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SYNTHESIS OF MECHANISMS WITH MORE THAN FOUR BARS USING BURMESTER THEORY

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Abstract: *To date Burmester Theory, as an analytical method, was predominantly used to design four-bar mechanisms that prescribe four precision points. This theory was later extended to design four-bar mechanisms prescribing five precision points. There have been few attempts to use the Burmester Theory in design of mechanisms with more than four bars and/or the ones prescribing more than five precision points. However, not much was done towards the design of mechanisms with six, seven, or more bars that prescribe more than four precision points. This paper describes possible ways in which the Burmester Theory can be utilized in the synthesis of six-bar planar mechanism prescribing four or five precision points.*

Key words: *Burmester theory, four-bar, six-bar, mechanism*

1. INTRODUCTION

In the world around, people come across mechanisms of some kind without being aware of its presence. For any object that's needs moving from one position to another a mechanism of some sort is required. Although mechanisms can be three dimensional, most of them are limited in two dimensions.

There are various types of mechanisms that form different kind of mechanism between different bars. The most common ones are sliding and rolling types of mechanisms. With the existence of different types of mechanisms there are numerous methods with which one can synthesise a mechanism.

The objectives of this paper are to utilize the Burmester Curves in combination with Inversion Method in a design of a WATT-II type of six-bar mechanisms that will prescribe five precision points as well as keep the desired angle of the element moved by the mechanism. This combination of these two methods will be shown using an extreme case where a mechanism has to prescribe a straight line. In addition, the Burmester Theory can be combined with other analytical methods including Freudenstein method in conjunction with Gauss Method of Least Squares.

2. ABOUT BURMESTER THEORY

When a body moves through two and three prescribed positions there are three respectively two infinities of solutions in the design of the mechanism; however, when the body passes through four and five prescribed positions then there is one-infinity respectively few possible designs of a mechanisms. Burmester found the solutions to problem of four prescribed positions of the plane using complex numbers (Sandor & Erdman, 1984).

Notice that the vectors defined above form a closed loop, including the first and j-th positions:

$$We^{i\beta j}+Ze^{i\alpha j}-\delta_j-Z-W=0 \qquad (1)$$

After the compatible sets of β_2 are obtained, then any method for solving simultaneous complex equations can be used to find Z and W. Then the circle point k and the center point m are given by the following expressions.

$$k = R_1 - Z \quad \text{and} \quad m = k - W \qquad (2)$$

The above pair of these two points is called Burmester Point Pair (B.P.P.), and the locus of these pairs for different values of β_2 forms the Burmester Curves.

In theory, the direct application of Burmester Theory is in the synthesis of four-bar mechanisms; however, the way that the Burmester Curves can be used in the design of four-bar mechanisms prescribing five positions is there will be two sets of dyads of the four-bar mechanisms created. One set prescribing first four precision points (1-2-3-4) and than the second set of dyads prescribing the first set off three points and the fifth precision point (1-2-3-5)(Chan Y. 1994).

3. STEPHENSON AND WATT SIX-BAR MECHANISMS

There are several types of six-bar mechanisms, however STEPHENSON (Figure 1) and WATT (Figure 2) six-bar mechanisms are the only one where all the joint of the bars (kinematic pairs) are rolling ones (no sliding kinematic pairs).

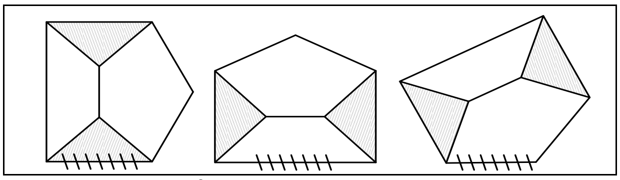

Fig. 1.Three types of STEPHENSON six-bar mechanisms

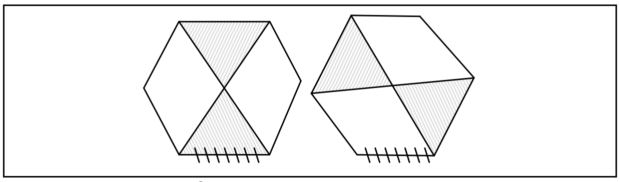

Fig. 2.Three types of WATT six-bar mechanisms

3.1 STEPHENSON type of six-bar mechanisms

There are three types of six-bar mechanisms: STEPHENSON I, II and III (Figure 1).

3.1.1 STEPHENSON III type of six-bar mechanisms

STEPHENSON I type of the mechanisms is a six-bar mechanis where the Burmester Theory can be easily applied. This mechanism can be split in to one four-bar mechanisms and one dyad (Figure 3).

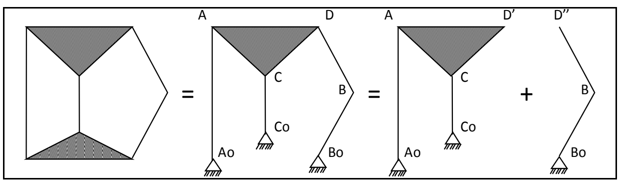

Fig. 3. STEPHENSON III type of six-bar mechanism Split into a four-bar and a dyad

The position C' of the main four-bar is the precision point that the mechanisms has to prescribe. The C'' in the remaining dyad is the corresponding point C whose coordinate is the same as point C' of the four-bar mechanism. The Burmester Theory can be applied and three sent of Burmester Curves generated.

3.1.2 STEPHENSON I type of six-bar mechanisms

In contrast to the STEPHENSON I type of the mechanisms, in the STEPHENSON II type of a six-bar mechanism the Burmester Theory cannot be easily applied, not in a straight forward way (Figure 4). One way of solving this problem is to split the mechanisms in two sets of four bar mechanisms, where each mechanism will have a dummy bar in addition to their main dyads. The precision point C and its coordinates are the same as C' and C''(Pira et al., 2006).

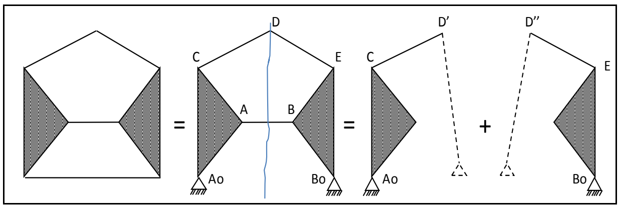

Fig. 4. STEPHENSON I type of six-bar mechanisms Split in two sets of four-bars with a dummy bar

Now, Burmester Theory can be used and four sets of Burmester Curves generates. From these curves, two set of dads can be synthesised, and that dyads Ao-C-E and Bo-D-E that form the five-bar mechanism Ao-C-E-D-Bo (Pira, 2007).

3.1.3 STEPHENSON II type of six-bar mechanisms

The STEPHENSON II type of the mechanisms is unique. What makes it unique is the fact that it has no four-bar construction in its shape (Figure 2). There have been several attempts to synthesise a mechanism STEPHENSON II type using Burmester Theory and all so far have produced no results. Further research is recommended to be undertaken to address this issue.

3.2 WATT type of six-bar mechanisms

There are two types of six-bar mechanisms: WATT I and II

3.2.1 WATT I type of six-bar mechanisms

The WATT I type of the mechanisms is a six-bar mechanisms consisted of two four-bar mechanisms linked together with an intermediately bar (triangle shaped) (Figure 5).

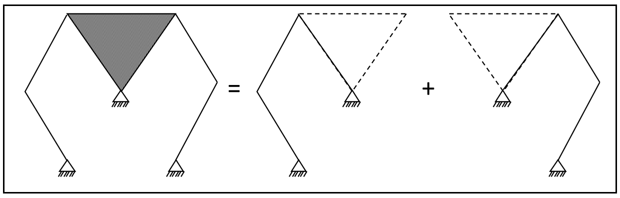

Fig. 5. WATT I type of six-bar mechanism

3.2.2 WATT II type of six-bar mechanisms

The WATT II type of the mechanisms is a six-bar mechanisms consisted of one four-bar mechanisms Ao-A-B-Bo and a dyad C-D-E. WATT-II has got only two ground points (binary link as base) (Figure 11). This means that as it is, there is no solution to the existing problem of the cutting mechanism using Burmester Theory. In fact, the Burmester theory can be applied only for the main four-bar and coupler point C, while the remaining dyad C-D-E, the Burmester Theory is difficult to be applied straight on.

One way of synthesising the Burmester Theory in the case of WATT-II type of six-bar mechanism is inverting the mechanism about point Bo (respectively about coupler Bo-B-E) only after the first main four bar has been synthesised using Burmester Theory (Pira B. 2007)

Therefore, the following steps should be taken in order to synthesise the WTT II mechanism yusing Burmester Theory:
First – synthesise the main four bar (A0-A-B-Bo) using Burmester Theory,
Second – invert the WATT II mechanism about point Bo to a new mechanism type WATT I. With the inversion of the mechanisms, the precision points also need to be inverted (Figure 6).
Third – even though the inverted mechanism turns into a WATT I type of a mechanism, where the Burmester Theory cannot be applied, we are interested only to synthesize the dyad E-D-C. Using Burmester Theory this can be done. Finally – the WATT II type of mechanism is synthesised (Pira et al., 2005).

This type of mechanisms is used to transmit the motion one four bar to the other using Function Generation methods. That in mind, there was no use of Burmester Theory to be used in the synthesis of the WATT I type of the six-bar mechanisms.

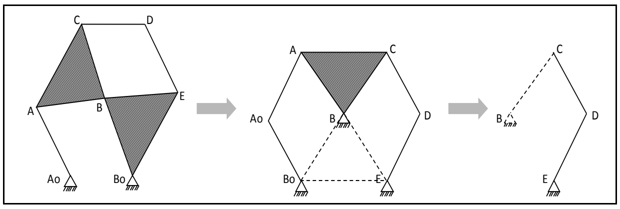

Fig. 6. Inverted WATT II type of six-bar mechanism

4. CONCLUSION

There have been numerous attempts to use Burmester Theory (or rather Burmester curves) in the synthesis of four-bar mechanisms, however only few have attempted to use it in the synthesis of the six-bar mechanism. Apart from the STEPHENSON III type of the six-bar mechanisms, where Burmester Theory could be applied directly, in two other cases the Burmester Theory had to be used in conjunction with other methods and that:

- Inversion method, and
- Freudenstein method in conjunction with Gauss Method of Least Squares.

On the other hand, there were two instances (STEPHENSON II and WATT I) where the Burmester Theory could not be applied despite several attempts. None of the above mentioned methods produced any results in this matter.

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