Synthesis of Structural Schemes of Balance Mechanisms for of a Portal Crane Jib System

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Abstract: *Structural schemes for plain linkage balance mechanisms appropriate for application in a portal crane have been synthesized. The synthesis includes the following limitations: saving the configuration of the crane's mechanism used in practice; the pairs must be only of the rotating type; the mechanisms must be second class; the links must be no more than eight; the jib of the crane must make pair with the frame and must be first (guiding) for the balancing mechanism.*

Keywords*: structural synthesis; portal crane; four bar linkage; balancing mechanism; jib system.*

INTRODUCTION

The present modern portal cranes have fully- or partially- balanced jibs, which provides the same hoisting capacity for the entire range of the reach of act. There upon preserving maximum potential crane efficiency is guaranteed for the whole service space, which is a basic work demand for portal cranes [1, 2].

Another requirement for portal crane work is the provision of a horizontal moving of the cargo, for which purpose more and more perfect guiding and balancing mechanisms for structural schemes are being developed for the jib system [3, 4, 5, 6, 7].

Several diagrams are proposed, one of them shown on Fig. 1, for a full static balancing of the guiding mechanism of the jib system, which theoretically can be presented as a four bar linkage.

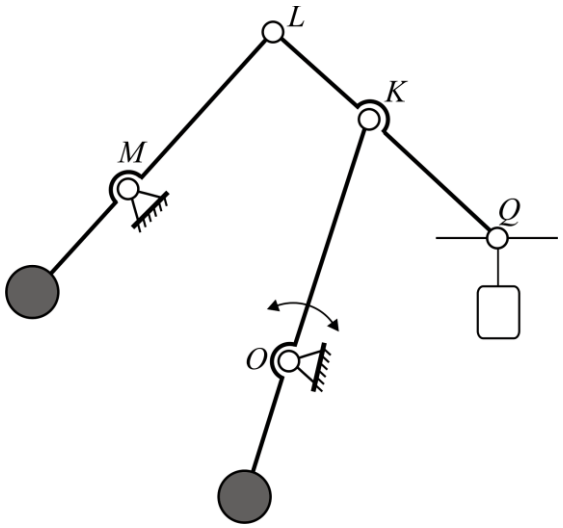


Fig. 1 Full static four bar balancing linkage

This method of balancing the portal crane guiding mechanism is unacceptable. The cause for that is the large masses of the mechanism bars, which will lead to high values of the counterweight masses.

An additional mechanism for the balancing of the portal crane guiding mechanism is used, most often – a four bar linkage – Fig. 2. One of the end bars 1* of this balancing mechanism is immovably linked to jib 1 of the guiding mechanism, and the counterweight is hanged on the other bar. A complete static balance can not be reached by using a balancing mechanism. It is approximate but is reached by a smaller counterweight mass. This mechanism can exist in two forms – parallelogramic and antiparallelogramic, presented in respectively solid and dashed lines. It is known from practice that a parallelogramic four bar linkage (Fig. 2) is mainly used as a balancing mechanism [8].

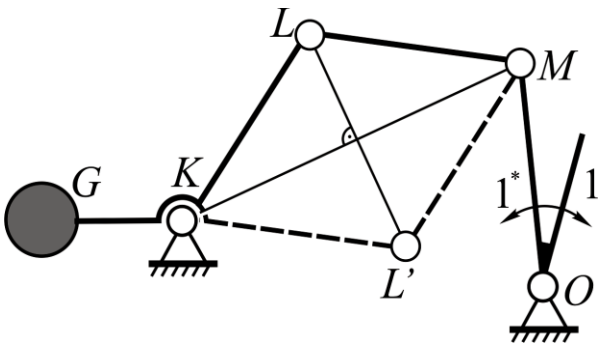


Fig. 2 Four bar balancing linkage - $У_1$

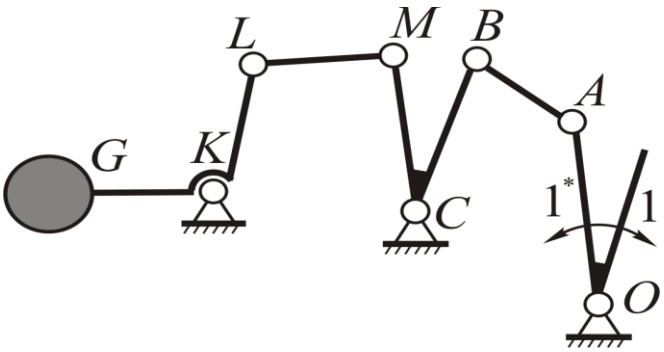


Fig. 3 Six bar balancing linkage -$У_2$

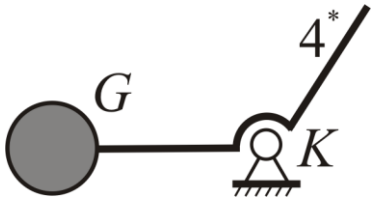


Fig. 4 Balancing linkage -$У_0$

Asix bar mechanism is known from books, shown on Fig. 3 and an eight bar mechanism as well, shown on Fig. 5 [9].

Because of its simplicity, balancing of a plain hoisting jib deserves attention – Fig.4. It can be an appropriate option for balancing mechanisms with more complicated structural schemes.

The purpose of this work is to synthesize other structural schemes of balancing mechanisms, suitable for use in portal cranes.

SYNTHESIS OF BALANCING MECHANISMS

For diminishing of large variety of schemes and guiding the structural synthesis for balancing machinery for portal crane towards desire result are initiated following limits:

a) Keeping the shape of the mechanism that is mostly used in practice – for to be stressed the applied characteristic of those who were synthesize structural schemes;

b) The new structural schemes have to contain only revolving pairs – due to hard loads to the crane;

c) The synthesized mechanisms to be with second class in the classification of ASSUR-ARTOBOLEVSKI, as the beginning bar 1^* is connect with the jib – on facilitating projecting mechanisms;

d) The number of the bars in the synthesized structural schemes not to be more than eight – for producing practical aptitude in obtained.

The structural synthesis of planar lever mechanisms can be done in a different manner. For structural deduction on symmetrical lever mechanisms it is possible to be used for the approach exposed in [10, 11]. As other method for structural deduction can be used exposed in [12] parallel decision replacement in kinematic synthesis approach.

Disadvantage of the first method is that conformity of the limitation cannot be guaranteed c) – mechanisms of different classes are obtained, but with the second method in principle there isn't guarantee that it will exhaust all possible scenarios on structural schemes.

For having new structural schemes at balancing mechanisms we will apply the classical approach of Assur, which permits exhaust all possible scenarios on structural schemes and gives possibilities for easily observing the limits - b), c) and d). To meet the requirements for limits in b) and c), in deduction just join ASSUR GROUP (AG) with revolving pairs.

The sequence of the considered deduction we will expose by the mechanism from Fig. 5. At the bar 1 and posture we join the AG *ABC*. It is received four-bar linkage *OABC*. The second AG *DEF* is possible to join towards the received four-bar linkage in a different ways, one of which is shown on Fig.5. The received mechanism is six-bar linkage and it consist of two joint in series four-bar linkage (*OABC* и *CDEF*). The bar *KL* from the last AG we always join to the frame, and the bar *LM* towards one of the previous AG – in this case the connection is towards the bar *EF*.

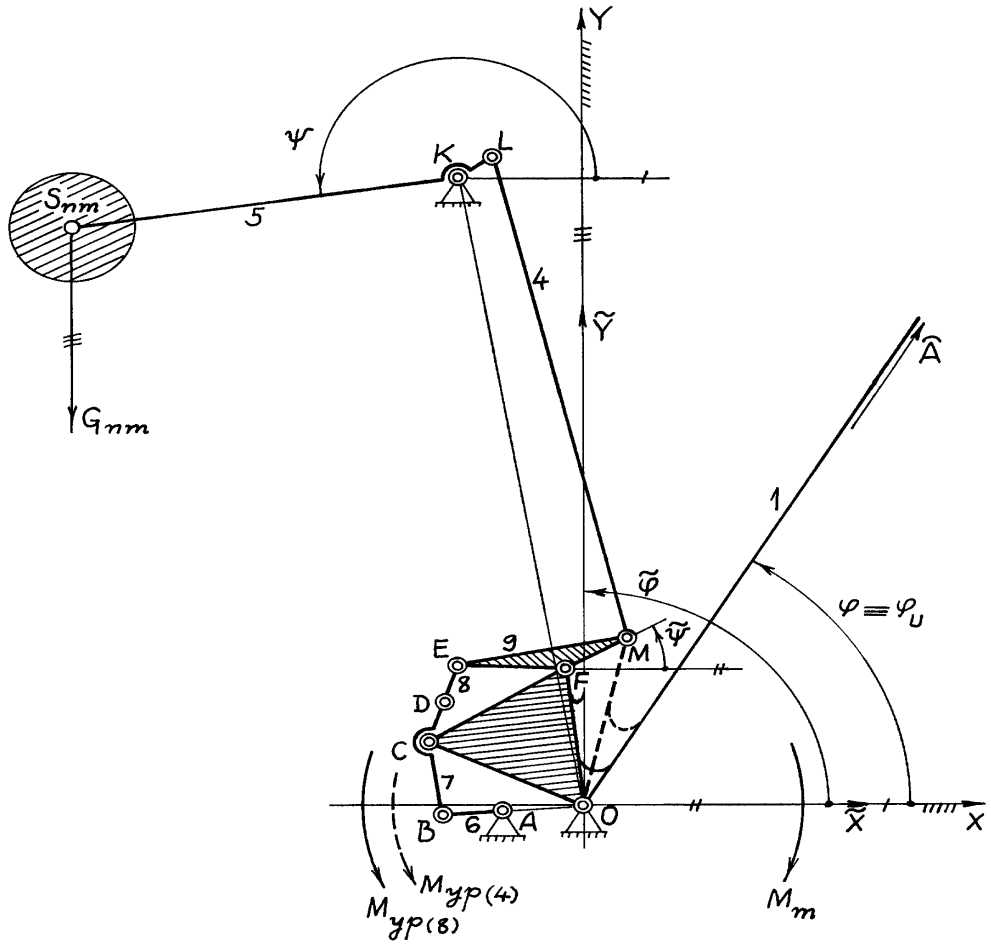
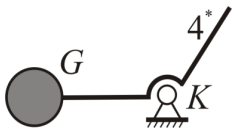
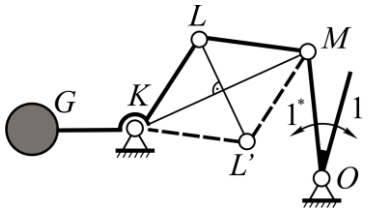
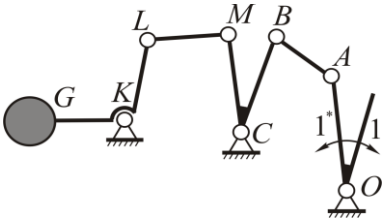
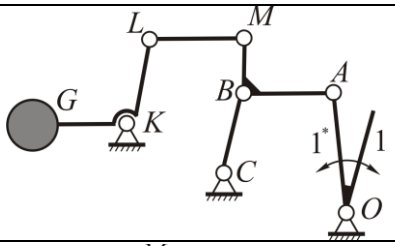
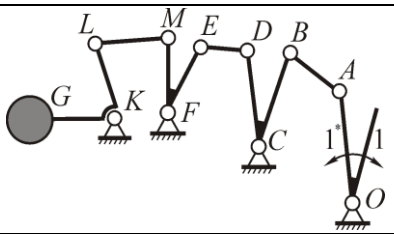
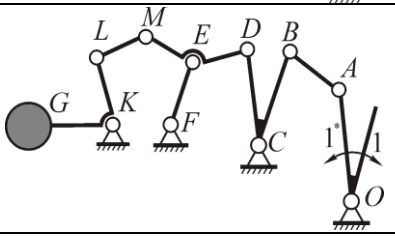
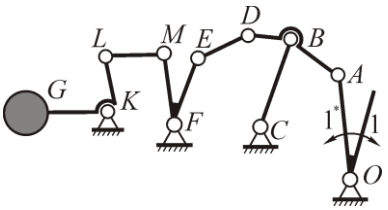
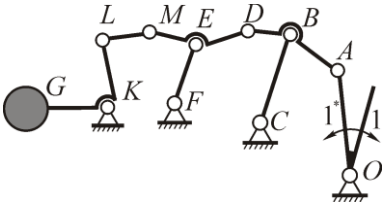
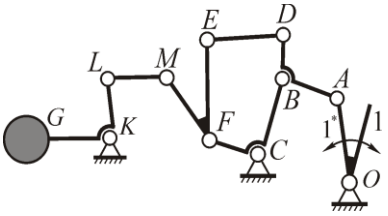
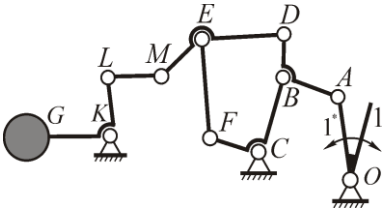
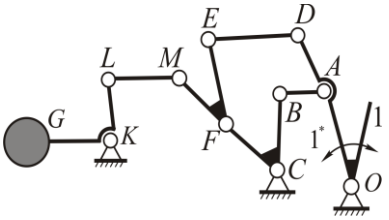
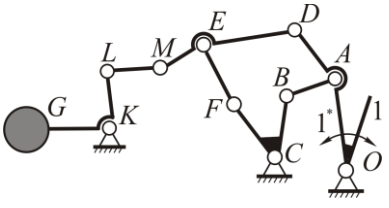
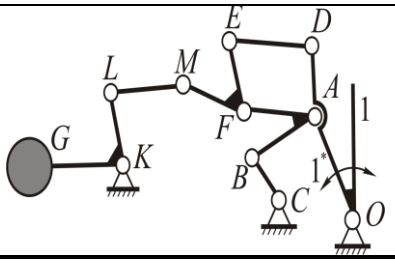
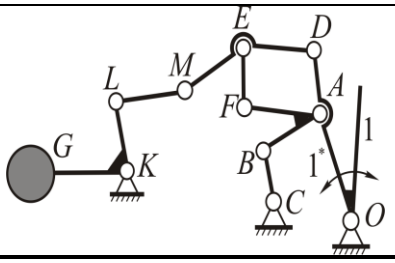


Fig. 5 Eight bar balancing linkage

***Table 1** Structural schemes of balancing mechanisms for a portal crane*

Symbol	Scheme	Number of linkage	Symbol	Scheme	Number of linkage
y_0		2	y_1		4
$y_2 \equiv y_{2,1}$		6	$y_3 \equiv y_{2,2}$		6
$y_4 \equiv y_{3,1,1}$		8	$y_5 \equiv y_{3,1,2}$		8
$y_6 \equiv y_{3,2,1}$		8	$y_7 \equiv y_{3,2,2}$		8
$y_8 \equiv y_{3,3,1}$		8	$y_9 \equiv y_{3,3,2}$		8
$y_{10} \equiv y_{3,4,1}$		8	$y_{11} \equiv y_{3,4,2}$		8
$y_{12} \equiv y_{3,5,1}$			$y_{13} \equiv y_{3,5,2}$		

Structural schemes of portal crane balancing mechanisms are synthesized in Table 1 along the chosen approach, all limitations regarded. It is easy to check that all of the mechanisms are of second class. In order the analysis to be thorough the already known schemes from Fig. 2, Fig. 3, and Fig. 4 are included. A symbol is used for each mechanism, the number of its bars is given. On the initial bar (the jib) is set a two-way arrow as a symbol of returning circular movement. Conditionally, for an "initial mechanism" (Yo) is assumed the balancing of the hoisting jib as well. (Fig. 4)

In the usage of the first AG, the synthesis yields the only solution Y_1 – four-bar linkage *OMLK* (Fig. 2). For the mechanisms $Y_2 \equiv Y_{2,1}$ and $Y_3 \equiv Y_{2,2}$ the second AG consists of the main bars of the balancing mechanism – the *KL* rocking arm, on which the *G* balancing counterweight and the connecting rod are hanged.

The methods of connecting the last bar LM (the rocking arm is always connected to the hinge prop) to the first AG bars are two – either to the bar *BC* of the already formed four-bar linkage *OABC* with a simple movement or to its connecting rod BA. In the two-index symbols, $Y_{2,1}$ and $Y_{2,2}$, the first index equals the number of the AG, and the second – the manner of connecting the *LM* bar from the last AG.

Now let's look into the methods of connecting the bars of the AG after the first. For the Y4 to Y13 mechanisms, after the first AG, two more AG are connected consecutively, the last of which is MLK with the G counterweight. The bars of the second AG can be connected to the four bar linkage OABC in six manners [8]:

1. To the hinge prop and the *BC* bar – thus $Y_4 \equiv Y_{3,1,1}$ and $Y_5 \equiv Y_{3,1,2}$ mechanisms are formed;
2. To the hinge prop and the *BA* connecting rod – Y_6 and Y_7;
3. To the *BC* bar and the *BA* connecting rod – Y_8 and Y_9;
4. To the 1* initial bar and the *BA* connecting rod – Y_{10} and Y_{11};
5. To the *BC* bar and the 1* initial bar – Y_{12} and Y_{13};
6. To the hinge prop and the 1* initial bar – this method does not lead to new mechanisms, because in this way the first AG loses its functionality and the thus formed mechanisms will act as Y_2 and Y_3. In the three-index symbols ($Y_{3,1,1}$ and $Y_{3,1,2}$ etc) the first index equals the number of the AG, the second – the method of connecting the second AG and the third – the manner of connecting the *LM* bar from the last AG.

The number of the balancing mechanism schemes is 14. When we additionally take into consideration the „anti-parallelogramacity" variation and the possibility of its combining with "parallelogramacity", the structural scheme number becomes 46.

CONCLUSION

In this work we synthesized the structural schemes of portal crane balancing mechanisms, which satisfy the imposed limitations. The limitations are strong, so the number of the formed schemes is not high, but if we reduce some of them, their number will possibly grow considerably. The synthesized schemes can be used to perfect and modernize the jib system of portal cranes after the implementation of an optimization synthesis.

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