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Assembly Modes of Linkages

This paper deals with the problem of so called „assembly modes" of linkages of both planar and spatial structure. This problem has not been adequately elucidated in the literature. New type of assembly modes named „non-standard assembly mode" is discovered.

1. Foundations

A linkage has, as a rule, two or more assembly configurations (AC) at the given values of the constant parameters and in the same position of the input link (it is suggested that the input link forms a revolute joint with the frame). If during the continuous rotation of the input link all other moving links will be transfered also continuously, then the mechanism will remain in the same assembly mode (AM). Each AM has the own existing domain.

There are full-rotatable assembly modes (FRAM) and non-full-rotatable assembly modes (NFRAM). FRAM exists at any value of the input link rotation angle φ; the output link position function $\psi=\psi(\varphi)$ is periodic one with a period 2π. NFRAM exists on the bounded segment $[\varphi_1, \varphi_2]$ of the angle φ change; the position function $\psi=\psi(\varphi)$ is non-periodic function. When $\varphi=\varphi_i$ (i=1 or 2) the given NFRAM has the common boundary with another NFRAM.

It is generally believed that the range $\Phi=\varphi_2-\varphi_1$ is less than 2π ($\Phi<2\pi$) for NFRAM. Meanwhile, it is proved by the paper's author that NFRAM of unusual format, for which the range $\Phi>2\pi$ but $\Phi<4\pi$, can be found. For such NFRAM the name „non-standard assembly mode" (NSAM) is proposed. Up to now it is considered as evident that two ACs for the given input link position can not belong to the same assembly mode. Now it is necessary to change this point of view since for non-standard assembly modes two ACs for the given input link position belong both to the same AM (see the example below). NSAMs take place comparatively rarely. They have been discovered for RRSRR, RRRSR, and RRRSP spatial mechanisms and six-link planar mechanisms with four-link Assur groups.

2. Terminology

The notion „assembly mode" is of considerable importance in linkage kinematics and could be related to the fundamental notion of the mechanism theory. Meanwhile, in the IFToMM „Terminology for the theory of machines and mechanisms" (1990) there is no term related to „Assembly modes of linkages". In the literature I have found out 9 terms in English regarding the notion „Assembly of linkages": geometric inversion, geometric configuration, assembly configuration, assembly mode, closure mode, closure, branch, circuit, posture. The proposed terms relating to the mentioned notion and recommended to use in the mechanism theory are depicted in the Table 1.

Table 1. The terms related to ASSEMBLIES of LINKAGES and recommended for use

Term	Sense of the term
Assembly configuration	One of the possible configurations of a linkage for a given position of the input link
Assembly mode	One of the possible configurations of a linkage in which continuous displacement of the input link within some interval leads to continuous displacements of the rest moving links
Assembly group	One of the possible configurations of a linkage in which continuous displacement of any link leads to continuous displacements of the rest moving links
Full-rotatable assembly mode	Assembly mode existing for any position of the input link
Non-full-rotatable assembly mode	Assembly mode existing within the bounded interval of the input link motion

Non-standard assembly mode	Non-full rotatable assembly mode in which the input link motion interval is more than one full turn
Dead position of a linkage	The linkage position corresponding to common boundary of two adjacent non-full rotatable assembly modes
Branch	Position function of a moving link (except the input link) for some assembly mode of the linkage
Branching defect	Unfavorable effect which can take place during linkage kinematic synthesis when the given function is approximated by the position function of one assembly mode on one part of the given segment of mechanism generalized coordinate change, but on another part of this segment it is approximated by the position function of another assembly mode, while in accordance with the main synthesis requirement the given function should be approximated by the position function of only one assembly mode on the whole prescribed segment

3. Example

Consider the spatial mechanism RRRSP (Fig. 1) with the following values of constant parameters: h_1=20, h_2=30, h_3=60, h_4=70, l_{12}=30, l_{23}=10, l_{34}=15, θ_1=60°, θ_2=0, θ_3=90° (R, P and S are revolute, prismatic and spherical joints). This mechanism has three AMs: 1st (FRAM), 2nd (NFRAM), 3rd (NSAM). The position functions X=X(φ) of the output link for three AMs are shown on the Fig. 2. For 2nd AM the range Φ=100°; for 3rd AM the range Φ=460°. This mechanism has two Assembly Groups (AGs). First AG consists of 1st AM only. Second AG is formed by 2nd and 3rd AMs. At any value of the input angle φ within the interval [15°, 275°] and [275°, 375°] the mechanism has two and four ACs respectively.

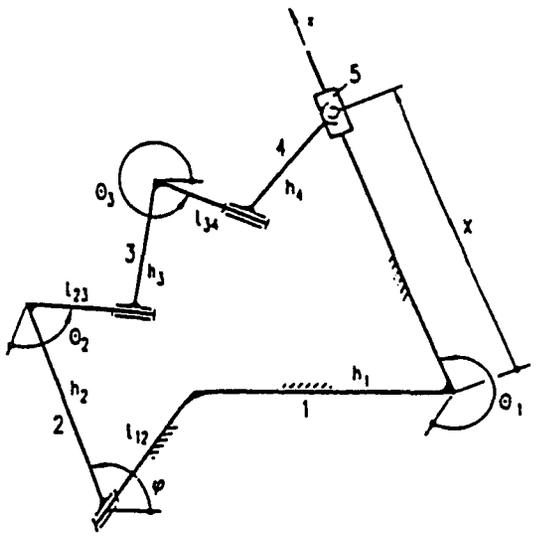

Figure 1. RRRSP spatial mechanism

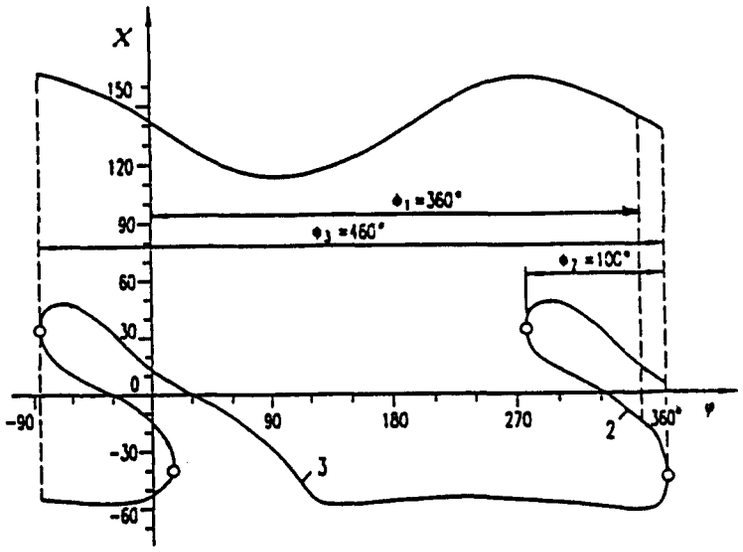

Figure 2. Position functions of the output link 5 (see Fig. 1) for all feasible assembly modes of the mechanism

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