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Dyad synthesis of planar seven bar mechanism with variable topology for function generation

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Abstract

Planar linkages may be thought of as combinations of vector pairs called dyads. Amongst the different methods for synthesizing planar mechanisms one of the methods is the dyad synthesis and has been applied to five-bar and seven-link variable topology mechanisms [VTM]. This paper attempts to synthesize Seven-link mechanism with variable topology for function generation of two finitely separated positions. An analytical method of dimensional synthesis is performed upon the envisaged mechanism by designating the equality constraints, assigning the variable types and then identifying the specified design space to determine the solution.

Keywords: synthesis, seven-link mechanism, variable topology

1 Introduction

A seven-link mechanism shown in Figure 1 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 [10] 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 [8]. 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 [9] involves writing and solving compatibility equations by iterative calculations. The suggested method of variable topology reduces the cumbersome calculations.

2 Variable Topology Mechanism

A planar seven-link mechanism is shown in Fig. 1. It operates in two phases; Phase-I and Phase-II (Fig.2 and Fig. 3). The two phases are discussed in the following paragraphs.

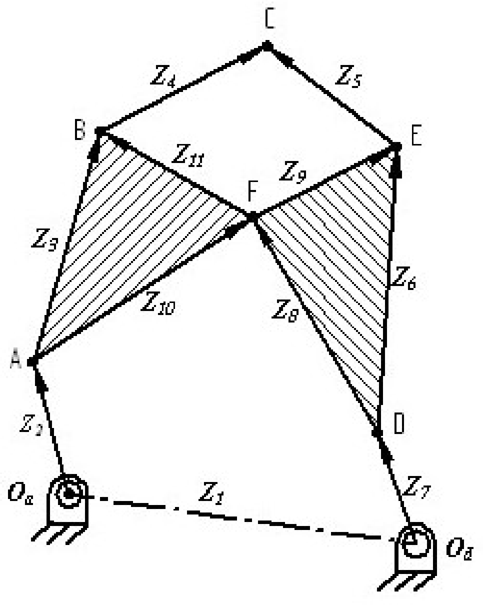

Figure 1. A planar seven-link variable topology mechanism

2.1 Phase-I

Figure 2 shows the Phase-I, where the link DO_d is fixed temporarily and the seven-link VTM moves from its original position-1 to position – 2. O_aA_1 is the input link. C is the possible path 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-link variable topology mechanism in Phase-I. It is to be noted that D is a temporarily fixed pivot. O_a and O_d are permanently fixed pivots.

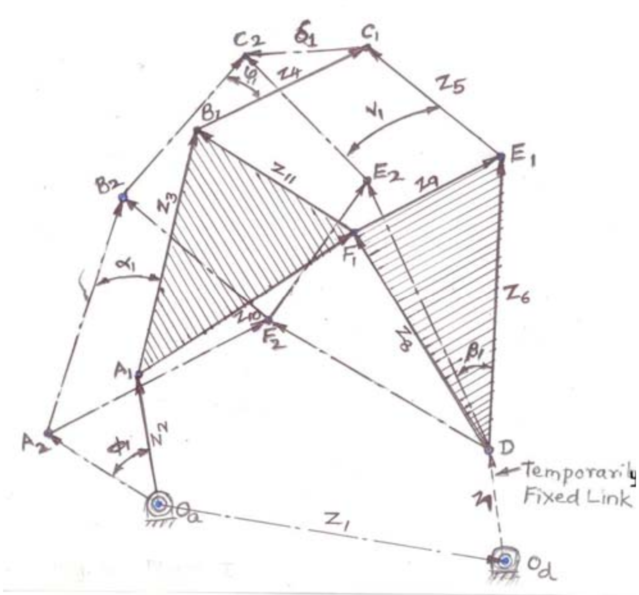

Figure 2. Seven-link variable topology mechanism in Phase-I

2.2 Phase-II [Table 1]

Once the above six-bar portion of seven-link mechanism, reaches the position 2, the link DO_d is released to move and the link A_2O_a is fixed temporarily. It is a single degree of freedom six-bar mechanism in Phase-II. Link DO_d is the input link, C is the possible tracer point. Suffix 2 and 3 of alphabets in Fig.3 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 a temporarily fixed pivot. O_a and O_d are permanently fixed pivots. Table 1. gives the summary of Phase-I and Phase-II.

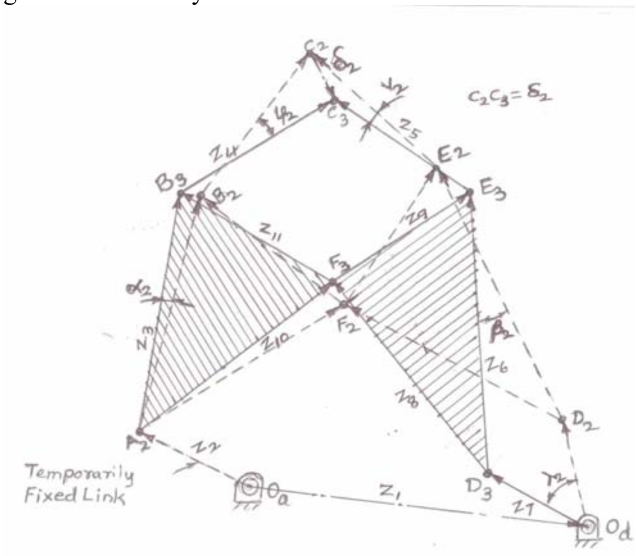

Figure 3. Seven-link variable topology mechanism in Phase-II

3 Solution Procedure

Here we have used the variable topology method [1]. 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 recognize the type of mechanism in each Phase (Stephenson, Watt or any other)
(iii) To write 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.
(iv) To identify the values to be specified, values to be chosen freely and the unknowns based on function generation.
(v) To solve the equations of function generation each in phase separately for the link lengths.
(vi) To retain the lengths of Phase I while solving the equations in Phase II.
(vii) To find out the total numbers of solutions by the method. [8]

4 Synthesis for function generation

A function generation mechanism is a linkage in which relative motion or forces between links (generally) connected to ground are of interest. It is required to coordinate the rotation of input and output links for two specified design positions. In function generation problem, the input and output crank motions (Φ_1, β_1) are prescribed. φ_1, α_1, Z_2 and Z_5 are the free choices. There fore, there will be ∞^6 numbers of solutions. Then the unknowns are determined as follows.

4.1 Phase-I

Link DO_d in Fig. 2 is temporarily fixed thus making it as six-link watt type single degree freedom mechanism. Writing loop closure equation for Z_5Z_6 dyad

$$Z_5\left(e^{i\nu_1}-1\right)+Z_6\left(e^{i\beta_1}-1\right)=\delta_1 \qquad (1)$$

Considering triad $Z_2Z_3Z_4$

$$Z_2\left(e^{i\Phi_1}-1\right)+Z_3\left(e^{i\alpha_1}-1\right)+Z_4\left(e^{i\varphi_1}-1\right)=\delta_1 \qquad (2)$$

Eq. 2 can be put in standard [8] form if we select Z_2 arbitrarily

$$Z_3\left(e^{i\alpha_1}-1\right)+Z_4\left(e^{i\varphi_1}-1\right)=\delta_1' \qquad (3)$$

Let $\delta_1' = \delta_1 - Z_2\left(e^{i\Phi_1}-1\right)$ (4)

From the equations (1) and (3) we can calculate

$$Z_3=\frac{\delta_1' - Z_4(e^{i\varphi_1}-1)}{(e^{i\alpha_1}-1)} \qquad (5)$$

$$Z_6 = \frac{\delta_1 - Z_5(e^{i\nu_1} - 1)}{(e^{i\beta_1} - 1)} \quad (6)$$

$$Z_2\left(e^{i\phi_1} - 1\right) + Z_{10}\left(e^{i\alpha_1} - 1\right) = \delta_1^{"} \quad (7)$$

$$Z_8\left(e^{i\beta_1} - 1\right) = \delta_1^{"} \quad (8)$$

$$Z_8 = \frac{\delta_1^{"}}{(e^{i\beta_1} - 1)} \quad (9)$$

$$Z_{10} = \frac{\delta_1^{"} - Z_2(e^{i\phi_1} - 1)}{(e^{i\alpha_1} - 1)} \quad (10)$$

$$Z_3 = Z_{10} + Z_{11} \quad (11)$$

$$Z_6 = Z_8 + Z_9 \quad (12)$$

Z_1 is determined as follows.

$$Z_1 = Z_2 + Z_{10} - Z_7 - Z_8 \quad (13)$$

4.2 Phase-II

Writing loop closure equations for Phase-II (refer Fig. 3)

$$Z_3\left(e^{i\alpha_2} - 1\right) + Z_4\left(e^{i\varphi_2} - 1\right) = \delta_2 \quad (14)$$

$$Z_7\left(e^{i\lambda_2} - 1\right) + Z_6\left(e^{i\beta_2} - 1\right) + Z_5\left(e^{i\nu_2} - 1\right) = \delta_2 \quad (15)$$

Let $\delta_2^{'} = \delta_2 - Z_5\left(e^{i\nu_2} - 1\right)$ (16)

Then

$$Z_7\left(e^{i\lambda_2} - 1\right) + Z_6\left(e^{i\beta_2} - 1\right) = \delta_2^{'} \quad (17)$$

Z_7 is determined as follows

$$Z_7 = \frac{\delta_2^{'} - Z_6(e^{i\beta_2} - 1)}{(e^{i\lambda_2} - 1)} \quad (18)$$

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	A_2O_a
Prescribed parameters	ϕ_1, β_1, ν_1 and Z_4	β_2, ψ_2 and λ_2
Free choices made	α_1, φ_1, Z_2 and Z_5	ν_2

5 Advantages

Following are the some of the advantages of the method.
(i) More number of unknown parameters are found in the Phase-I and less calculations are required in Phase-II.
(ii) Simplicity, ease of application and generality are the attractions of the method.
(iii) Unlike graphical methods, it is not limited by drawing accuracy.

6 Limitations

(i) The proposed method is applicable only to complex number approach and solution by variable topology method.
(ii) The mechanism synthesized by the method may suffer from branch, Grashof or circuit defects, which can be rectified separately.
(iii) The solution does not permit good initial guesses for all possible solutions i.e. free choices.

7 Conclusions

This present work suggests application of Dyad technique for synthesizing seven-link planar mechanism containing two ternary links which can be reduced to Watt-I type mechanism in both the phases by applying variable topology method. 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. The method is suggested as an alternative to the multi-loop synthesis method which involves writing and solving compatibility equations by iterative calculations.

8 Numerical Example

It is required to synthesize above seven-link mechanism with variable topology for two finitely separated positions and for the following tracer point specifications.
Phase-I from point (90,150) to the point (63,148)
Phase-II from point (63,148) to the point (69,137). The dimensions of the mechanism for function generation have been worked as follows.

Solution:
Phase-I synthesis:
Given that $\Phi_1 = 50^0$, $\beta_1 = 27^0$, $\nu_1 = 10^0$ and $Z_4 = 30 + 0i$
Let $\alpha_1 = 5^0$, $\varphi_1 = 0^0$ and $Z_2 = -6 + 29i$
$\delta_1 = -27 - 2i$, $Z_5 = -32 + 23i$
From Eq. (5), $Z_3 = 5.8175 + 57.8757i$ i.e. $|Z_3| = 58.1673$
From Eq. (6), $Z_6 = 17.8925 + 11.9646i$ i.e. $|Z_6| = 21.5242$
From Eq. (9), $Z_8 = 17.0314 – 2.0985i$ i.e. $|Z_8| = 17.1602$
From Eq. (10), $Z_{10} = -15.7168 - 23.9544i$ i.e. $|Z_{10}| = 28.6501$
Phase-II synthesis:
Given that $\beta_2 = 23^0$, $\lambda_2 = 50^0$, $\psi_2 = 22^0$,
$\nu_2 = 10^0$, $\delta_2 = 6 - 11i$
From Eq. (16), $\delta_2^{'} = -65.3628 + 13.89i$
From Eq. (17), $Z_7 = -19.993 + 20.1937i$
i.e. $|Z_7| = 28.4166$
Link lengths after synthesis are summarized in Table 2.

Table 2. Link lengths of synthesized seven-link mechanism

Link	*Length*	*Link*	*Length*
$\lvert Z_1 \rvert$	169.7182	$\lvert Z_4 \rvert$	41.5933
$\lvert Z_2 \rvert$	29.1642	$\lvert Z_5 \rvert$	39.4081
$\lvert Z_3 \rvert$	58.1673	$\lvert Z_6 \rvert$	21.5242
$\lvert Z_7 \rvert$	28.4166	$\lvert Z_8 \rvert$	17.1602
$\lvert Z_9 \rvert$	14.0894	$\lvert Z_{10} \rvert$	28.6501
$\lvert Z_{11} \rvert$	84.6161		

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