Triad and Dyad Synthesis of Planar Seven-Link Mechanisms with Variable Topology

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Abstract

This paper suggests variable topology method using Dyad and Triad techniques for synthesizing seven-bar planar mechanisms. An analytical method for synthesizing seven- links mechanism with variable topology for two positions is suggested for function generation. Numerical examples are provided and are verified. Complex numbers, which readily lend themselves as an ideal tool for modeling linkage members as parts of planar mechanisms, are used for writing displacement equations for dyads and triads.

Keywords: Seven-link mechanism, Variable topology, dyad and triad synthesis.

1. Introduction

A seven-link mechanism has two degrees of freedom. There are many methods proposed for synthesizing such a mechanism. A seven-bar linkage with variable topology operates in two phases. In each phase, a link adjacent to the permanently fixed link of seven-bar linkage is also fixed temporarily and the resulting portion acts like a six-bar mechanism with single degree of freedom'[1].

To begin with an overview of the variable topology mechanism is given to form the basis of the method developed in the present work. Rose [2], Ting and Tsai [3] and Ting [4] made indirect reference of five-bar variable topology mechanism with the help of graphical methods. Rawat [5] established a synthesis technique for five-bar topology mechanism operating in two phases. Joshi et.al.[6] and Joshi [7] used the dyad synthesis of a five-bar topology mechanism for circuit breaker applications. Balli and Chand [1] deal with various aspects like transmission angle control defects and solutions rectification of five-bar variable topology mechanism. Chand and Balli [1] proposed a method of synthesis of a seven-link mechanism with variable topology.

A variable topology synthesis method is suggested as an alternative to the multi-loop synthesis method suggested by Sandor and Erdman. Many multi-loop mechanisms can be synthesized by repeated use of the same standard form solution method by employing compatibility equations [8]. Triad synthesis suggested by Lin and Erdman involves writing and solving compatibility equations by iterative calculations. The method of variable topology suggested in this paper reduces the cumbersome calculations.

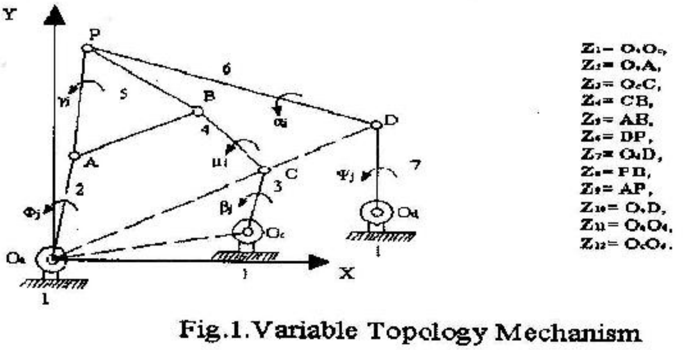

Fig.1.Variable Topology Mechanism

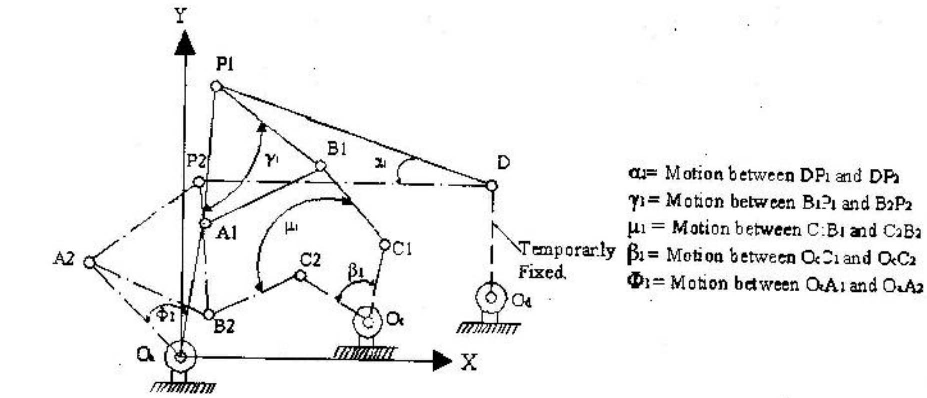

Fig.2.Phase-I Synthesis.

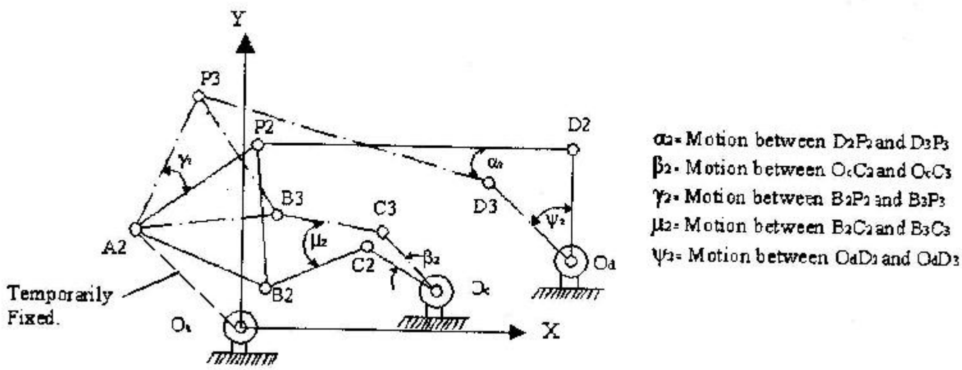

Fig.3.Phase-II Synthesis.

2. Variable Topology of Seven-Links Mechanism

Any mechanism with five or more links and with two or more degrees of freedom can be made to acts as variable topology mechanism operating in two or more phases [1]. The planar seven-links mechanism is shown in Fig.1. Figs 2 and 3, show Phase-I and Phase-II respectively and are discussed in the following paragraphs:

2.1. Phase-I

In the present work a seven-link variable topology mechanism consisting of a ternary link-5 is considered. In Phase-I, the link DO_d is temporarily fixed and therefore, linkage becomes a six-bar mechanism with single degree of freedom, a Stephenson III type Linkage. O_aA is the input link; B is the possible tracer point. Suffix 1 and 2 of alphabets in Fig.2 show the two finitely separated positions of the six-bar portion of the seven-bar variable topology mechanism in Phase-I. It is to be noted that D is a temporarily fixed pivot; O_a and O_d are the permanently fixed pivots.

2.2 Phase-II

Once the above six-bar portion of seven-bar mechanism, reaches the position 2, the link DO_d is released to move and the link O_aA is fixed temporarily, thus switching on to the Phase-II. In Phase-II also, it is single degree of freedom, six-bar mechanism of Watt II type. Link DO_d is the input link; B is the possible tracer point. Suffix 2 and 3 of alphabets in Fig.2. show the two finitely separated positions of the six- bar portion of the seven-link variable topology mechanism in Phase II. It is to be noted that D is no more a fixed pivot whereas A_2 is temporarily fixed pivot. O_c and O_d are the permanently fixed pivots.

3. Solution Steps

Following are the some of the existing complex number methods of synthesis of seven link mechanisms using dyads and triads:

- Dyad synthesis of mechanisms by Sandor and Erdman. [8]
- Triad synthesis by Lin and Sen. [9]

In the present work the variable topology method [1] is followed. The problem to be solved consists of the following steps:

(i) To identify the link to be fixed temporarily and input link in each phase of operation.

(ii) To write down the standard dyad and triad equations for function generation between position 1 and position 2 of Phase I and also between position 2 and 3 of Phase II.

(iii) To identify the values to be specified, values to be chosen freely and the unknowns based on function generation.

(iv) To solve the equations of function generation in each phase separately for the link lengths.

(v) To retain the lengths of Phase I while solving the equations in Phase II.

(vi) To find out the total number of solutions by the method.

4. Synthesis

A function generation mechanism is a linkage in which relative motion or a force between links connected to ground is taken into account. It is required to coordinate the rotation motion of input and output links for two specified design positions.

4.1. Phase-I Synthesis for function generation

In function generation problem, the input and output crank motions ($\phi_1,\beta_1,\delta_1,\alpha_1$), and Z_6 are prescribed. γ_1,μ_1,Z_2 and Z_3 are the free choices. Therefore, there will be ∞^6 numbers of solutions Then the unknowns Z_4, Z_5, Z_8, Z_1, Z_9, Z_{10} are determined as follows [1]

$$Z_2(e^{i\phi_1}-1)+Z_5(e^{i\gamma_1}-1)=\delta_1 \quad (1)$$

$$Z_3(e^{i\beta_1}-1)+Z_4(e^{i\mu_1}-1)=\delta_1 \quad (2)$$

$$Z_6(e^{i\alpha_1}-1)+Z_8(e^{i\gamma_1}-1)=\delta_1 \quad (3)$$

Since δ_1 is known displacement vector to be prescribed, then the unknowns are determined as follows:

$$Z_5=\frac{\delta_1 - Z_2(e^{i\phi_1}-1)}{(e^{i\gamma_1}-1)},\quad Z_4=\frac{\delta_1 - Z_3(e^{i\beta_1}-1)}{(e^{i\mu_1}-1)},\quad Z_8=\frac{\delta_1 - Z_6(e^{i\alpha_1}-1)}{(e^{i\gamma_1}-1)} \quad (4,5,6)$$

Z_1, Z_9 and Z_{10} are determined from the following loop closure equations.

$$-Z_1+Z_2+Z_5-Z_4-Z_3=0 \quad (7)$$

$$Z_1=Z_2+Z_5-Z_4-Z_3 \quad (8)$$

Similarly,

$$Z_2 + Z_9 + Z_8 - Z_4 - Z_3 - Z_1 = 0 \quad (9)$$

$$Z_9 = Z_4 + Z_3 + Z_1 - Z_2 - Z_8 \quad (10)$$

Similarly,

$$- Z_{10} + Z_2 + Z_9 - Z_6 = 0 \quad (11)$$

$$Z_{10} = Z_2 + Z_9 - Z_6 \quad (12)$$

Thus in Phase-I synthesis of seven link containing ternary link variable topology mechanism, the known dimensions of the links are Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_8, Z_9 and Z_{10}. The only unknowns Z_7, Z_{11} and Z_{12} are to be determined from Phase-II synthesis.

4.2. Phase-II Synthesis for function generation

Writing the equations (refer Fig.3) [8, 9],

$$Z_7(e^{i\psi_2}-1) + Z_6e^{i\alpha_1}(e^{i\alpha_2}-1) + Z_5e^{i\gamma_1}(e^{i\gamma_2}-1) = \delta_2 \quad (13)$$

$$Z_3 e^{i\beta_1}(e^{i\beta_2}-1) + Z_4 e^{i\mu_1}(e^{i\mu_2}-1) = \delta_2 \quad (14)$$

Equation [13] is a triadic type. This can be reduced to standard dyadic form [8]. Since δ_2 is prescribed and other vectors are known, Z_7 can be found out easily as follows:

$$Z_7 = \frac{\delta_2 - [Z_6e^{i\alpha_1}(e^{i\alpha_2}-1) - Z_5e^{i\gamma_2}(e^{i\gamma_2}-1)]}{(e^{i\psi_2}-1)} \quad (15)$$

Writing loop closure equation for loop 1 of from Fig. 3,

$$-Z_{11} = O_aO_d$$

$$-Z_{11} + Z_2 + Z_9 - Z_6 - Z_7 = 0 \quad (16)$$

$$Z_{11} = Z_2 + Z_9 - Z_6 - Z_7 \quad (17)$$

Writing loop closure equation for loop 2 of from Fig. 3,

$$-Z_{12} = O_cO_d$$

$$-Z_{12} = Z_3 e^{i\beta 1} + Z_4 e^{i\mu 1} + Z_5e^{i\gamma 1} - Z_6e^{i\alpha 1} - Z_7$$

$$-Z_{12} + Z_3 e^{i\beta 1} + Z_4 e^{i\mu 1} + Z_5e^{i\gamma 1} - Z_6e^{i\alpha 1} - Z_7 = 0 \quad (18)$$

Table. 1

Summary of Phase-I and Phase-II synthesis of seven-link variable topology mechanism for two finitely separated positions.

Description	Phase-I	Phase-II
Link fixed temporarily	DO_d	O_aC_1
Prescribed parameters	$\phi_1, \beta_1 \alpha_1$, and Z_6	β_2, ψ_2 and δ_2
Free Choices made	γ_1, μ_1, Z_2 and Z_3	γ_2, μ_2
Unknowns	Z_4, Z_5, Z_8 Z_1, Z_9, Z_{10}	Z_7, Z_{11}, Z_{12}
Number of solutions	∞^6	∞^2
Total Number of Solutions	∞^8	

5.0 Advantages of the method

Following are the some of the advantages of the method.

- More number of unknown parameters are found in the Phase-I and less calculations are required in Phase-II.
- The solution is consistent with the definitions of standard kinematics tasks like function generation, path and motion generations for two positions resulting in a unified method of synthesis.
- Simplicity, ease of application and generality are the attractions of the method.
- Unlike graphical methods, it is not limited by drawing accuracy.

6. Limitations of the method

- The proposed method is applicable only to complex number approach.
- The mechanism synthesized by the method may suffer from branch, Grashof or circuit defects, which can be rectified separately.
- The solution does not permit good initial guesses for all possible solutions i.e free choices.
- Solution method is applicable to some of the seven-bar variable topology mechanisms.

7. Conclusion

This present work suggests variable topology method using dyad and triad techniques for synthesizing seven-bar planar mechanisms. An analytical method for synthesizing seven-links mechanism with variable topology for two positions is suggested for function generation. Complex numbers, which readily lend themselves as an ideal tool for modeling linkage members as parts of planar mechanisms, are used for writing displacement equations for dyads and triads. The method is suggested as an alternative to the multi-loop synthesis method and triad synthesis which involves writing and solving compatibility equations by iterative calculations.

8. Numerical example

A seven-bar variable topology mechanisms acting as Stephenson III type six-bar mechanism in Phase I and Watt II type six-bar mechanism in Phase II is considered (Fig.1).

Problem: It is required to synthesize a seven-link mechanism, which contains a ternary link with variable topology for the function between the two positions and for the following tracer point displacement specifications;

Phase-I: from point (52.0000,68.0000) to the point (11.0000,15.0000)

Phase-II: from point (11.0000,15.0000) to the point (14.0000,28.0000)

$\phi_1 = 55^0$, CCW $\beta_1 = 70^0$ CCW , $\alpha_1 = 18^0$ CCW , and $Z_6 =$ (-104.+35i) ,$\psi_2 = 10^0$

Suggest the dimensions of the mechanism for a function generation.

Solution : Phase-I Synthesis :

Given that: $\phi_1 = 55^0$, CCW $\beta_1 = 70^0$ CCW , $\alpha_1 = 18^0$ CCW , and

$Z_6 =$ (-104.0000 +35.000i) Let $\gamma_1 = -48^0$ CW, $\mu_1 = 70^0$ CCW, Z2= (8.0000+48.0000 i)

And $Z_3 =$ (6.0000+29.0000i), $\delta'_1 =$ (-41. 000 -54.0000 i)

From equation (4)

$Z_5 =$ (44.1507+21.9860i) = 49.3221 and 26.47^0

From equation (5)

$Z_4 =$ (-24.0600+27.2770i) =36.3720 and 131.4136^0

From equation (6)

$Z_8 =$ (40.2652 - 29.5375i) = 49.9385 and 323.7375^0

From equation (8)

$Z_1 =$ (70.2107+13.709i) = 70.54 and 11.048^0

From equation (10)

$Z_9 =$ (3.8848+51.5253i) = 51.6715 and 85.69^0

From equation (12)

$Z_{10} =$ (115.8848+64.5253i) = 132.6379 and 29.1093^0

Phase-II:

Assume: $\gamma_2 = 26^0$, CCW, $\mu_2 = 12^0$ CW

From equation (15)

$Z_7 =$ (-5.5560e+001 +1.1317e+002i) = 126.0726 & 116.15^0 angle

From equation (17)

$Z_{11} =$ (171.4448i-48.6447i)) = 178.2123 and 344.16^0

From equation (19)

$Z_{12} =$ 152.1100 - 130.1400i) = 200.1829 and 319.486^0

Table 2: Shows the synthesized seven-link variable topology mechanism, which contains a ternary link.

Link	Length	Link	Length
$\|Z_1\|$	70.54	$\|Z_7\|$	126.0726
$\|Z_2\|$	48.662	$\|Z_8\|$	49.9385
$\|Z_3\|$	29.6142	$\|Z_9\|$	51.6715
$\|Z_4\|$	36.3720	$\|Z_{10}\|$	132.6379
$\|Z_5\|$	49.3221	$\|Z_{11}\|$	178.2123
$\|Z_6\|$	109.7315	$\|Z_{12}\|$	200.1829

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