Structure Analysis of Six- and Eight-Link Walking Mechanisms

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Abstract* – *Structure analysis of six- and eight-link walking mechanisms is carried out. Structure formulas of corresponding mechanisms are formed. The recommendations for further kinematic analysis method selection are presented.

Keywords – structure analysis, walking mechanism, degree of freedom, kinematic analysis, structure formula, drive, mover.

I. Introduction

The vast majority of ground-based vehicles have wheel or track drive. The necessity of their use and further improvement is substantiated by comparatively simplicity of the structure and high operation efficiency. However, sometimes there are such operating situations, when the use of wheel or track drives is inexpedient, inefficient or sometimes even impossible [1]. That is why the investigations related with development of new types of drives, which conform to the requirements of high cross-country capability, environmental friendliness, maneuve-rability (mobility) etc., are permanently carried out [1]–[3]. Alternative drives in particular include walking movers [4].

Taking into account the prospective spheres of walking machines usage there exists the necessity of further improvement of existent transporting and technological equipment of various purposes by means of use of walking drives in its structure [4]. This fact causes the necessity of realization of new possibilities of transforming of rotational motion of driving motor (electrical, petrol, etc.) into the walking motion of supporting elements [3]. That is why technical and operational features of walking machines form the object of further investigations on the subject of this paper. The basic purpose of this research consists in structure analysis of six- and eight-link walking mechanisms formed on the basis of hinge-lever mechanisms of Klann and Jansen.

II. Principles of six- and eight-link walking mechanisms operation

Walking drives based on rigid lever systems, in particular cyclic mechanisms, guarantee the prescribed motion trajectory (path) of the supporting foot and may be characterized by the fact that they use ready (complete) mechanical transformer or new mechanism, synthesized in accordance with the prescribed supporting foot path, as walking mechanism [1].

In this paper the major attention is emphasized on six- and eight-link mechanisms, the principal diagrams of which are presented in the Figure 1. The motion of these mechanisms is carried out due to rotation of the link 1 (crank), in other words, these mechanisms have one degree of freedom. This fact allows considerable simplifying of the drive and control system of the walking mover. The hinges O, O_1, O_2 are placed on the frame of the machine. The foot 6 is connected to the hinge H and interacts with supporting surface, along which the walking machine is moving. The motion trajectory (path) of the foot depends on geometrical parameters of the machine frame and of elements of walking mover. That is why with the aim to ensure the prescribed motion parameters of the machine (speed, step length, height of foot raising etc.) the chain of problems of optimization synthesis of walking mechanisms were solved and the corresponding geometrical parameters were substantiated.

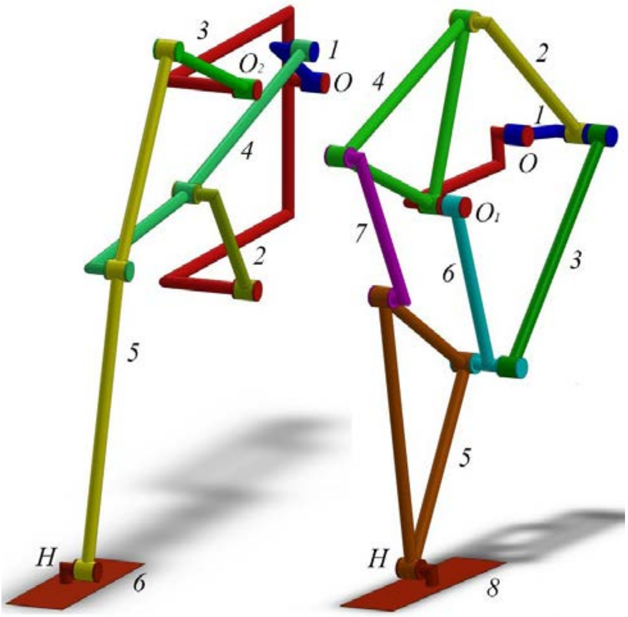

Fig. 1. Principal diagrams of six- and eight-link walking mechanisms.

III. Structure analysis of walking mechanisms

Structure diagrams of hinge-lever cyclic walking mechanisms, formed on the basis of Klann and Jansen mechanisms, are presented in the Figure 2.

The number of moving links in each mechanism correspondingly equals $n_a = 5$, $n_b = 7$, and the number of single-moving (rotating) kinematic pairs $p_{5a} = 4$, $p_{5b} = 4$. The presented mechanisms don't have kinematic pairs of higher degree, so $p_4 = 0$.

The degree of freedom of each mechanism may be calculated by the formula of Chebyshev [5]:

$$W = 3 \cdot n - 2 \cdot p_5 - p_4 :$$

- Fig. 2, a: $W = 3 \cdot 5 - 2 \cdot 7 - 0 = 1$; (1)

- Fig. 2, b: $W = 3 \cdot 7 - 2 \cdot 10 - 0 = 1$.

Based on the results of conducted calculations of degrees of freedom with a help of formula of Chebyshev (2) we may state that each presented mechanism has one degree of freedom and, in other words, one initial (original) link and one independent coordinate, which uniquely determines positions of all other links of mechanisms. Let us take crank 1 with rotation axis O as initial (original) link for each mechanism. In this case the angle φ of crank inclination from horizontal axis, directed to the right from the point O, may be considered as generalized coordinate. The positive direction of the angle φ frame of reference is anti-clockwise.

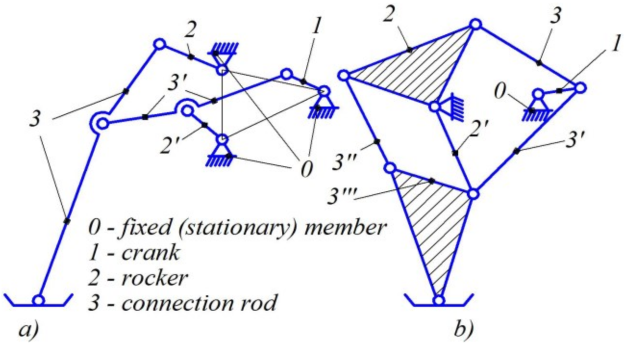

Fig. 2. Structure diagrams of six- and eight-link walking mechanisms.

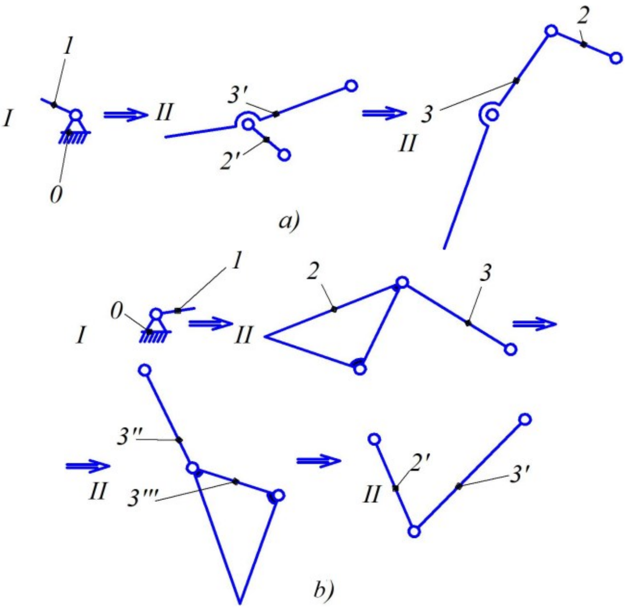

Fig. 3. Structure formulas of six- and eight-link walking mechanisms.

In order to choose the rational method of further kinematic analysis of presented walking mechanisms (Fig. 1) let us expand them into Assur groups (Fig. 3) and deduce structure formula of each mechanism

$$\begin{array}{ll} \text{Fig. 2, a:} & \begin{array}{l} I(\text{fixed member } 0,\ \text{crank } 1) \rightarrow \\ \rightarrow II(\text{connection rod } 3',\ \text{rocker } 2') \rightarrow \\ \rightarrow II(\text{connection rod } 3,\ \text{rocker } 2) \end{array} \\ \text{Fig. 2, б:} & \begin{array}{l} I(\text{fixed member } 0,\ \text{crank } 1) \rightarrow \\ \rightarrow II(\text{connection rod } 3,\ \text{rocker } 2) \rightarrow \\ \rightarrow II\begin{pmatrix} \text{connection rod } 3'', \\ \text{connection rod } 3''' \end{pmatrix} \rightarrow \\ \rightarrow II(\text{connection rod } 3',\ \text{rocker } 2') \end{array} \end{array} \quad (2)$$

Conclusion

On the basis of structure analysis results we may state that walking mechanism, presented in the Fig. 2, a, is hinged six-link mechanism of II class (with one structure group of I class and two structure groups of II class I type (Fig. 3, a)). The walking mechanism, presented in the Fig. 2, b, is eight-link mechanism of II class (with one structure group of I class and three structure groups of II class I type (Fig. 3, b)). So in order to carry out further kinematic analysis of presented walking mechanisms we will use the method of closed vector loops, which was developed by V.A. Zinoviev [5].

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