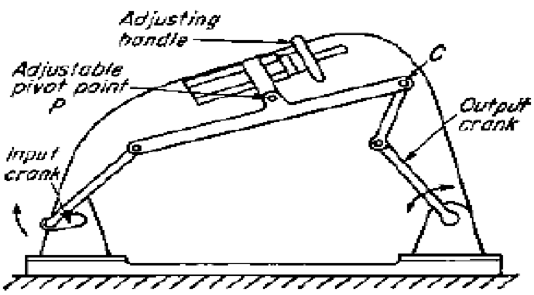


*Figure 1 Basic Design Concept*

Quadric Crank Chain
The structure of a quadric crank chain is shown in Fig. 2(a). the lengths of links a, b, c and d are different, and each link is connected by a rotation joint. The link mechanism becomes a crank-rocker mechanism if the condition of the four link lengths is satisfactory. It is assumed that it is possible to rotate the shortest link, a, which is the crank, completely around the rotation axis A. Link b, the connecting rod, transmits the movement of link a to the link c. Link c is a rocker whose shuttling corner moves by centering on rotation axis D. When the link d, which is adjoined to rotation joint A, is fixed, the links of the quadric crank chain forms a crank-rocker mechanism. In a precise sense, there is a relationship between the lengths of the different links.
In the quadric crank chain, there are also another three kinds of movements: i) a double-crank mechanism and ii) a parallelogram mechanism, which are continuously in motion, and iii) a double-rocker mechanism whose motion is not continuous. The condition that the movement of the crank-rocker mechanism is appropriate if and only if the sum of the lengths of the shortest link, a, and another one of links is smaller than the sum of the lengths of the other two links [4]. To achieve the movement as the crank-rocker (lever-crank) mechanism, it is necessary to derive the limitation condition in the length of four links. We consider about the length of each link in the state when the link c comes to the right side of edge, as shown in Fig. 2(b). In Δ AC1D, the inequality
$a + b < c + d$ (1)
is satisfied, and in Δ AC2D, about the length of each link in the state when the link c comes to the left side of edge,

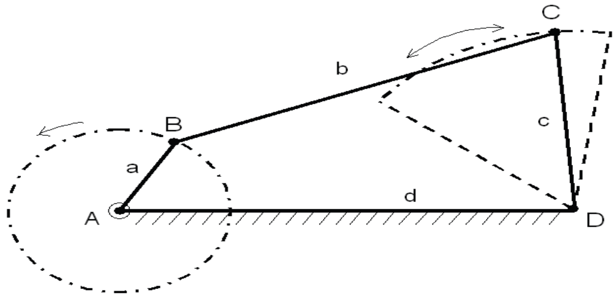


*Figure 2(a)*

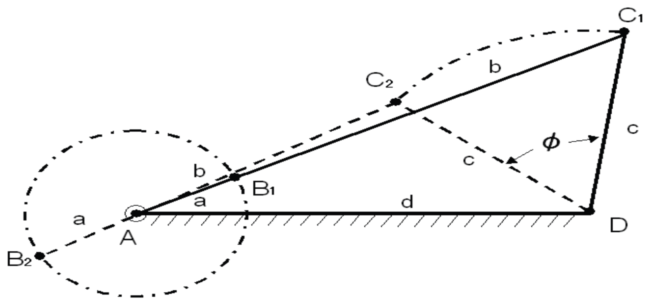


*Figure 2(b)*

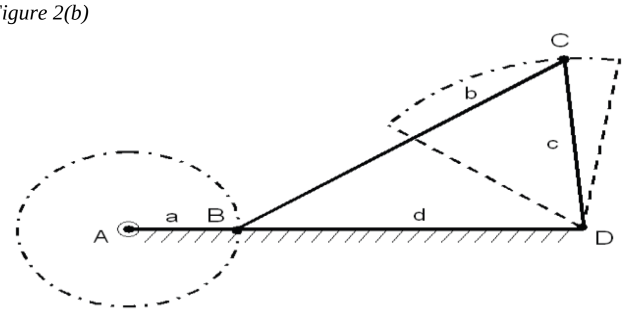


*Figure 2(c)*

as shown in Fig. 2(b), the inequality
$b - a + c > d$ , (2)
that is,
$a + d < b + c$ (2)'
is satisfied. As shown in Fig. 2(c), in Δ BCD, the inequality
$d - a + b > c$ (3)
that is,
$a + c < b + d$ (3)'
is satisfied, at the same time, the inequality (1) is also satisfied in this case. The inequality (2)' can also be satisfied when the point B comes to the other side for the center point A in Fig. 4(c). Consequently, the shortest link a can rotate if and only if the sum of the lengths of the shortest link a itself and the other one link is smaller

than the sum of the lengths of the other two links [4], [4].

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 3.

The synthesis of the output to be derived from the linkage mechanism is derived by application of Graphical method of kinematic design named the, kinematic overlay method'. The input link is rotated through 180 degree to plot the locations of the output link at start and end of cycle to determine the output from the linkage.

In this case the desired output is derived by moving the control pivot in two positions namely

- Control link position –A
- Control link position- B

The permutations of the same are as shown below

To achieve the desired rated output the linkage control link is moved from Control link position –A to control link position –B. The Control link pivot thereby changes the degree of oscillation of the output link which is further rectified using one way clutches to get a uni-directional output. Another unique feature of the drive being that the speed changes are step-less and hence the speed changes can be closely and precisely monitored.

By application of kinematic overlay method the plots of the input and output link position are determined to derive the desired speed change at a given location of the control link. The figure 4 below illustrates the phenomenon of speed change.

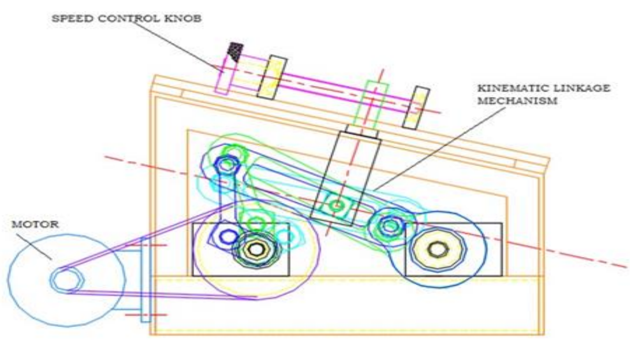


*Figure 3 Proposed Mechanism Model for Kinematic Variable Speed drive*

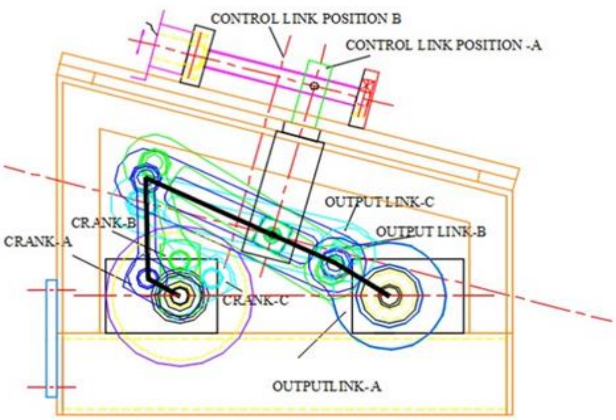


*Figure 4 Kinematic Position Control of Mechanism for variable speed*

Kinematic Position Analysis

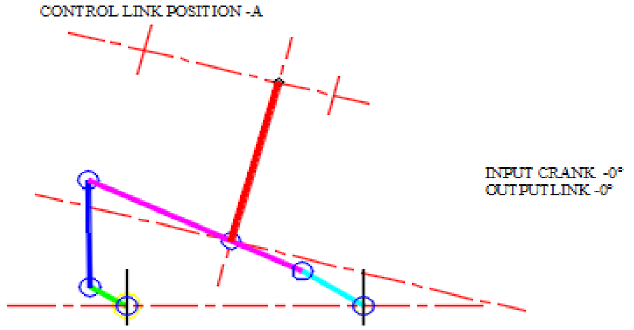


*Figure 5 Controller Link Position A at 0°*

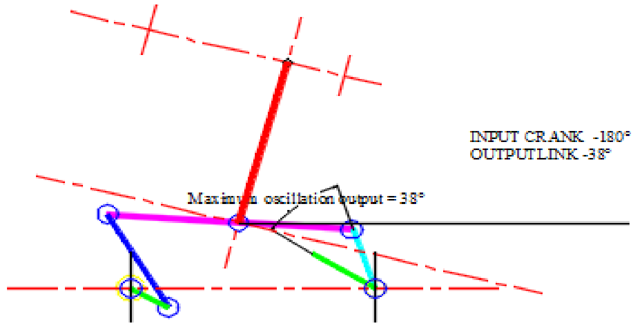


*Figure 6 Input Crank at 180°, output crank at 38°*

| Input element | Degree of rotation | Output oscillation | Total output |
|---|---|---|---|
| Crank-A | 0 to 120 | 38 | 114 degree |
| Crank-B | 0 to 120 | 38 | |
| Crank-C | 0 to 120 | 38 | |

*Table 1*

Thus it is safe to assume that at control link position the ratio achieved by the kinematic linkage is Minimum of 1:4 as 90 degree output for 360 degree rotation of input is possible. Thus the target of 1:4 ratio is achieved

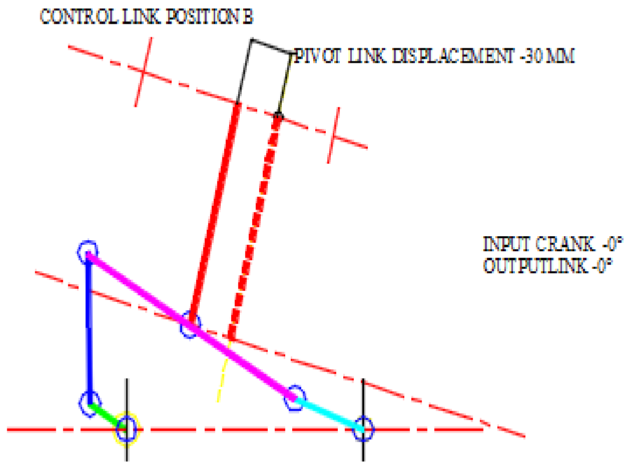


*Figure 7 Controller Link Position B at 0°*

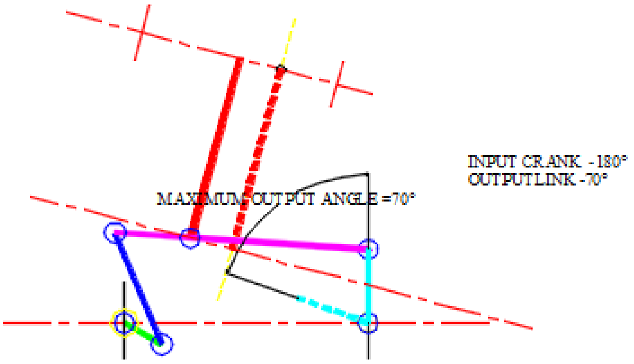


*Figure 8 Input Crank at 180°, output crank at 70°*

| Input element | Degree of rotation | Output oscillation | Total output |
|---|---|---|---|
| Crank-A | 0 to 120 | 70 | 210 degree |
| Crank-B | 0 to 120 | 70 | |
| Crank-C | 0 to 120 | 70 | |

*Table 2*

Thus it is safe to assume that at control link position the ratio achieved by the kinematic linkage is Maximum of 1:2 as 180 degree output for 360 degree rotation of input is possible. Thus the target of 1:2 ratio is achieved.

## IV. Results & Discussion

1. Minimum ratio of 1:4 speed reduction can be attained.
2. Maximum Ratio of 1:2 speed reduction can be attained.
3. Speed changes can be attained in a step less manner.
4. With Above Synthesis data Project can proceed for Next Phase 3 Onwards for Design, Model Fabrication & testing for Actual Test Results.

## V. Conclusion

This paper describes a synthesis technique and experimental validation of an adjustable linkage for use as a Stepless variable speed kinematic linkage drive. The speed range is infinitely adjustable from 1/2 to 1/4 of input speed under full rated load . Such a linkage is made by creating a base four bar Attaching to fix frame & giving a provision of fine link length adjustment to achieve Stepless variable speed under full rated load.

## Acknowledgment

Completing a task is not one man effort. It is often Contribution of many people direct or indirect ways. The help of people, which has enabled this activity towards completion, is Unforgettable. I feel happiness in forwarding this project report as an image of sincere efforts. The successful project report heartfelt gratitude to our guide Dr. F.B.Sayyad. Also I would like to express our heartfelt gratitude to our Head of Department for his constant interest and encouragement throughout the completing of our project report.

## References


[1] Norman H. Beachle , Andrew A. Frank ,College of Engineering University of Wisconsin, Madison ,"Continuously Variable Transmissions: Theory And Practice" August 1979

[2] William T. Beale," Automatic Transmission With Stepless, Continuously Variable Speed And Torque Ratio" Pat.2006

[3] Brian S. Andersen ,"An Investigation Of A Positive Engagement Continuously Variable Transmission" August 2007

[4] Yukawa ." Department of Mechanical Engineering Iwate University" 4-3-5 Ueda, Morioka, Iwate, 020-8551 (Japan)

[5] Jeffrey M. Araujo, Michael A. DeMalia, Christopher M. Lambusta, "Switch-Mode Continuously Variable Transmission " ME-JDV-0902 , April 2009

[6] Derek Frei Lahr," Continuously Variable Transmission With External Cam"U.S. Pat.( 2011) 7,878,935

[7] Shawn R. Wilhelm, James D. Van de Ven," Design and Testing of an Adjustable Linkage for and Robotics , November 2013,Vol.5

[8] Dennis W. Hong, Derek F. Lahr." The Operation And Kinematic Analysis Of A Novel Cam-Based Infinitely Variable Transmission.September 2006

[9] Jiten Patel, G.K. Ananthasuresh." A kinematic theory for radially foldable planar linkages" January 2007.

[10] [10] Wayne Paul Bishop, Wilmington DE(US)."Positive Drive Infinitely Variable Transmission" U.S. Pat.2011



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