ANALYSIS OF THE POSSIBILITY OF MOBILE POWER UNIT AGGREGATION WITH MOUNTED IMPLEMENTS

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The paper presents a formalized description of the process of transferring the mobile power unit (MPU) of the mounted implements (MI) to the transport position by the lifting and hinging device. Based on the proposed functional mathematical model (FMM), the output parameters of the lifting and hinging device are calculated.

Introduction. A sufficient level of lifting and hinging device (LHD) of a mobile power unit is a condition for its ability to be mounted with implements (hinged working machinery or tools). The purpose of this work is the formation of the FMM LHD of a mobile power unit that is aggregated with MI.

Main part. The linkage mechanism (LM) is the main component of LHD, which determines the nature of interaction between MPU and hinged machines. The working machinery traction through the connecting triangle is connected with the MI, which is taken as the output link of the closed kinematic chain consisting of the MPU frame, the MI and the LM links. Calculation of output parameters of LM is carried out on the basis of its flat analog obtained from the 3d model by projecting the centers of LM hinges on its longitudinal plane of symmetry MPU. The structurally flat analog of the LM includes a four-link, to which two Assyrian groups of the 2nd order, the 1st type, are successively attached, forming a single-link eight-link lever mechanism (Fig. 1). The change in the input coordinate (ΔS) LM, is uniquely related to the change in its output coordinates ($\Delta\varphi_6$, ΔY_{S6}, ΔX_{S6}). Geometric and kinematic analysis of a closed kinematic chain is performed sequentially, in accordance with its structure and on the basis of the closed vector contour method [1].

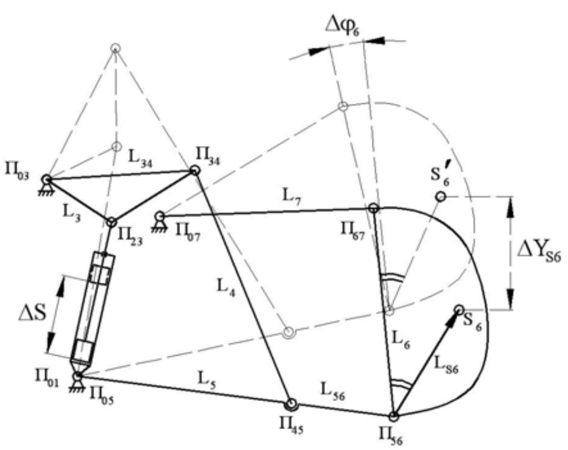

Fig. 1. Scheme of the transfer of implements from the worker to the transport position

In the coordinate system associated with the MPU, the coordinates of the moving joints LM and the characteristic points of the closed kinematic chain are determined. In particular, the coordinates of the suspension axis LM – are determined by the expressions:

$$X_{56}(S) = X_{05} + L_{56}\cos\varphi_5(S), \quad Y_{56}(S) = Y_{05} + L_{56}\sin\varphi_5(S), \tag{1}$$

where X_{05}, Y_{05} – coordinates of the fixed hinge П05 on the MPU frame; φ_i – the angle formed by the corresponding link in the right Cartesian coordinate system.

Coordinates of the characteristic point – the center of gravity of the MI are determined by the expressions:

$$X_{S6}(S) = X_{56}(S) + L_{S6}\cos[\varphi_6(S) + \varphi_{S6}]; \tag{2}$$

$$Y_{S6}(S) = Y_{56}(S) + L_{S6}\sin[\varphi_6(S) + \varphi_{S6}], \tag{3}$$

where L_{S6} and φ_{S6} is the characteristics of the vector drawn from the suspension axis to the center of gravity of the MI.

The procedure of kinematic analysis is formed in accordance with the LM structure by differentiating with respect to the independent variable (t) equations describing closed vector contours [1]. Definition of analogues of angular velocities of links LM is conducted in the direct order, since the rotary lever ($\Pi_{03}\Pi_{34}\Pi_{23}$). The expression for the analogue of the angular velocity of the lifting lever [3] has the form:

$$\varphi_3'(S) = \frac{d\varphi_3}{dS} = \frac{2S}{\sqrt{4 \cdot L_{13}^2 \cdot L_3^2 - \left[S^2 - (L_{13}^2 + L_3^2)\right]^2}}. \tag{4}$$

The transfer ratios $U_{53}(S)$ and $U_{65}(S)$, which connect the angular velocities of the links L_{56} and L_3, and also L_{56} and L_6, are determined as a result of a sequential kinematic analysis of the closed contours and $\Pi_{03}\Pi_{34}\Pi_{45}\Pi_{05}$ и $\Pi_{07}\Pi_{67}\Pi_{56}\Pi_{05}$ (Fig. 1):

$$U_{53}(S) = \frac{d\varphi_5(S)}{d\varphi_3(S)} = \frac{L_{34}\sin[\varphi_{34}(S) - \varphi_4(S)]}{L_5 \sin[\varphi_5(S) - \varphi_4(S)]}; \tag{5}$$

$$U_{65}(S) = \frac{d\varphi_6(S)}{d\varphi_5(S)} = \frac{L_{56}\sin[\varphi_5(S) - \varphi_7(S)]}{L_6 \sin[\varphi_7(S) - \varphi_6(S)]}. \tag{6}$$

Also for the given scheme LM the following relations are valid:

$$\varphi_5'(S) = \varphi_3'(S)U_{53}(S), \quad U_{63}(S) = U_{53}(S)U_{65}(S), \quad \varphi_6'(S) = \varphi_3'(S)U_{63}(S), \tag{7}$$

where $\varphi_5'(S)$ and $\varphi_6'(S)$ are analogs of the angular velocities of the links L_{56} and L_6; $U_{63}(S)$ – the gear ratio that connects the angular speeds of the lifting arm and implements.

The gear ratio implements is an analogue of the vertical velocity of the center of gravity of the KNK-500 [3]:

$$I_{S6}(S) = \varphi_3' U_{53}\left[L_{56}\cos\varphi_5 + U_{65} L_{S6}\cos(\varphi_6 + \varphi_{S6})\right]. \tag{8}$$

In accordance with the established design practice of LHD [4], a similar kinematic parameter was determined – the gear ratio of the LM on the axis of its suspension – $I_m(S)$, which is represented by the first term in expression (8). The diagrams of the change in gear ratios of LM MPU are presented in Figure 2.

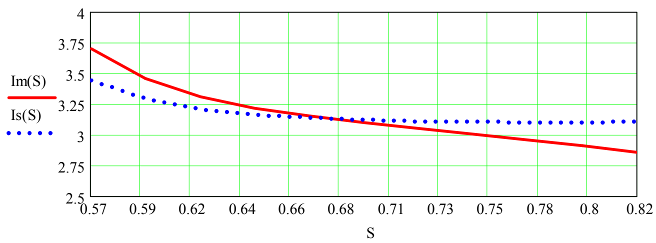

Fig. 2. Dependences of the gear ratios MH on the suspension axis (solid line) and at a distance from it (dashed line) from the generalized coordinate

The force analysis of the LM consists in determining the forces acting in the joints of the links, and is carried out according to the Assurian groups in the reverse order to the kinematic analysis, according to a known technique [2], [4].

The value of the load applied to the piston of the hydro cylinder HC – $F_L(S)$ consists of a useful component, as well as reduced frictional force (F_f^L) and force of inertia (F_{in}^L) [2].

$$F_L(S) = F(S) + F_{in}^L(S) + F_f^L(S). \quad (9)$$

The load applied to the HC is proportional to the gear ratio LM – $I_{S6}(S)$ [2]:

$$F(S) = P_6 I_{S6}(S), \quad (10)$$

where P_6 – is the weight of the ME.

The maximum driving force developed on the HC rod to overcome the load applied to the HC is determined by the expression:

$$F_{df}^{\max} = p_{HC}^{\max} F_c, \quad (11)$$

where F_c – the area of the piston HC; $p_{нс}^{\max}$ – is the maximum pressure in the HC.

The maximum pressure in the HC is limited by the setting of the safety valve and the pressure losses in the hydraulic drive:

$$p_{HC}^{\max} = p_{SV} - (\Delta p_{dl} + \Delta p_{ml}), \quad (12)$$

where p_{SV} is the setting pressure of the hydraulic safety valve; Δp_{dl} – pressure loss on the throttle in the drain line; Δp_{ml} – loss of pressure in the main line.

Dynamic analysis of the hydraulic drive of LHD associated with the MI through LM is described in [2]. The law of motion of the loaded piston HC $S(t) = f(S_0, \dot{S}, \ddot{S}, t)$ was determined, as well as the pressure change in the cavity of the HC on the side of the pressure line p_2.

The lifting capacity of LHD is determined by the formulas:

$$G_m(S) = \frac{p_2^{\max} \eta S_{HC}}{I_m(S)}; \quad G_{S6}(S) = \frac{p_2^{\max} \eta S_{HC}}{I_{S6}(S)}, \quad (13)$$

where $G_m(S)$ – the load capacity of the LHD on the suspension axis; $G_{S6}(S)$ – the load capacity of the LHD corresponding to the location of the center of gravity of the MI; $p_c^{\max}$ – the maximum possible pressure in the hydraulic cylinder LM; η – the efficiency of the LM; S_{HC} – the area of the workers' HC pistons.

On the basis of the expression for determining the payload and the received LM ($\eta = 0{,}85$) efficiency, the load capacity of the LHD of the "SEU-350" was determined on the suspension axis and at a distance S_6 from it. The calculation showed that the lifting capacity of the LHD at a distance S_6 from the suspension axis is 62.02 kN.

The results of calculating output parameters of LHD "SEU-350", aggregated with "KNK-500", are presented in Tables.

Output parameters of LDH “SEU-350”

S, m	Y_{56}(S), m	$\varphi_6(S)$, g	$\varphi_3'(S)$, 1/m	$I_m(S)$	$I_S(S)$	$Fg(S)$, kN	$p_2(S)$, MPa	$G_m(S)$, kN	$GS_6(S)$, kN
0,571*	–	–	–	–	–	–	–	–	–
0,596	0,320	90,019	4,844	3,454	3,291	157,931	14,313	59,101	62,05
0,621	0,404	89,869	4,425	3,312	3,210	154,092	13,963	61,635	63,597
0,646	0,486	89,780	4,175	3,218	3,164	151,849	13,760	63,440	64,536
0,671	0,566	89,741	4,022	3,149	3,135	150,490	13,637	64,824	65,118
0,696	0,644	89,746	3,935	3,095	3,118	149,658	13,561	65,967	65,480
0,721	0,720	89,794	3,896	3,048	3,107	149,159	13,516	66,989	65,699
0,746	0,796	89,884	3,896	3,003	3,102	148,884	13,491	67,977	65,821
0,771	0,870	90,021	3,932	2,959	3,100	148,779	13,482	69,003	65,867
0,796	0,944	90,209	4,003	2,911	3,101	148,833	13,487	70,136	65,843
0,821	1,016	90,459	4,112	2,858	3,106	149,086	13,509	71,445	65,732

*Connection of the mounted feed-handling combine “KNK-500” is performed when the height of the suspension axis (Y_{56}) is 0,33 m, which corresponds to S = 0,596 m.

Conclusion. It should be noted that the above methodology for determining the load capacity and other output parameters of the MPU LHD allows you to evaluate the performance of the aggregation and other MI with any other MPU LHD model having identical structure.

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