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THE IMPACT OF THE POSITION OF THE HYDRAULIC CYLINDER MOUNTING POINT ON THE CHASSIS LOAD IN MOBILE ELEVATING WORK PLATFORMS

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Abstract

The paper deals with the structural analysys of the typical mobile elevating work platform moving quasi-statically in the vertical plane. With certain approximations included, a model for calculating load transmission from the basket to the support on the vehicle chassis has been developed. It allows tracking changeable load conditions for each structural element, as well as tracking force changes in each hydraulic cylinder of the articulating boom, depending on the angles of boom joints and the geometric parameters of boom sections. Derived analytical dependences can be used as the basis for design and optimization of the hydraulic installation and hydraulic component selection. On the other hand, the functions obtained enable position adjustment of the hydraulic cylinder mounting point of the first section in order to reduce the load impact on the chassis.

Key words*: mobile elevating work platform, articulating boom, load transmission, chassis load*

1 INTRODUCTION

A hoisting device that provides temporary access of men and equipment to hardly reachable spots, which are placed at certain heights (from a few meters to several tens of meters), is called hydraulic elevating platform. The most often in use are the hydraulic elevating platforms mounted on vehicle. Such machine is called Mobile Elevating Work Platform - MEWP [1].
The advantage in exploitation often goes to hydraulic elevating platforms with articulating booms, which are typical representatives of structures with variable geometry [2] (Fig.1), in contemporary urban conditions, just because of configuration of terrain which has lot of obstacles such as street lights, traffic signs, advertising panels, trees, electric, phone and other public installations, parked cars and other objects.

Fig. 1 *MEWP boom types: telescopic, articulating and combined boom type*

The most important parameters of an elevating platform are, besides the lifting capacity, working height and horizontal reach (Fig. 2).
Named application features distinct them from hoisting devices with permanent access to working places and put them into special purpose construction hoisters.

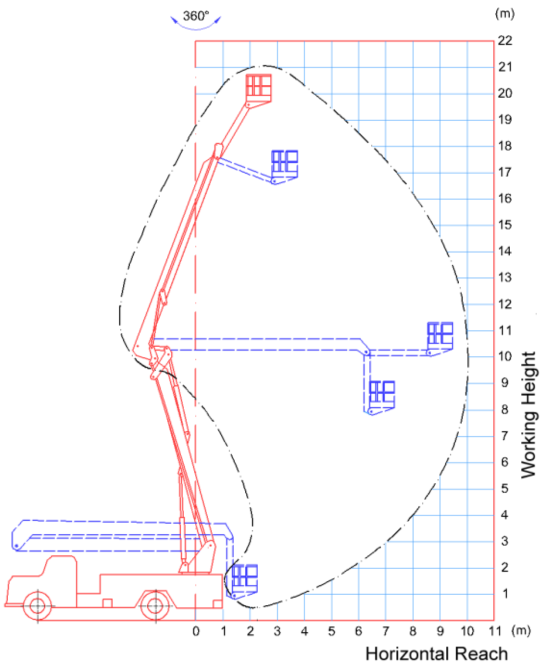

Fig. 2 *Working diagram of MEWP*

2 CALCULATION MODEL

Fig. 3 depicts various configurations of MEWP articulated boom while aproximated model for calculation and structural analysis of MEWP articulated boom in relation to basket position is partially shown in Figure 4.
Sections lengths and appropriate boom joint angles determine basket position within the work range (lifting

height and horizontal reach). The angles defining basket position are those that sections enclose with constant directions: α_1 and α_2 are the angles that sections 1 and 2 enclose with the horizontal direction and α_3 is the angle that section 3 encloses with the vertical direction. Each section is attached to the local (separate) movable coordinate system ($\xi_i \eta_i \zeta_i$, $i = 1,2,3$), at which the coordinate origin is placed at the joint connection with the previous section and ξ_i axes are perpendicular to the figure plane. At the section 1 support, that is the whole boom support, the global coordinate system $AXYZ$ is set. Table 1 shows constrained values of boom sections angles.

Table 1 Constrained values of boom sections angles

$\alpha_1 [°]$				0		
		45				
	75					
$\alpha_2 [°]$	-60	-30	0	15	45	70
$\alpha_3 [°]$	0÷20	0÷50	0÷80	15÷95	45÷125	70÷150

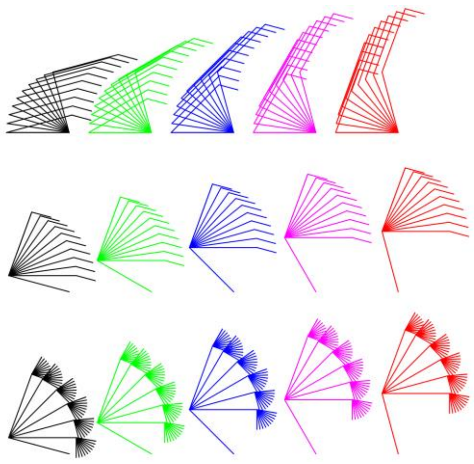

Fig. 3 *Various configurations of MEWP boom*

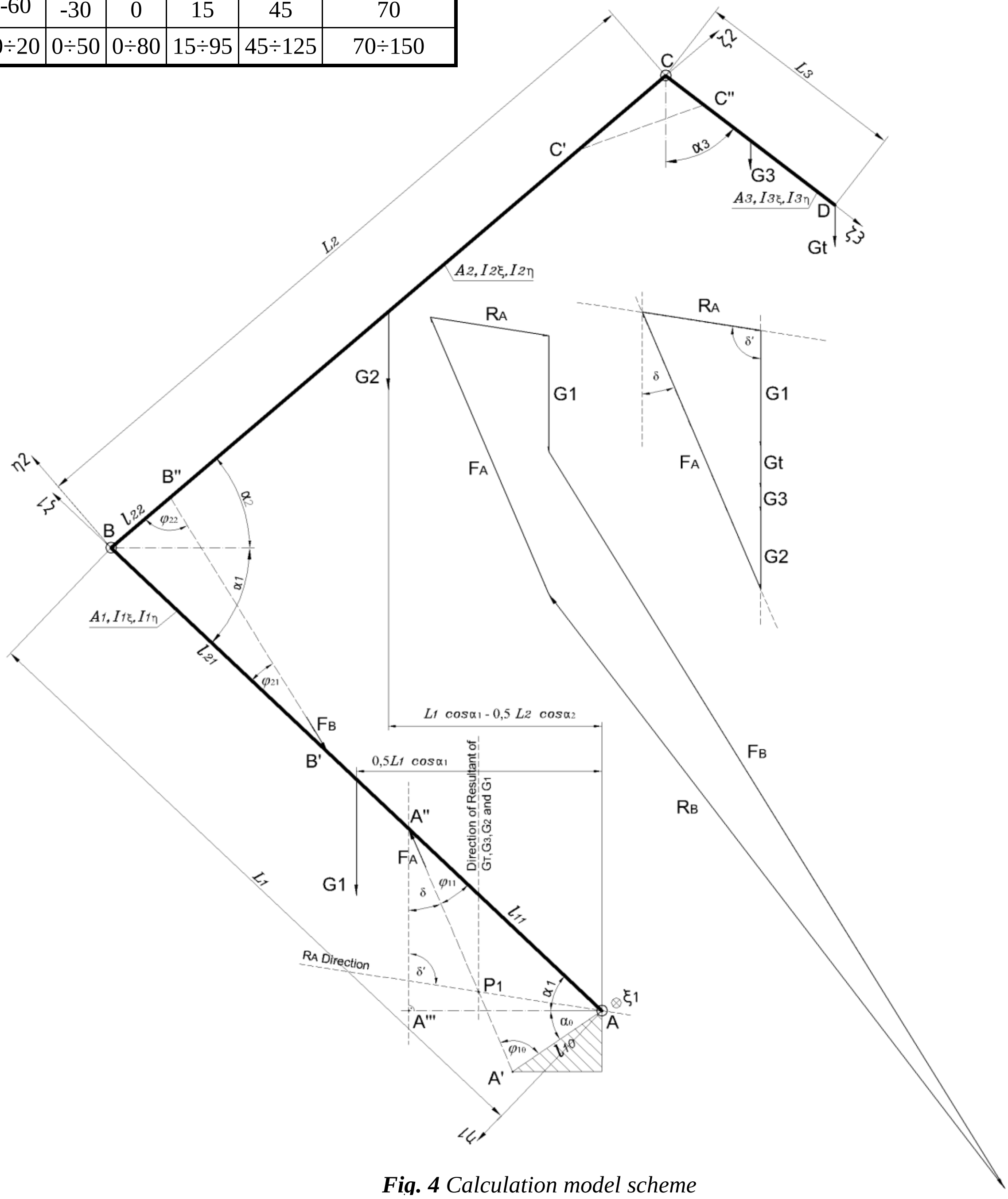

Fig. 4 *Calculation model scheme*

Complete analysis of presented model can be found in [3], where obtained analytical dependencies enable designer to use limited endpoint displacement ($f < f_{allowed}$) as a constraint function for optimization in order to reduce mass of the structure [4-7]. Based on detailed scheme of section 1 in Fig. 4, force in hydraulic cylinder F_A was determined from moment equation for support A :

$$\begin{aligned} &hl_1 \cos\alpha_1 (0,5G_1 + G_2 + G_3 + G_T) - \\ &-l_2 \cos\alpha_2 (0,5G_2 + G_3 + G_T) - \\ &-l_3 \sin\alpha_3 (0,5G_3 + G_T) = F_A l_{11} \sin\varphi_{11} \end{aligned} \quad (1)$$

where $\sin\varphi_{11} = \dfrac{l_{10}\sin(\alpha_1+\alpha_0)}{\sqrt{l_{10}^2 + l_{11}^2 - 2l_{10}l_{11}\cos(\alpha_1+\alpha_0)}}$.

Reaction of boom support in joint A is obtained as follows:

$$R_A = \sqrt{\begin{aligned}&(G_1+G_2+G_3+G_T)^2 + F_A^2 - \\ &-2(G_1+G_2+G_3+G_T)F_A\cos\delta\end{aligned}} \quad (2)$$

where $\cos\delta = \sin(\varphi_{11}+\alpha_1)$. All the forces should be projected on the local coordinate system $A\xi_1\eta_1\zeta_1$ in order to obtain the diagram of section 1 loads. After certain angle transformations and equation substitutions, we get the expressions for the force in the hydraulic cylinder and section 1 loads:

$$\begin{aligned} R_{A\eta 1} = &\frac{l_1}{l_{11}}(G_T + \frac{G_1}{2} + G_2 + G_3)\cos\alpha_1 - \\ &\frac{l_2}{l_{11}}(G_T + \frac{G_2}{2} + G_3)\cos\alpha_2 - \\ &-\frac{l_3}{l_{11}}(G_T + \frac{G_3}{2})\sin\alpha_3 - (G_T + G_1 + G_2 + G_3)\cos\alpha_1 \end{aligned} \quad (3)$$

$$\begin{aligned} R_{A\varsigma 1} = &(G_1+G_2+G_3+G_T)\sin\alpha_1 - \\ &-\frac{l_{11} - l_{10}\cos(\alpha_1+\alpha_0)}{l_{11}l_{10}\sin(\alpha_1+\alpha_0)} \cdot [-l_2(G_T + \frac{G_2}{2} + G_3)\cos\alpha_2 + \\ &+l_1(G_T + \frac{G_1}{2} + G_2 + G_3)\cos\alpha_1 - l_3\sin\alpha_3(\frac{G_3}{2} + G_T)] \end{aligned} \quad (4)$$

$$\begin{aligned} F_A = &\frac{\sqrt{l_{10}^2 + l_{11}^2 - 2l_{10}l_{11}\cos(\alpha_1+\alpha_0)}}{l_{10}l_{11}\sin(\alpha_1+\alpha_0)} \cdot \\ &\cdot[l_1\cos\alpha_1(0,5G_1 + G_2 + G_3 + G_T) - \\ &l_2\cos\alpha_2(0,5G_2 + G_3 + G_T) - l_3\sin\alpha_3(0,5G_3 + G_T)] \end{aligned} \quad (5)$$

$$\begin{aligned} F_{A\eta 1} = &-\frac{l_1}{l_{11}}(G_T + \frac{G_1}{2} + G_2 + G_3)\cos\alpha_1 + \\ &+\frac{l_2}{l_{11}}(G_T + \frac{G_2}{2} + G_3)\cos\alpha_2 + \frac{l_3}{l_{11}}\sin\alpha_3(\frac{G_3}{2} + G_T) \end{aligned} \quad (6)$$

$$\begin{aligned} F_{A\varsigma 1} = &\frac{l_{11} - l_{10}\cos(\alpha_1+\alpha_0)}{l_{11}l_{10}\sin(\alpha_1+\alpha_0)} \cdot \\ &\cdot[l_1(G_T + \frac{G_1}{2} + G_2 + G_3)\cos\alpha_1 - \\ &-l_2(G_T + \frac{G_3}{2})\cos\alpha_2 - l_3\sin\alpha_3(\frac{G_3}{2} + G_T)] \end{aligned} \quad (7)$$

3 VARIATION OF THE MOUNTING POINT POSITION AND ITS INFLUENCE ON THE FORCE VALUES ACTING ON THE CHASSIS

The further analysis of influence of the mounting point position of the hydraulic cilinder on the forces acting upon chassis was conducted for the geometry configuration of the MEWP articulated boom with maximum horizontal reach, i.e. $\alpha_1 = 75°, \alpha_2 = 0°, \alpha_3 = 80°$. Fig. 5 shows the position of hydraulic cylinder mounting point in polar coordinates with the origin in support A.

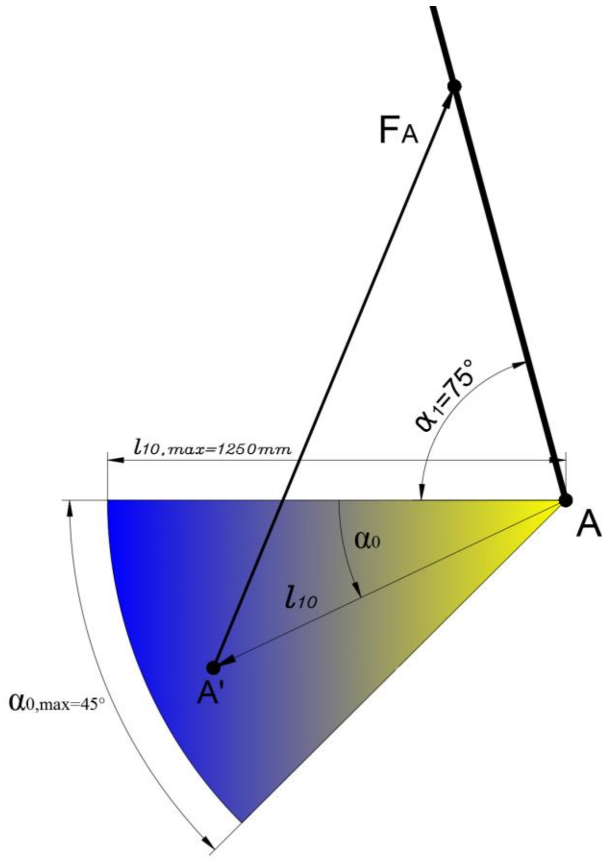

***Fig. 5** Position of hydraulic cylinder mounting point in polar coordinates*

The following numerical values for diagram plotting purpose were used:

$$\begin{aligned} &L_1 = 7602mm, L_2 = 8210mm, \\ &_3 = 2400mm, l_{33} = 540mm, \\ &l_{32} = 1288mm, l_{22} = 876mm, \\ &l_{21} = 3361mm, l_{11} = 2987mm, \\ &G_1 = 15kN, G_2 = 10kN, G_3 = 4kN, G_T = 5kN \end{aligned}$$

Polar coordinates of the hydraulic cylindr mounting point position were taken within ranges of $\alpha_0 = [0° \div 45°]$ and $l_{10} = [500mm \div 1250mm]$.

Numerical calculations were carried out by MATLAB software routines and the results of the gained dependances are presented in the following diagrams.

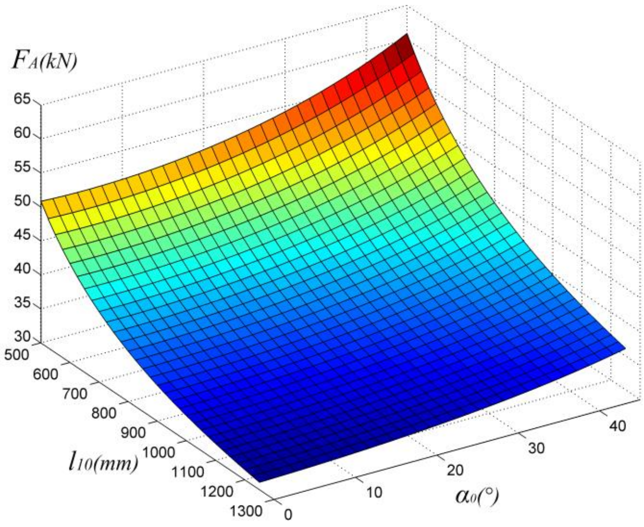

Fig. 6 *The impact of the position of hydraulic cylinder mounting point on its force*

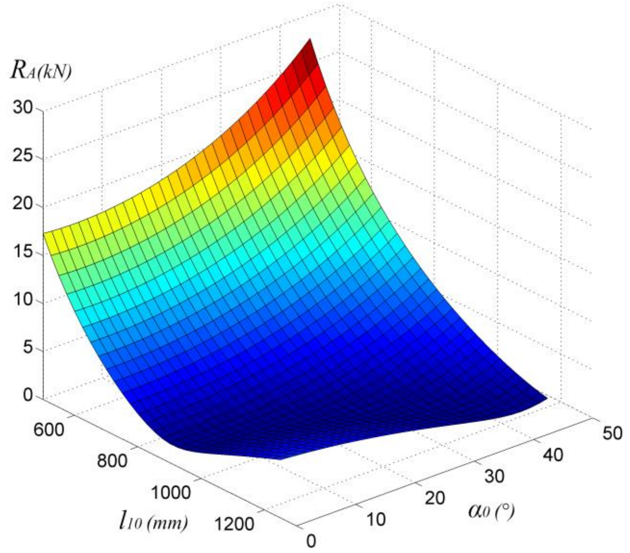

Fig. 7 *The impact of the position of hydraulic cylinder mounting point on reaction force in boom support A*

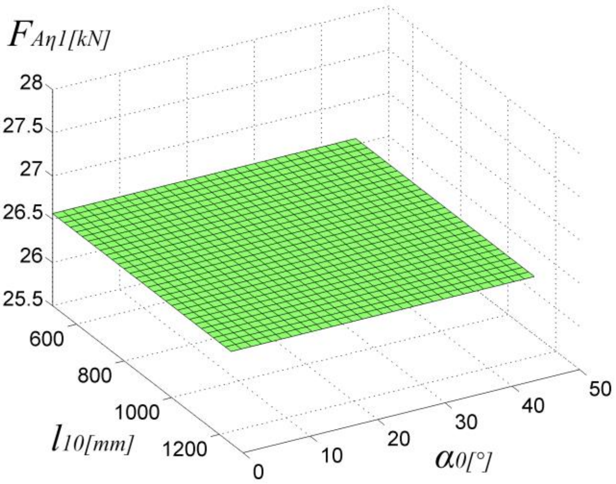

Fig. 8 *Component of hydraulic cylindar force perpendicular to section 1 longitudinal axis*

4 CONCLUSION

As expected, the values of the forces acting upon MEWP chassis in the hydraulic cylinder mounting point and the first section support A change with the variation of the mounting point position considerably. In order to achieve the needed value of its component which is perpendicular to the longitudinal axis of section 1 (Fig. 8), by which the moment equilibrium is maintained, the overall force in the hydraulic cylinder F_A (Fig. 6) increases as the distance l_{10} decreases and the angle α_0 increases. This has the consequence in similiar behaviour of the force value R_A in support A (Fig. 7). The final decision on the position of the mounting point can be made in relation to the operational parameters of the hydraulic cylinder, such as stroke and rated maximum force.

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