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Alternative Approaches in Variable Topology as Applied to Degree(s) of Freedom and Modes of Operation in Mechanisms

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ABSTRACT: The paper introduces alternative approaches in variable topology that would be considered as one of the access in variable topology method. These approaches focus on reducing the degree of freedom in order to synthesize a new mechanism and modes of operating the synthesized mechanism in different Phases. In order to discuss these concepts, an example of five link mechanism as well as eight link gear mechanism are considered with the assistance of linkage software. The possible ways that may unfold the thinking direction of the designer are discussed in detail.

KEYWORDS: Variable Topology Mechanism, Degree(s) of Freedom, Modes of Operation

I. INTRODUCTION

Synthesis of mechanism is one of the fundamental aspects followed in kinematic synthesis. Kinematic synthesis can be categorized into dimensional, type and number synthesis to perform the tasks like motion, path and function generation. The choice of synthesis process and task is dependent on the designer. The synthesis procedure starts with a basic idea on why the mechanism is required, how many links are required and of what type. Once this is done next is to have a rough sketch of the desired mechanism and determine the degree of freedom. Determination of degree of freedom is of prime importance as the input given to the mechanism to operate, depends mainly on the degree of freedom.

II. REVIEW: AN OVERVIEW

This paragraph summarizes the literature review on variable topology method suggesting the footing of the approach adapted by different people working in this area. Balli and Chand [1] intimated that, an analytical method can be used to synthesize five bar mechanism with variable topology. The work was carried out for movement between extreme positions of the mechanism for function generation. Balli and Chand [2] proposed the complex number method and utilized it to synthesize the mechanism having five links for motion and path generation tasks with variable topology for movement between extreme positions. Balli and Chand [3] suggested an analytical method to synthesize planar seven link mechanism with variable topology for motion between two dead centers. Gadad et al., [4] focused on synthesis of planar seven link mechanism using triad and dyad with variable topology for the task function generation. Daivagna and Balli [5] dealt with synthesis process of an off-set five link slider mechanism with variable topology. Ren-Chung Soong et al., [6] applied a geared seven-bar mechanism for mechanical forming presses. Daivagna and Balli [7] synthesized a variable topology seven-bar slider mechanism to have motion between two dead-center positions. Volken et al., [8] presented an analysis and synthesis method for a geared four-bar mechanism. Daivagna and Balli [9] worked on the synthesis of variable topology mechanism with five-bar slider for finitely separated positions. Prashant and Balli [10] reviewed the works on variable topology method. H. M. Naveen et al., [12] dealt with synthesis of eight link gear mechanism for motion generation. H. M. Naveen et al., [13] dealt with synthesis of In-Line Ten Link Gear Slider Mechanism of Variable Topology. Prashant and Balli [15] synthesized a seven bar slider for limiting positions using variable topology.

The need for variable topology is discussed in this paragraph. A mechanism can be defined as a mechanical device that serves the role

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of transferring the motion or force from an input link to an output link during the operation [11]. This helps the mechanism to carry out different tasks that may be useful in one or the other way. The mechanism may consist of links or bars connected by joints to form a closed loop. The mechanism may also contain lower pairs, higher pairs or combination of both pairs. In order to ease the process of synthesis the designer may focus on reducing the degree of freedom and also provide some feasible operating solutions to mechanisms.

The possible types of solutions are discussed in the following paragraphs with the aid of Computer Aided Design (CAD) program called Linkage. This is a CAD program used for modeling of mechanisms. This is one of the simplest CAD programs which offer quick analysis and modifications while working on the modeling of designs. The accessibility to the program is at DAVE'S BLOG which is developed by David M. Rector [14]. The program is viewed with wide variety of windows versions. Considering this as a base the mechanisms and possible methods are studied for their efficiency and efficacy. The link to download the software has been provided in reference section.

III. ALTERNATIVE APPROACHES IN VARIABLE TOPOLOGY METHOD WITH A FOCUS ON DEGREE(S) OF FREEDOM AND MODES OF OPERATION

Approaches are solutions to deal with a particular concept and adapt the same in the process of synthesis. These approaches mainly provide some aspects to cope up with difficulties faced during the synthesis process. They can be adapted during the synthesis or after the synthesis process. Approaches dealing with degree of freedom mainly focus on reducing the degree of freedom of a mechanism and thus help in reducing the number of inputs to be given to the mechanism. Synthesis using complex number method includes writing dyad equations in standard forms by considering different loops of the mechanism. Hence, this effort can be reduced if the degree of freedom is lowered.

Approaches dealing with modes of operation mainly focus on a mechanism which is already synthesized and put to work. The fundamental concept of a mechanism involves providing input to a crank capable of rotating completely on its axis, whose motion is transferred to the coupler and the then to output link. Utilizing this, the designer can opt for a change the mode of operating the mechanism which can perform multiple tasks instead of carrying out a single operation. This can be achieved either by changing the direction of rotation of crank or the speed of the crank.

III.I Approaches in Variable Topology based on Degree of Freedom

In this case, the methods to reduce the degree of freedom of a mechanism are considered with an illustration of five link mechanism. Following are some of the approaches that can be considered.

1. Fixing a Link Temporarily in the mechanism
2. Combining Two Links in the mechanism
3. Adding a New Link to the mechanism
4. Adding Two Gears to the mechanism

III.II Approaches in Variable Topology based on Modes of Operation applied to One Degree of Freedom Mechanisms

In this case, the methods in modes of operation that can be treated as approaches of variable topology are discussed which are applied to one degree of freedom mechanisms. The approaches of modes of operation that are speculated on this basic idea are as follows.

1. Change in Speed of Crank
2. Change in Direction of Crank - Clockwise or Counter Clockwise
3. Fixing a Link Temporarily

III.III Approaches in Variable Topology based on Modes of Operation applied to Two Degrees of Freedom Mechanisms

In this case, the methods in modes of operation that can be treated as approaches of variable topology are discussed. These are applied to two degrees of freedom mechanisms. The following are the postulated approaches developed on this basic idea are considered.

1. Change in Rotation of both the Cranks - Clockwise or Counter Clockwise
2. Making one Crank to Rotate Clockwise and another Counter Clockwise
3. Operating a Two Degrees of Freedom Mechanism with only One Input
4. Changing the Speeds of Two Cranks

The Fig.1 shows the alternative approaches in Variable Topology Method using the flowchart.

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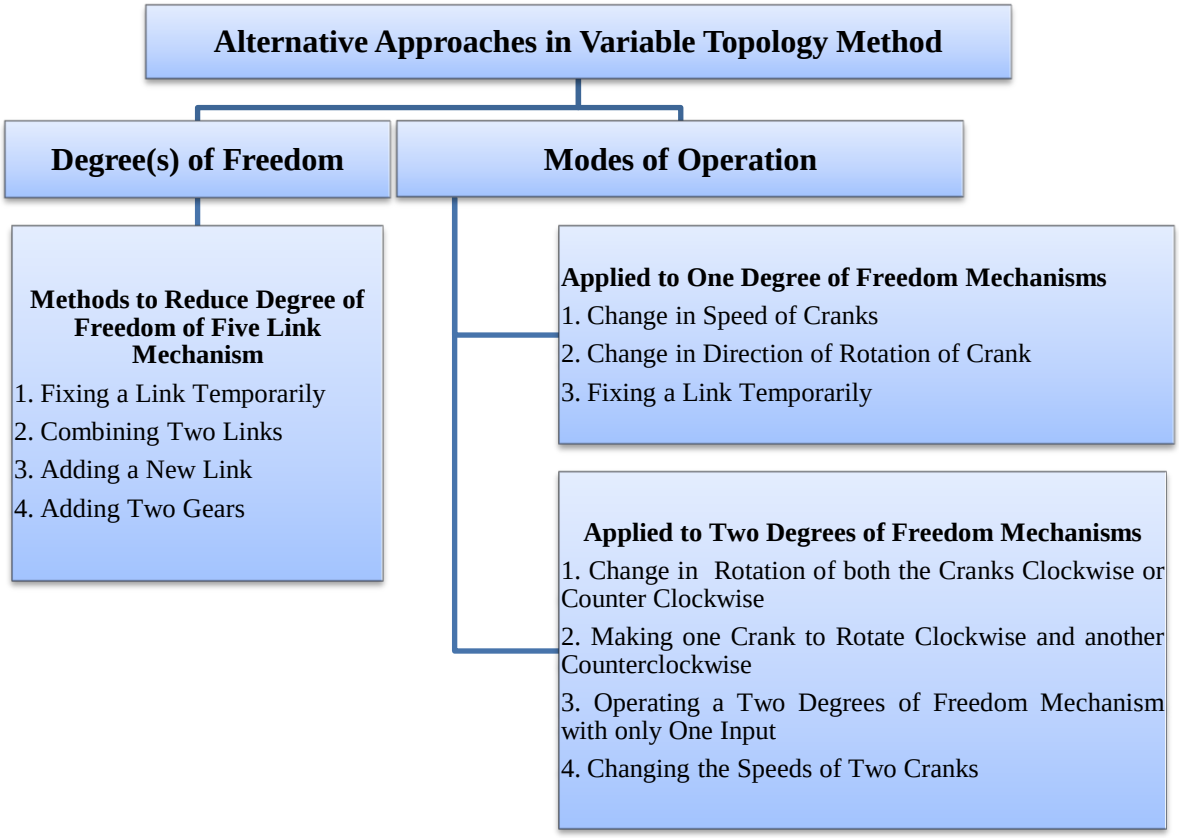

Fig. 1 Flow Chart of Alternative Approaches in Variable Topology Method

The detailed explanation of the approaches is dealt in the following paragraphs. An example of five link mechanism is considered for the study and all the possibilities that can be adapted in variable topology as approach are illustrated.

III.I Approaches in Variable Topology based on Degree of Freedom

In this case, the methods to reduce the degree of freedom of a mechanism are considered with an illustration of five link mechanism. Following are some of the approaches that can be considered in this section.

1. Fixing a Link Temporarily in the mechanism
2. Combining Two Links in the mechanism
3. Adding a New Link to the mechanism
4. Adding Two Gears to the mechanism

1. Fixing a Link Temporarily in the Mechanism

The below Fig.2 shows a five link mechanism with two degrees of freedom consisting of an input link and output link attached to two couplers.

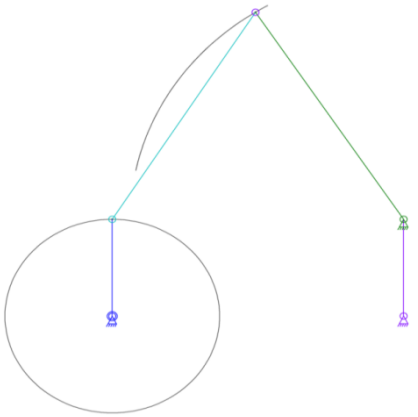

Fig. 2 Five Link Mechanism with One Link Fixed Temporarily

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In order to synthesize this mechanism, it is essential to fix a link temporarily to reduce it to a four bar mechanism of single degree of freedom and to determine the link lengths. This is treated as Phase I synthesis process. In Phase II, another link which can be a link adjacent to input link or output link, is fixed temporarily and the required link lengths are determined.

Thus, fixing of a link temporarily will play a vital role in reducing the degree of freedom of a mechanism. This is the fundamental concept of variable topology method which is followed in the synthesis process.

2. Combining Two Links in the Mechanism

The following Fig.3 shows a five link mechanism with two degrees of freedom consisting of an input link and output link attached to two couplers.

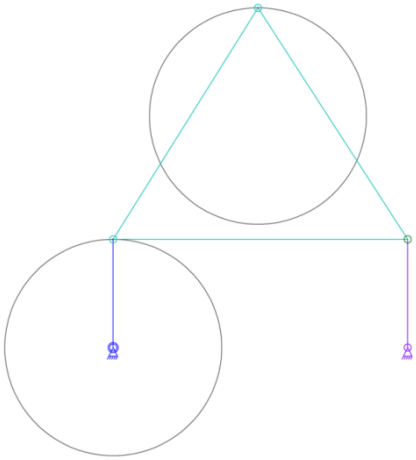

Fig. 3 Five Link Mechanism with Two Combined Links

In order to synthesize this mechanism it is required to reduce it to a four bar mechanism of single degree of freedom and determine the link lengths. This can be achieved by combining two links so that, two degrees of freedom five link mechanism reduces to single degree of freedom four link mechanism.

Thus, combining two links shall play a vital role in reducing the degree of freedom.

3. Adding a New Link to the Mechanism

The following Fig.4 shows a five link mechanism with two degrees of freedom consisting of an input link and output link attached to two couplers.

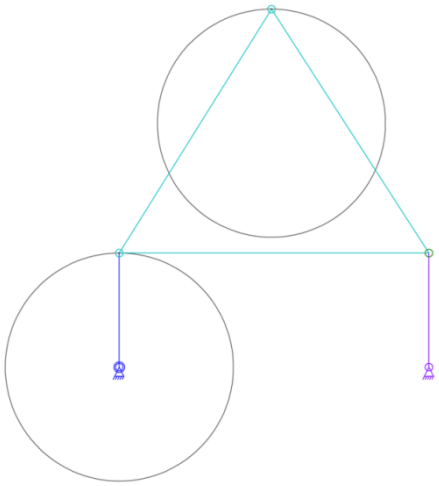

Fig. 4 Five Link Mechanism with Additional Link (Six Link Mechanism)

In order to synthesize this mechanism it is required to reduce it to a six bar mechanism of single degree of freedom and determine the link lengths. This can be achieved by adding a new link to the mechanism so that, two degrees of freedom five link mechanism reduces to single degree of freedom six link mechanism.

Thus, adding a new link to the mechanism plays a key role in reducing the degree of freedom.

4. Adding Two Gears

The following Fig.5 shows a five link gear mechanism with one degree of freedom consisting of gear as input link and crank as output link.

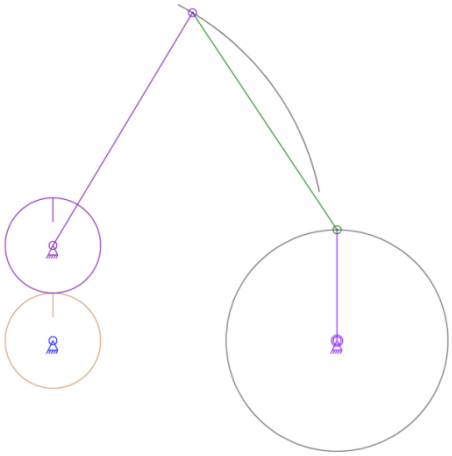

Fig. 5 Five Link Mechanism with Two Gears

Basically, a five link mechanism is treated as two degrees of freedom mechanism. Thus, by replacing a link with a combination of pair of gears in two degrees of freedom mechanism results in a single degree five link gear mechanism.

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III.II Approaches in Variable Topology based on Modes of Operation applied to One Degree of Freedom Mechanisms

In this case, the methods adopted in various modes of operation can be treated as approaches in variable topology. These are discussed as applied to one degree of freedom mechanisms.

1. Change in Speed of Crank
2. Change in Direction of Crank - Clockwise or Counter Clockwise
3. Fixing a Link Temporarily

1. Change in Speed of Crank

The four link mechanism shown in Fig. 6 is a single degree of freedom mechanism consisting of crank as input and rocker as output.

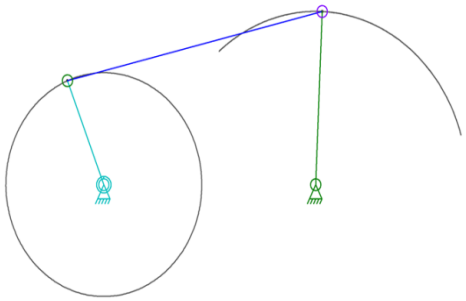

Fig. 6 Four Link Mechanism Operating with Varying Speeds

The operation of the crank can be done with variation in speed. Suppose for one cycle if the crank rotates at 100 rpm, for another cycle the same crank can be made to rotate at 50 rpm based on the requirement. This method of operating the input crank at different speeds can be treated as one of the trends in variable topology mechanism. This can be implemented in slider crank mechanism to perform cutting operation in first phase and smoothening operation in second phase.
The mode of operation is as follows:
Phase I: Input crank rotates 100 rpm
Phase II: Input crank rotates 50 rpm

2. Change in Direction of Crank - Clockwise or Counter Clockwise

The slider crank mechanism shown in Fig. 7 is a single degree of freedom mechanism consisting of crank as input and slider as output.

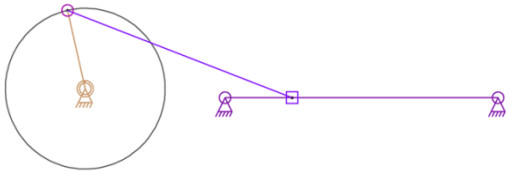

Fig. 7 Slider Crank Mechanism Operating in Various Directions of Rotations

The operation of the crank can be done in clockwise or counter clockwise direction. Suppose, for one cycle if the crank rotates in clockwise, for another cycle the same crank will be made to rotate in counter clockwise direction based on the requirement to perform various tasks. This method of operating the input crank in different directions can be treated as one of the trends in variable topology mechanism.
The mode of operation is as follows:
Phase I: Input crank rotates in clockwise direction
Phase II: Input crank rotates in counter clockwise direction

3. Fixing a Link Temporarily

Consider a five link gear mechanism with one degree of freedom as shown in Fig.8. This mechanism can be made to operate in two phases which can be treated as a trend in variable topology mechanism.

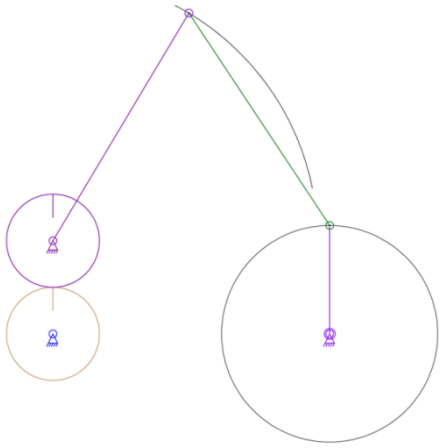

Fig. 8 Five Link Gear Mechanism

When rotary motion is given to the gear, the mechanism operates. This is treated as Phase I operation. Phase II operation can be performed by fixing the input gear temporarily and operating the other gear, satisfying the prerequisite of epicyclical gear condition.

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The mode of operation is as follows:
Phase I: Gear 1 rotates as input
Phase II: Gear 2 with extension rotates as input with epicyclical gear condition

III.III Approaches in Variable Topology based on Modes of Operation applied to Two Degrees of Freedom Mechanisms

In this case, the methods in modes of operation that can be treated as approaches of variable topology are discussed. These methods are applied to two degrees of freedom mechanisms. Following are some of the approaches that are illustrated.

1. Change in Rotation of both the Cranks - Clockwise or Counter Clockwise
2. Making one Crank to Rotate Clockwise and another Counterclockwise
3. Operating a Two Degrees of Freedom Mechanism with only one Input
4. Changing the Speeds of Two Cranks

1. Change in Rotation of both the Cranks - Clockwise or Counter Clockwise

The following Fig. 9 illustrates a five link mechanism with two degrees of freedom. This mechanism operates with two inputs working simultaneously. The tracer path of coupler point will draw the attention for its applications.

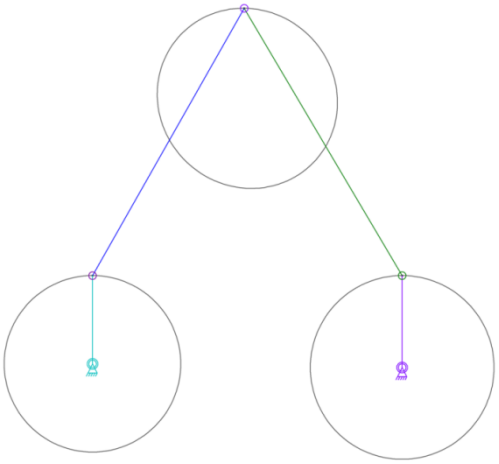

Fig. 9 Five Link Mechanism with Cranks Rotation - Clockwise or Counter Clockwise

This mechanism can be made to operate in two different Phases.
The mode of operation is as follows:
Phase I: Both the cranks rotate clockwise
Phase II: Both the cranks rotate counter clockwise

2. Making one Crank to Rotate in Clockwise and another in Counterclockwise

The Fig. 10 illustrates a five link mechanism with two degrees of freedom. This mechanism also operates with two inputs working at the same time as it is two degrees of freedom mechanism. The tracer path of coupler point will draw the attention for its applications.

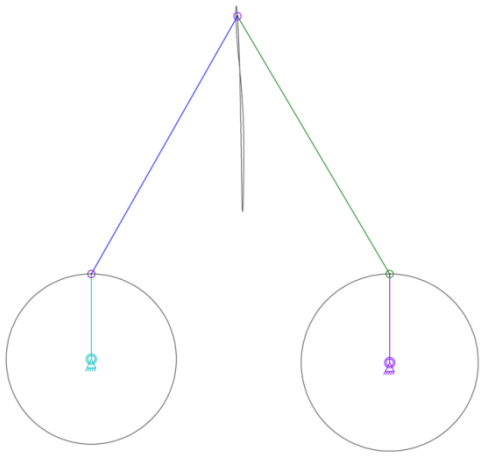

Fig. 10 Five Link Mechanism with Crank Rotation in Clockwise and another in Counter Clockwise

This mechanism can be made to operate in two different Phases.
The mode of operation is as follows:
Phase I: Both the cranks rotate counter clockwise
Phase II: Both the cranks rotate clockwise or counter clockwise

3. Operating a Two Degrees of Freedom Mechanism with only one Input

The following Fig. 11 shows the two degrees of freedom mechanism with eight link gear. This is the synthesized mechanism with variable topology. In this operation, cranks act as input whereas gears act as output in the proposed mechanism.

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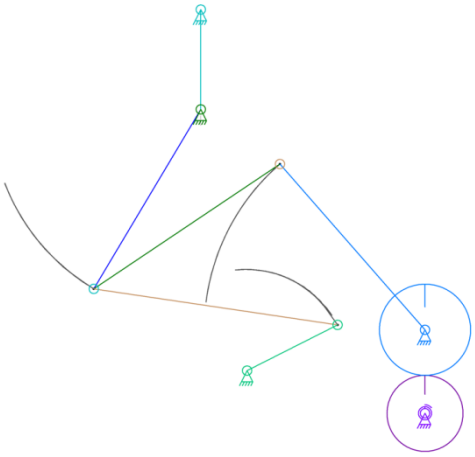

Fig. 11 Eight Link Gear Mechanism

This mechanism can be made to operate in two different Phases.
The mode of operation is as follows:
Phase I: Either of cranks act as input
Phase II: Gear act as input

4. Changing the Speeds of Two Cranks

The following Fig. 12 shows a five link gear mechanism with cranks as inputs. This mechanism can be made to operate in two different Phases. The tracer path of coupler point will draw the attention for applications.

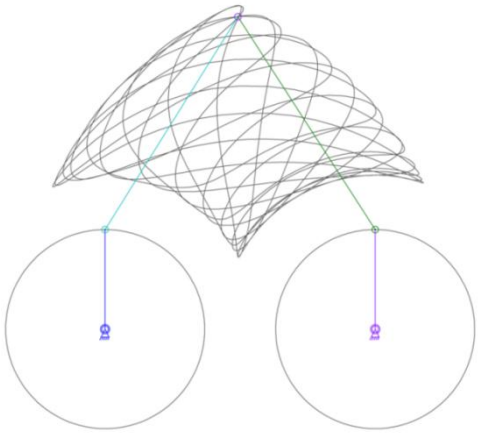

Fig**. 12** Five Link Gear Mechanism with Two Inputs

The mode of operation is as follows:
Phase I: Both cranks rotate in clockwise direction with variable speed.
Phase II: Both cranks rotate in counter clockwise direction with variable speed.

IV. FUTURE PERSPECTIVE OF ALTERNATIVE APPROACHES IN VARIABLE TOPOLOGY

The scope of conceptual analysis of approaches in variable topology is to identify various access plans in mechanisms and to implement in the field of synthesis. The alternative approaches in Variable Topology as applied to Degree of Freedom and Modes of Operation in Mechanisms defines clearly that, any mechanism having one, two or more degrees of freedom can be considered under variable topology for synthesis process. The discussion on concepts, involving degree of freedom and modes operation may be considered as one of the methods in variable topology which may specify the importance and consideration of the method and to apply wherever and whenever necessary.

The Phases occurring in the area of variable topology may not be limited in number and can be increased based upon the choice of the designer. In the same sense, the Phases will also open up a new approach in operating the mechanism at variable modes. Thus, utilizing the input to provide a wide range of outputs in a proposed mechanism leads the role.

V. CONCLUSION

A conceptual study of alternative approaches in variable topology with Linkage Software predicts that, the new approaches may be considered under variable topology and can be applied to any mechanism. Probability of considering variable topology method in different aspects, increases the tendency of the method and not limiting it to only synthesis part of the mechanisms but also extend it to operation part of mechanisms. The designer may focus on these conceptual aspects opening a wide range of routes in the field of mechanisms.

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