STRUCTURAL SYNTHESIS OF REVERSE PLANETARY GEAR CAM MECHANISMS

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Abstract: The mechanisms of permanent kinematical structures with two degrees of freedom are widely applied in the technical practice, but there is no structural systematization, which gives an graphical survey of possible kinematical types and which enables the choice of an optimal solution. In the study, there have been identified basic kinematical chains on the basis of which there has been given a systematization of planetary cam gear mechanisms for the generation of periodical (gear) transmitting functions.

Keywords: mechanisms, kinematics structure, structural synthesis, planetary gear

1. INTRODUCTION

Periodical movement with the momentary stoppage or the phases of standstill of the working-executive elements of different technological machines, rotary tables, additional or the moving and displacing of the working object from one technological position into the other, is realized in practice with the help of the two kinematics types of mechanisms:

- Mechanism of changeable structure,
- Mechanism of permanent structure.

The work of the mechanisms of changeable structure is, from the dynamic, and thus from the technological point of view, unfavourable, because the change of the kinematic structure which occurs at the beginning and at the end of every conjugation of the driving and the driven member of the kinematics chain has, as a consequence, the occurrence of the increase of acceleration and because of that, the occurrence of the inertial forces too, which hinders the accuracy of the positioning. Because of that, the usage of this type of mechanism (Geneva mechanism, the mechanism with gear segments) in the basic kinematics shape is limited onto the slow runners, mainly onto the statically burdened machines which have no high requirements for the accuracy of moving, that is, positioning. Differing from these mechanisms of permanent structure, there is the uninterrupted contact between the members of the kinematics chain, which enables a peaceful transition from the phase of standstill into the phase of moving of the executive member, and vice versa, during the defined periodical working cycle. In the basic kinematics shape, those are the different types of cam- and 5- membered, 6- membered and 8-membered cam-lever mechanisms.

However, the link-lever mechanisms can achieve (realize) standstill, or the momentary stoppage, only in one, final position, which is often not enough, and the remaining movement phase cannot be influenced upon, because of the real dimensions of the members. Also, because of the high number of links of the kinematics chain, they are often clumsy, so that they are "unconstructive".

Because of that, it is necessary to model such kinematics types of mechanisms whose movement of the executive member in all the phases can be prescribed. Most frequently, in that way, the combined mechanisms are achieved, and their plane cam mechanism has the function of the generator of the periodical movement, and some other (lever or gear) mechanism has the function of the additional. So, the complex mechanism is achieved, which functions as the analogous auditioning mechanism for the summing of the two variables of type $x_1 = q\, x_2 + p x_3$.

2. STRUCTURAL SYNTHESIS OF THE KINEMATIC REVERSE MECHANISMS WITH TWO STAGES OF FREE RUNNING

The basis for the modelling of the kinematics structures with two stages of free running for the realization of any kind of periodical movement is the 7- membered kinematics chain.

Then the structural synthesis is carried out under the following suppositions, that is, limitations:
- all the members of the kinematics chain are absolutely rigid and without mutual clearance,
- centers of gravity of members are in the line of movement,
- angular velocities of the driving members are constant,
- real members of the kinematics chain are plane kinematics pairs,
- kinematics chain has maximum 2 stages of free running, 7 members and without sliding links
- kinematics chain has one kinematics pair at the most, which is in the shape of the oval centroid and one pair in the shape of the cylindrical centroid.

On the basis of the classification of the kinematics pairs, according to [1] , [3], the 7- membered kinematics chain consists of two ternary members, Fig. 1, out of which one can be chosen to be the immovable member.
Such kinematics chain has three modifications KL.1. KL.2. and KL.3., out of which, however, only the modification KL.3., Fig. 1, can satisfy the established (set) suppositions and limitations. Kinematics chain KL.3. consists of two indirectly connected ternary and of two binary members. Such a relation of the ternary members enables their mutually relative movement.

In order to impose the periodical relative movement upon the other ternary member, if the first one is used as the immovable member, one binary member must be really given the kinematics shape of the oval centroid, and the reversibility of the mechanism must be realized by the real shaping of the other binary member as the cylindrical centroid pair, that is by shaping of one binary member as the plane cam mechanism and the other as the cylindrical gear pair.

In that way, out of the 7-membered kinematics chain, by the transformation of the binary members, the 5-membered modification of structure KL.3/3 is created, Fig. 1, of the reverse summing mechanisms with two stages of free running. By reduction of the immovable ternary member, modifications 3K4, 2K4 and 1K3 are created.

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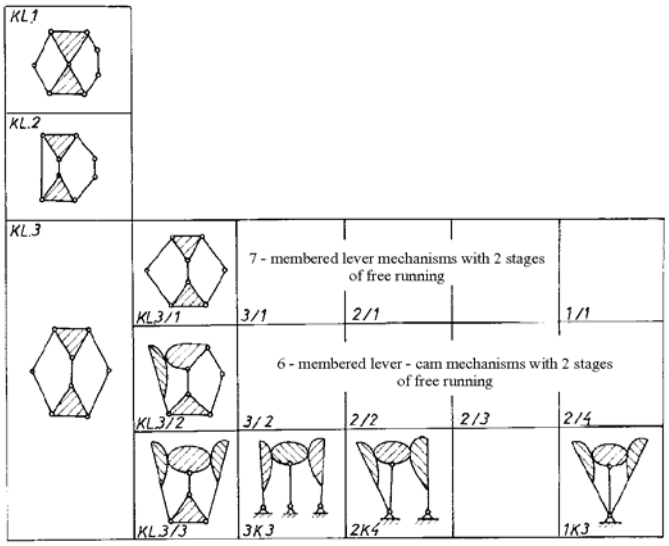

Figure 1. Classification of the 7.-membered kinematics chains

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In that way, out of the 7-membered kinematics chain, by the transformation of the binary members, the 5-membered modification of structure KL.3/3 is created, Fig. 1, of the reverse summing mechanisms with two stages of free running. By reduction of the immovable ternary member, modifications 3K4, 2K4 and 1K3 are created.

Each modification gives the summing reverse mechanisms with two stages of free running of different type:
1) on the basis of the structure of the kinematics chain of type 3K3, 8 types of the 5- membered summing lever-cam mechanisms and with two plane cam members are created,
2) on the basis of the structure of the kinematics chain of type 2K4, which has the link (connection) of the rotary members for the immovable ternary member reduced onto the two axis, 12 types of the lever-cam mechanisms with two cam members and 18 types of the planetary gear-cam mechanisms are created, Fig.2.
3) the structure of the kinematics chain of type 1K3 presents 18 types of the summing planetary gear-cam mechanisms, Fig. 2, and, if the gear pair is observed as a multiply repeated cam mechanism, because each gear can be considered as a cam, that is, if the both binary members are shaped as the oval centroids, 10 types of the summing two stage reverse planetary mechanisms [*], (Fig. 3.).

The connection of the rotary members of the kinematics chain for the immovable ternary member is reduced onto one axis.

[*] If both binary members are the cylindrical centroids, 10 types of the summing two stage reverse planetary mechanisms are obtained, with two stages of free running, by which the constant angular velocity of the output member is realized (Fig. 3.).

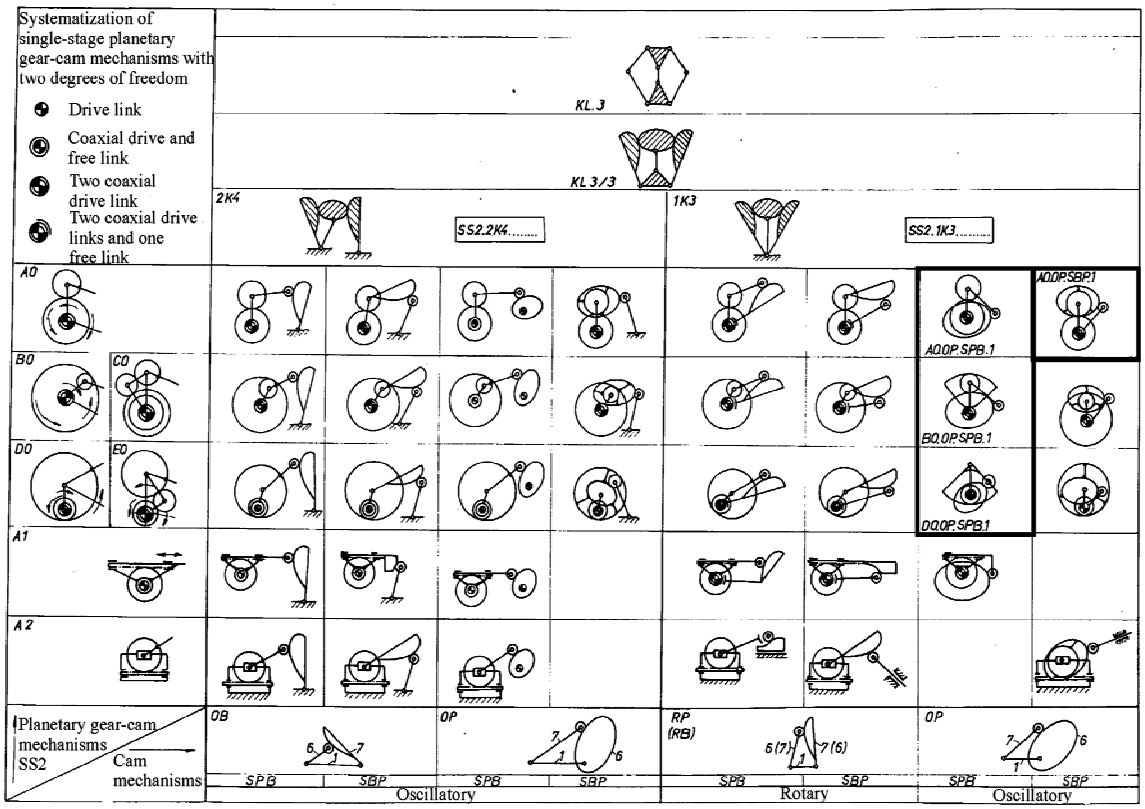


Figure 2. Systematization of the one-stage planetary gear-cam mechanisms of types SS2. 1K3 and SS2. 2K4

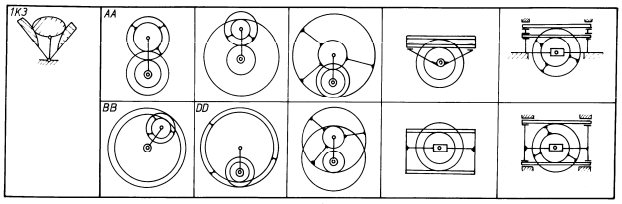
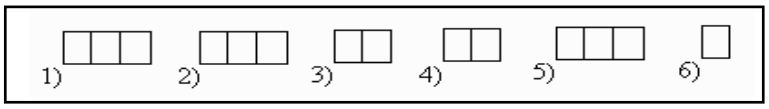


Figure 3. Systematization of the two-stage planetary gear mechanisms on the basis of the kinematics chain of type 1K3

On the basis of the presented methodology of the structural modelling of the kinematic types of mechanisms, the structural-functional marking of any type of planetary gear-cam mechanism can be formed, in the following shape:



Certain groups of letters and numbers in the marking of the mechanism type present the following:

1) The number of the stages of free running: SS1 or SS2.
2) The type of the kinematics chain: 1K3 or 2K4.
3) The type of the planetary gear mechanism; markings according to tables 1-I, 1-II, 1-III, according to [2].
4) The type of the cam mechanism:
   0 – oscillatory, which can be:
   OP - oscillatory - the driven member is the oscillatory lever,
   OB - oscillatory - the driven member is the oscillatory cam plate of the open contour,

R – rotary, which can be:
RP - rotary - the driven member is the rotary lever,
RB - rotary - the driven member is the cam plate of the open contour.

5) The sequence (order) of members of the kinematics chain, at which the first two letters indicate the mutually immobilized movable members, and the third letter is the member which is nestled on the stand. The following combinations are possible:
   a) Regarding the planetary mechanisms with one stage of free running of type 1K3 and 2K4 and two stages of free running of type 1K3:
      SPB: S - satellite ≡ P – lever of cam mechanism - B – cam plate,
      SBP: - satellite ≡ B - cam plate - P - lever of cam mechanism,
      SBB: S - satellite ≡ B - cam - B - cam (oval gear pair).
   b) Regarding the two stage planetary mechanisms with two stages of free running of type SS2.2K4:
      RPB: R - handle - carrier ≡ P – lever of the cam mechanism -B-cam,
      ZPB: Z - gear (central) ≡ P - lever of the cam mechanism -B-cam,
      RBP: R - handle - carrier ≡ B – cam plate of the open contour -P-lever.
6) Numeral marking 1 or 2, which indicates the type of mechanism regarding the possibility of choice of the output member.

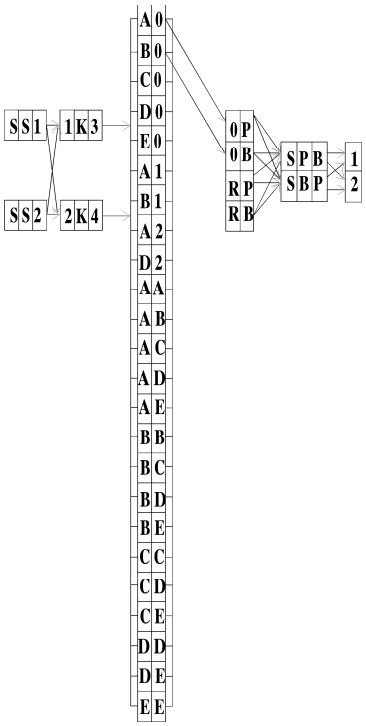


Figure 4. Structural-functional marking of the planetary gear-cam mechanisms

Structural functional marking of the planetary gears of the cam mechanisms is shown on block scheme on Fig. 4. From the block scheme, the number of the one stage or two stage types of mechanisms with one or two stages of free running is calculated, on the basis of the kinematics chain of types 1K3 and 2K4.

3. CONCLUSION

The presented methodology of the structural modeling gives the complete overview of the systematization of the planetary gear-cam mechanisms with two and with one stage of free running. It presents the basis for the choice of the optimal kinematics type of mechanism for the realization of any kind of periodical movement on the basis of summing of one uniform (invariable) and of one periodically changeable movement. The criteria for the

choice of the optimal kinematics type, from the constructive point of view, are the minimal dimensions of the oval centroid and the optimal transmitting relation of the summing gear mechanism.

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