ANALYSIS OF THE MAIN MOBILE LINKS OF THE MULTILOOP COULISSE MECHANISM FOR GUIDING COTTON BUSHES INTO THE WORKING CHAMBER OF A VERTICAL SPINDLE COTTON HARVESTER

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ABSTRACT

The article is devoted to the type analysis of the main mobile links of the multiloop coulisse mechanism of the vertical-spindle drum of a cotton harvester. The aim of the study is to conduct a type analysis of the main mobile links of a multiloop coulisse mechanism designed to direct cotton bushes into the working chamber of a cotton harvester.

The multiloop coulisse mechanism designed to guide the cotton bushes into the working chamber of the cotton harvester has, in addition to the main movable links, additional movable links that make up additional contour links and are necessary for technological considerations. In this paper, we consider only the basic moving links of the kinematic chain of a multi-circuit rocker mechanism.

Based on the results of the type analysis, the classes and degrees of freedom of the kinematic pairs of the main moving parts of the mechanism are determined and the degree of freedom of the kinematic chain without additional moving links is determined.

Research methods are based on the type analysis of the kinematic chain of the multiloop of the coulisse mechanism.Main results: A type analysis of the main mobile links of the multiloop of the coulisse mechanism was performed, the classes of kinematic pairs and the degree of freedom of the kinematic chain of the mechanism without additional contour connections were determined.

Key word: vertical spindle cotton harvester apparatus, mechanism, structure, kinematic couple, multicircuit, crank, slidings' blocks', coulisse.

INTRODUCTION.

A cotton harvester with spindle drums equipped with a multiloop coulisse mechanism for guiding cotton bushes into the working chamber [1,2], which, in comparative state tests of vertical-spindle cotton harvester, has proved its advantage in agronomic performance at Tashkent State Technical University (Tashkent State Technical University), was developed increased by 50% operating speed relative to serial machines.

The multiloop coulisse mechanism is a crank-link mechanism (Fig. 1), located inside the serial spindle drum, having three main movable links. The movable links of the mechanism are round rods of rotating and swinging wings, while protruding from the slidings' blocks'on the spindle drum in the input part of the working chamber, they act on the fruit branches and cotton bolls, directing them to opposite spindles.

This ensures that the spindles are contacted with cotton boxes earlier and longer than in serial production, i.e. favorable conditions are created for the process of collecting raw cotton spindles at increased machine speeds.

Object and methodology.

The object of study is the multiloop coulisse mechanism of the spindle drum. By the method of type analysis, we determine the classes and degrees of freedom of the kinematic pairs of the main moving components of the mechanism. In the kinematic chain of the main movable links of the spindle drum with a multiloop coulisse mechanism, the movement (torque) from the gear 5 (see Fig. 1) is transmitted through the shaft 6 to the upper disk 7.

A cylinder 1 is welded to the flanges of the upper 7 and lower disk 9, which transmits torque to the lower disk and the working links of the multi-circuit rocker mechanism. The crank (cylinder) transmits torque to the round rod of the revolutes coulisse 31 by means of slidings’ blocks’ 2. The round rod 31 is rigidly connected to the cassette 32.

Eleven swinging coulisse 4 are in turn pivotally connected to each cassette of the revolutes coulisse4. The swinging coulisse are driven by means of the crank at point Bi and from the cassette of the revolute coulisse at the point of hinge connection Si, while the rotation of the cassette of the revolute coulisse depends on crank rotation according to some regularity.

There are two such mechanisms in the spindle drum - the upper cassette - at a height of 400 ... 450 mm and the lower cassette - at a height of 200 ... 250 mm from the lower disk of the spindle drum.

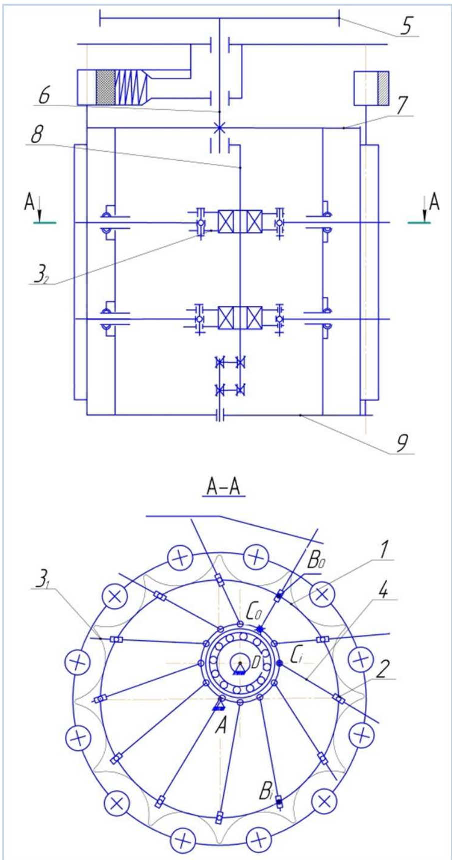


Fig. 1. principle diagram of a spindle drum with multiloop coulisse mechanism.
1 - crank (cylinder); 2- slidings’ blocks’; 31- round rod of the revolutes coulisse ; 32- cassette of a revolutes coulisse; 4- round rod rollings coulisse; 5-gear wheel; 6- shaft of the upper disk; 7- upper disk; 8- axis revolutes coulisse, 9 - lower disk.

Each mechanism consists of three main movable links (crank, slidings’ blocks’ and revolutes coulisse) and eleven swinging wings, which are pivotally connected to the rotating link at point C_i and to the crank by means of creepers at point B_i, and form contour (repeated) connections. These links can be attributed due to the identity in the form of construction and the principle of movement, into two groups - slidings’ blocks’ 11pcs., And rollings coulisse 11pcs.

It is well known that rocker mechanisms are widely used in mechanical engineering. The rocker mechanisms are considered and studied in many textbooks of famous authors [5-11] and have been sufficiently investigated by many leading scientists in the field of the theory of machine mechanisms [12-25]. However, the structural diagram of the foregoing multiloop coulisse mechanism was not investigated in these works.

To achieve this goal, we use the methodology of type analysis of the kinematic chain of the mechanism.

To determine the degree of freedom of the kinematic chain of the mechanism, we analyze the main moving links of the mechanism.

1-link - spindle drum cylinder - initial link - this is the link to which the movement is communicated, converted by the mechanism into the required movements of other links. It rotates around the axis A (see Fig. 2 *a)* 360 °, is called the-crank [5-8];

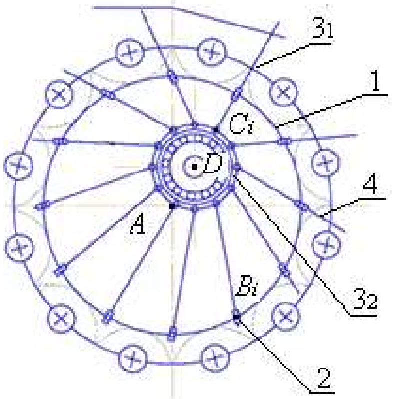
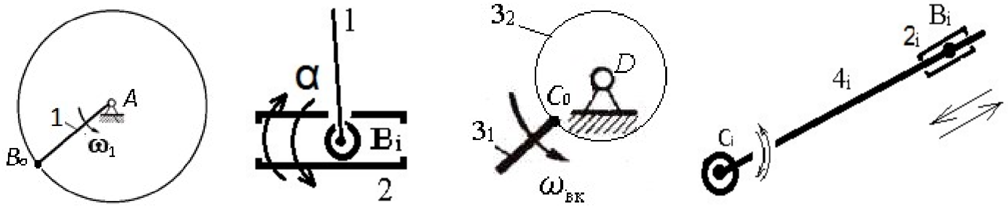


Fig. 2. Schematic diagram of a multiloop coulisse mechanismfor a spindle drum
1 crank (cylinder); a 2- slidings' blocks'; A 3_1-round rod of the revolutes coulisse;
3_2 - the cassette of the revolutes coulisse; 4- rollings coulisse (a round rod)

1 link – a cylinder of a spindle drum - the entrance link is a link to which the movement transformed by the mechanism to required movements of other links is reported. It rotates around axis O (see fig. 3, *a*) on 360 °, is called - a crank [6];



a) b) c) d)

Fig. 3. Structural diagrams of mobile links of the multiloop coulisse mechanism a) 1 link – a crank; b) 2 link – a slidings' blocks'; c) 3 link – revolutes coulisse:
3_1-round rod, the 3_2nd cassette; d) the rollings coulisse.

2 –the slidings' blocks'- turns on some limited coal around the vertical axis of fastening to a crank (cylinder) in B_i point (see fig. 3, *b*);

3 – the link - the revolutes coulisse, consists of two rigidly connected details: **3_1** – the round rod has reciprocating motion concerning a slidings' blocks' in B_3 point, and is rigidly connected to the cassette in C_0 point; **3_2** – the cassette – it is pivotally connected to a rack on axis D and rotates around this axis on 360 ° (see fig. 3, *c*);

Round rod **3_1** is connected to cassette **3_2** rigidly, points of their relative positioning do not change therefore we will consider them as a link consisting of two rigidly connected details. As the round rod has reciprocating motion concerning a slidings' blocks'to B_0 point, and the cassette rotates around axis ***D*** on 360 °, we will call it the revolutes coulisse.

4 link – other all **1_1** round rods as they have reciprocating motion concerning a slidings' blocks'in Bi point (see fig. 3, *d*), and with the cassette have a swivel joint in a point of C_i which allows to turn on limited угол-α_i (see fig. 3, *d*), we will call them – the shaking scenes.

4 links - the remaining 11 round rods, as they perform reciprocating motion with respect to the sliding "blocks" at point B_i (see Fig. 3, d), and with the cassette they have a swivel joint at point C_i, which allows rotation through a limited angle α_i, then we call them rollings coulisse.

For type analysis we will consider communications of kinematic couples separately. According to the theory of mechanisms of machines on any kinematic couple from two firm links having movable connections are imposed from one to five conditions of communication – S, on relative the movement of these links [6]. And the number of degrees of freedom of a link of a kinematic couple – N is defined from expression:

$$H=6-S \qquad (1)$$

In the vertically spindle drum, as described above, there are two such mechanisms and they are identical in design, with one common starting link - a crank (1-link). Since the crank with the strut is a common initial link for both cassettes, the number of the main movable links (without additional contour connections) on the second cassette is two (n = 2) - a slidings’ blocks’ and a rotating link.

The first kinematic pair consists of two parts: the fixed axis of the spindle drum A and the crank (cylinder) pivotally connected to it (see Fig. 2, a), which has only rotational movement around this axis. Since the first link - the axis of the spindle drum at point A - we take it stationary, it refers to the rack, and the cylinder has only 360°rotational movement around axis A, then it refers to the crank. The remaining 5 possible movements are subject to communication conditions. We determine the degree of freedom of the kinematic pair from the expression (1):

$$H = 6-S = 6-5 = 1$$

Kinematic pair: *p*1 (r) single-moving, rotational -1 pc.

The second kinematic pair of the slidings’ blocks’ to the crank has the ability to rotate a limited angle α_i along the vertical axis of its attachment at point B_i (see fig. 3, *b*), the connection conditions are imposed on the remaining 5 possible movements. We determine the degree of freedom of the kinematic pair from the expression (1):

$$H = 6-S = 6-5 = 1$$

Kinematic pair - *p*1 (r) is single-moving, rotational. Since two cassettes are installed on the spindle drum at different levels in height, there are also two p1 (r) = 2pcs of such kinematic pairs in the mechanism.

The third kinematic pair - a revolutes coulisse- a slidings’ blocks’. The round rod of the rotating wings, relative to the slidings’ blocks’, has a reciprocating movement at point Bi (see Fig. 3 b), the remaining 5 possible movements impose communication conditions. We determine the degree of freedom of the kinematic pair from the expression (1):

$H= 6-S = 6-5 = 1$

Kinematic pair - p1 (p) is single-moving, progressive. Kinematic pair also on the spindle drum installed two p1 (p) = 2pcs.

The fourth kinematic pair is a revolutes coulisse - at rack D, a revolutes coulissehas only 360°rotational movement around the stand (see fig. 3 c), and the communication conditions S = 5 are imposed on the remaining 5 possible movements.

The degree of freedom of the kinematic pair: $H = 6-S = 6-5 = 1$

Kinematic pair - p1 (r) is single-moving, rotational. Kinematic pair also on the spindle drum installed two p1 (p) = 2pcs.

When analyzing a mechanism with an optimal type, it is taken into account that the strut, regarded as a rigid fixed link, under real conditions, under the influence of applied loads, undergo deformations. In a deformed state, they can affect the relative positions of the elements not only within the same kinematic pair, but also within the closed kinematic chain of the mechanism.

If the structural scheme is incorrectly selected during operation, jamming (pinching) of some elements of the kinematic pair is possible, significant additional loads may appear due to skew, bending, stretching of the links, excessive wear of the elements of the kinematic pair, which leads to an increase in the energy consumption of the mechanism, low reliability, and frequent failures designs

Taking into account possible manufacturing and assembly errors, flat mechanisms can be considered as spatial in [6]. In this regard, to determine the degree of freedom of the kinematic chain of spatial mechanisms, we determine by the Malyshev formula, which becomes a universal structural formula that allows us to evaluate the rationality of the structure of the mechanism in question.

$$W= 6n - (5p_1+4p_2+3p_3 +2p_4 +p_5-q)$$

or

$$W = 6 \cdot n - \sum_{i=1}^{5} (6-i) \cdot p_i + q \qquad (2)$$

where: 6 is a number indicating that with spatial movement each link has six degrees of freedom; 5, 4, 3, 2, and 1 — the number of bonds imposed on the relative motion of the links corresponding to one-, two-, three-, etc. moving kinematic pairs; p1, p2, ..., p5 - respectively, the number and type of one-, two-, three-, four- and five moving kinematic pairs.

In formula (2), the degree of mobility of the kinematic chain of the mechanism (W) is, from geometric considerations, a known quantity equal to the number of generalized coordinates, i.e., the number of initial link (initial links) with a given law of motion, only the number of redundant bonds must be determined in it -q

$$q = W - 6n + \sum_{i=1}^{5}(6-i)p_i \qquad (3)$$

The total number of superimposed bonds may include a certain number q — the number of redundant (repeated) bonds that duplicate other bonds without decreasing the mobility of the mechanism, only turning it into a statically indeterminable system [6]. Numerically, the number of excess bonds (q) is equal to the number of sizes requiring exact execution.

Given that the degree of freedom of the mechanism is W = 1, i.e. has one initial link, we determine q-redundant bonds of the mechanism under consideration according to the Malyshev formula:

$$\boldsymbol{W= 6n - (5p_1+4p_2+3p_3 +2p_4 +p_5-q)= 6\cdot 5 - 5\cdot 7 + q = q}-5$$

Excessive connections for the mechanism under consideration, where the degree of freedom of the kinematic chain W = 1, is determined from the expression (3):

$q=W- 6\cdot n+(5\cdot p_1 +4\cdot p_2 +3p_3 +2p_4 +p_5) = 1- 6\cdot 5+5\cdot 7 = 6$

This means that in this mechanism, 6 sizes require precise execution. Such dimensions are displacement along the OУ axis and rotations along the OX and OZ axes of the closing kinematic pair. For the normal functioning of this mechanism, it is necessary that the axes of all rotational kinematic pairs be parallel, without skewing relative to the plane of motion of the kinematic links, which should also not be skewed (i.e., not curved).

When designing the structural diagram of the mechanism, without excessive contour connections, the assembly conditions of closed kinematic chains (circuits) of the mechanism should ensure assembly of the mechanism without interference even if there are deviations in the sizes of the links and deviations in the location of the surface and axes of the elements of the kinematic pair. For real mechanisms, they strive to develop such a structural scheme that would eliminate the possibility of additional loads in the kinematic pair due to a change in the configuration of the link contour, regardless of the accuracy of manufacturing parts or the deformability of the rack and other links [6].

If there are no redundant bonds, i.e. $q = 0$, then the assembly of the mechanism occurs without deformation of the links. The links, as it were, are installed and fully satisfy the requirements of reliability, durability and manufacturability. In practice, mechanisms without excessive connections work without creaking and noise. A mechanism without redundant bonds has an optimal structure and is called self-settling by the definition of Reshetov [7]. If there are redundant bonds, i.e. $q > 0$, then the assembly of the mechanism and the movement of its links are possible only when they are deformed. Signs of excessive connections in the mechanism are creaking, screeching and noise during the operation of such mechanisms.

In the mechanism, the kinematic chain of the main mobile links has 6 excess bonds. $q > 0$ - this means the given kinematic system is statically indeterminable. To bring it into a statistically determinable kinematic system, it is necessary that there are no excessive connections in the mechanism. To achieve this, one of the lowest kinematic pairs must be replaced with a higher kinematic pair, with a degree of freedom $H = 4$.

For this, the kinematic pair of the slidings' blocks' with the crank - the lowest kinematic pair, is replaced by the highest (ball in the cylinder), as a result of which we obtain a kinematic system statistically determinate.

The kinematic pair of the slidings' blocks' relative to the crank has the ability to rotate a limited angle along the axis of its attachment at point B_i (see Fig. 3, *b*), with a degree of freedom $p1 = 1$ (r). Point B_i refers directly to the three links of the mechanism: crank -1, creep - 2 and rotating link - 3. Replace the articulated joint of the creep with the crank (see fig. 3, *b*) with a ball in the cylinder (Fig. 4), we obtain the spatial kinematic a couple with a degree of freedom 3-rotational along the coordinate axes XУZ, and on a limited translational in the cylinder p4 (r, r, r, p), the remaining 2 possible displacements are imposed by the communication conditions.

We determine the degree of freedom of the kinematic pair from the expression (1)

$$H = 6 - S = 6 - 2 = 4$$

The kinematic pair of the crank - creeper (ball in the cylinder) has 4 degrees of mobility $p4$ (3r, p) and 2 such kinematic pairs, one for each cassette.

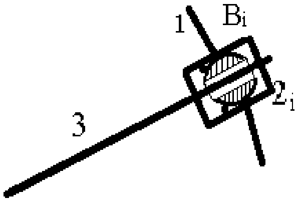


Fig. 4. Scheme of a kinematic pair of a crawler with a crank ball in a cylinder with $p4$ (r, r,r, p)

Taking into account the introduced changes, we determine the excess bonds in the kinematic scheme of the main moving parts of the mechanism.

$$\boldsymbol{q=W-6\cdot n+5\cdot p_1+4\cdot p_2+3p_3+2p_4+p_5}=1-6\cdot 5+5\cdot 5+2\cdot 2=0$$

Now the kinematic chain of the main moving parts of the mechanism is statically determinable.

Results and discussion. After solving the tasks, with the conversion of kinematic pairs, the structural diagram of the multiloop coulisse mechanism under consideration is brought into the optimal structure and has the following indicators listed in table 1.

Comparative data of results of type analysis of multiloop coulisse mechanismare shown in table 1.

Table 1

	On considered mechanism	On the mechanism with optimum structure
Input link	1	1
Number of the main mobile links, n (piece)	4	4
Kinematic couples (piece)	7	7
Kinematic couples of the fifth class p_1 (piece)	7	5
Kinematic couples of the second class p_4 (piece)	0	2
Degree of freedom of a kinematic chain, W	5	1
Excess communications of q (piece)	6	0

Conclusion

According to the results of studies of the main mobile links in the kinematic chain of the multi-circuit rocker MPC of the spindle drum, excess connections are eliminated. The kinematic chain of the main kinematic pairs of the mechanism acquired a statically determinate.

Such a structural diagram is assembled without interference even if the dimensions of the links and the location of the surfaces and axes of the elements of the kinematic pairs are deviated, eliminates the possible occurrence of additional loads in the kinematic pairs by changing the configuration of the link contour, regardless of the precision of manufacturing parts or the deformability of the racks and other links. Elimination of excess connections provides high reliability, reduced wear of parts, increased efficiency of the machine, reduced operating costs [5,6,7].

In the developed structure of the kinematic chain of the main moving links, the mechanism has a degree of freedom W = 1, i.e. the input link of the mechanism is driven by one engine.

But in this mechanism there are 44 additional contour movable links with kinematic pairs.

Further research will continue on additional contour connections, which also need to be analyzed to develop the optimal structure of the multiloop coulisse mechanism as a whole.

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