DETERMINATION OF THE LOADS ACTING ON THE SLEWING SUPPORT OF A TRUCK MOUNTED CRANE AND SELECTION OF A SLEWING SUPPORT

Hristo Sheiretov

University of Mining and Geology "St. Ivan Rilski", 1700 Sofia; sheiretov@abv.bg

ABSTRACT. The loads, acting on the slewing support of a truck mounted crane are determined - the resultant vertical force, the resultant horizontal force and the unbalanced moment of the forces acting on the slewing part of the crane. The mass of the counterweight is determined in advance using the condition of equality of the arms of the resulting forces to the rotation axis at the two endmost positions of the boom. Four cases are considered - at maximum and minimum length of the boom and at maximum and minimum angle of inclination of the boom. From the calculations it can be seen that the heaviest loads are obtained at minimum boom length and minimum boom inclination, because the unbalanced moment is the greatest. On the basis of the obtained forces and moments a slewing support is selected from the diagrams of the serially produced supports for the heaviest case of loading. A concrete example for the crane KC-45717, mounted on the truck chassis KamAZ, is solved.

Keywords: truck mounted crane, slewing support, unbalanced moment

ОПРЕДЕЛЯНЕ НА НАТОВАРВАНИЯТА ВЪРХУ ВЪРТЯЩАТА СЕ ОПОРА НА АВТОМОБИЛЕН КРАН И ИЗБОР НА ВЪРТЯЩА СЕ ОПОРА

Христо Шейретов

Минно-геоложки университет "Св. Иван Рилски", 1700 София

РЕЗЮМЕ. Определени са натоварванията върху въртящата се опора на автомобилен кран - резултантната вертикална сила, резултантната хоризонтална сила и неуравновесения момент от силите, действащи върху въртящата се част на крана. Предварително е определена масата на противотежестта от условието за равенство на рамената на равнодействащите сили спрямо оста на въртене за двете крайни положения на стрелата. Разгледани са четири случая - при максимална и минимална дължина на стрелата и при максимален и при минимален ъгъл на наклон на стрелата. От направените изчисления се вижда, че най-тежкия случай на натоварване е при минимална дължина на стрелата и минимален наклон на стрелата, тъй като при него се получава най-голям неуравновесен момент, действащ върху опората. Въз основа на получените натоварвания е избрана въртяща се опора от диаграмите на серийно произвеждани опори, за най-тежкия случай на натоварване. Решен е конкретен пример за кран КС-45717, монтиран на автомобилно шаси КамАЗ.

Ключови думи: автомобилен кран, въртяща се опора, неуравновесен момент

Introduction

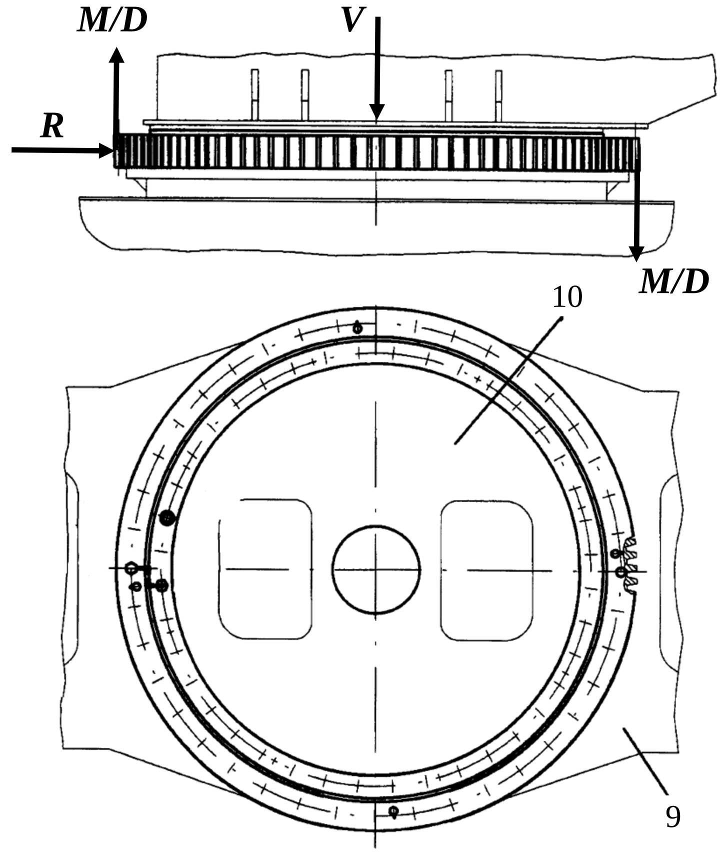
The aim of the present study is to determine the loads acting on the slewing support of a truck mounted crane at different lengths and angles of the inclination of the boom and to select a standard slewing support. A concrete example is solved for the crane КС-45717 (Kran strelovoy avtomobilnyiy КС45717К-1), mounted on the truck chassis KamAZ.

The slewing support of the crane КС-45717 (fig. 1) consists of the crown 1, the ring 6 and the balls 7, situated between them. The outgoing gear of the slewing mechanism meshes with the crown 1. The crown is fixed to the crane support frame by the bolts 2. The ring 6 is fixed to the slewing platform by the bolts 8.

Input data

The input data for the determination of the loads acting on the slewing support are (Kran strelovoy avtomobilnyiy КС45717К-1):

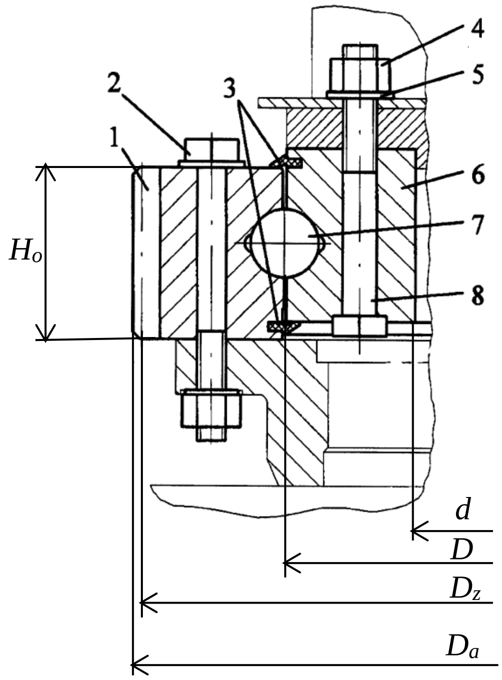
- length of the boom L = 9÷21 m;
- angle of inclination of the boom β = 5÷75°;
- maximum capacity of the crane (at stretched side supports, L = 9 m and β = 75°) Q = 25 t;
- capacity of the crane at stretched side supports, L = 9 m and β = 5° Q_1 = 6.35 t;
- capacity of the crane at stretched side supports, L = 21 m and β = 75° Q_2 = 6.35 t;
- capacity of the crane at stretched side supports, L = 21 m and β = 5° Q_3 = 0.9 t;
- capacity of the crane at unstretched side supports, L = 9 m and β = 5° Q_4 = 1.15 t;
- mass of the boom m_c = 1.99 t;
- mass of the slewing platform m_o = 5.1 t;
- mass of the block with the hook $m_{рб}$ = 306 kg.



V - vertical force, acting on the support

R - radial (horizontal) force, acting on the support

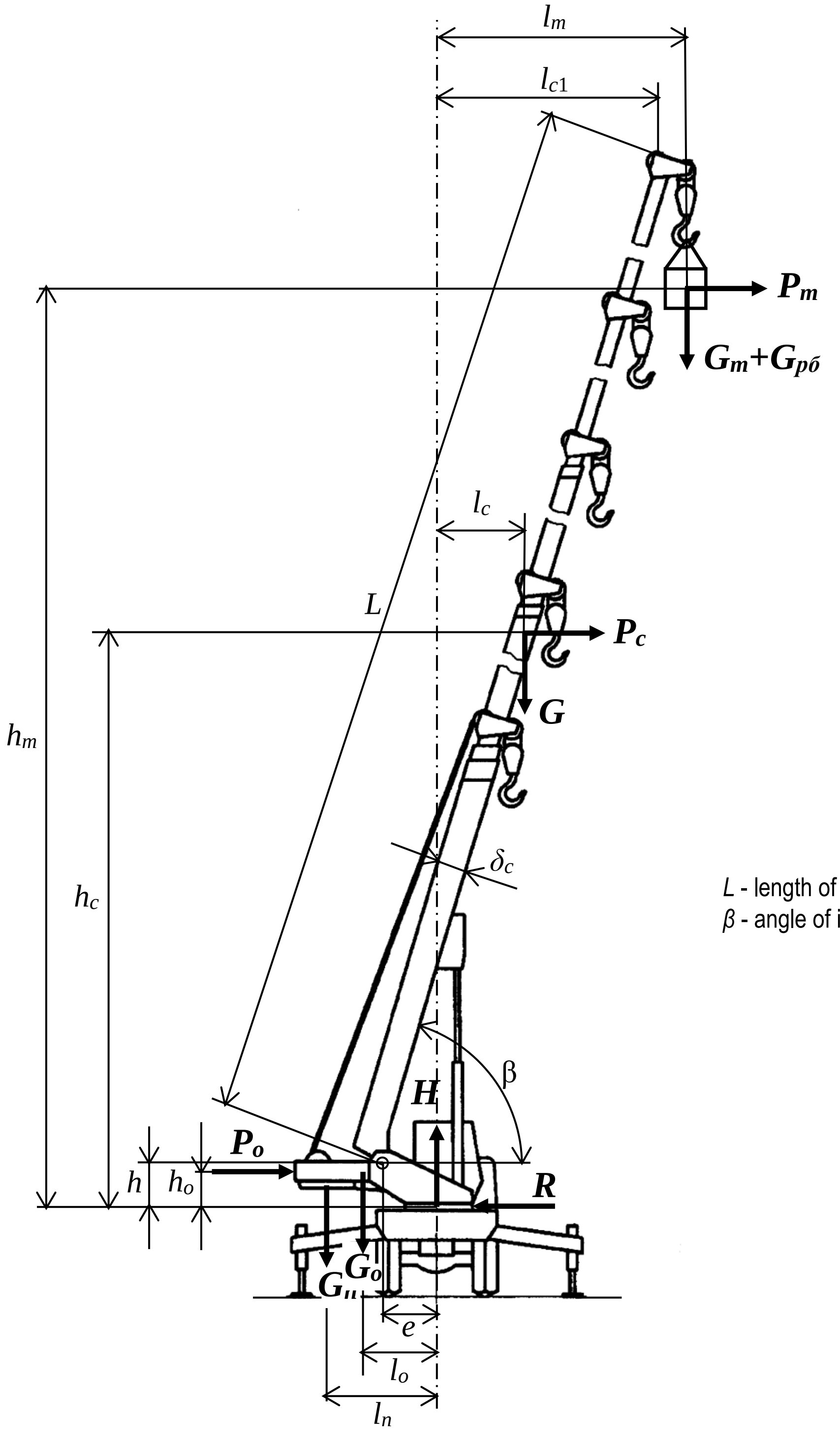
M/D - couple of forces from the unbalanced moment *M* of the forces, acting on the slewing platform



1 - crown;
2 - bolt for fixing to the unslewing part of the crane;
3 - sealing;
4 - nut;
5 - washer;
6 - inner ring;
7 - ball;
8 - bolt for fixing to the slewing part of the crane;
9 - support frame of the crane;
10 - slewing platform

d - inner diameter
D - diameter of the circuit over which the balls are rolling
D_z - centre diameter of the crown
D_a - outer diameter of the crown

Fig. 1. Scheme for the determination of the dimensions of the slewing support and the forces acting on the support



L - length of the boom
β - angle of inclination of the boom

Fig. 2. Scheme for the determination of the mass of the counterweight and the forces and moments acting on the slewing support

G_m, $G_{рб}$, G_c, G_o, G_n - gravity forces of the load, the block with the hook, the boom and the slewing platform and force of the counterweight
P_m, P_c, P_o - wind forces over the load, the boom and the slewing platform
l_m, l_c, l_o, l_n - arms of the gravity forces toward the axis of rotation
h_m, h_c, h_o - arms of the wind forces toward the centre of the slewing support
e - distance between the suspension point of the boom and the axis of rotation; *h* - distance between the suspension point of the boom and the centre of the slewing support; l_{c1} - distance between the end of the boom and the axis of rotation; δ_c - height of the side wall of the boom
H, R - vertical and horizontal resultant forces acting on the slewing support

Mass of the counterweight

The mass of the counterweight m_n [kg] is determined by the condition for the equality of the arms of the resultant vertical forces toward the axis of rotation for the two endmost positions of the boom (at maximum angle of inclination of the boom with load and at maximum angle of inclination of the boom without load) at unstretched side supports. The mass m_n is assumed in such a way, that the arms l_p and l'_p, determined by the formulae (1) and (8), are equal (I set different values for m_n and calculate l_p and l'_p, until the received values coincide l_p=l'_p=0.98 m).

After the accomplished calculations it is obtained that the mass of the counterweight must be m_n = 357 kg.

Arm of the resultant vertical force towards the axis of rotation at *L*=9 m, *β*=5° and *Q*$_4$=1,15 t

$$l_p = \frac{\left(G_m + G_{рб}\right).l_m + G_c.l_c - G_o.l_o - G_n.l_n}{G_m + G_c + G_o + G_n} = 0.98 \text{ m}, \quad (1)$$

where: G_m, $G_{рб}$, G_c, G_o, G_n [kN] - gravity forces of the load, the block with the hook, the boom, the slewing platform and the counterweight (fig.2) (they are determined by formulae (2÷6));
l_m, l_c, l_o, l_n [m] - arms of the gravity forces toward the axis of rotation (fig.2) (l_m and l_c are determined by formulae (7) and (8), l_o and l_n are checked by the drawing of the slewing platform, l_o=1.3 m; l_n=2.2 m);

$$G_m = Q_4.g = 11.3 \text{ kN} \quad (2)$$

$$G_{рб} = 0.001.m_{рб}.g = 3 \text{ kN} \quad (3)$$

$$G_c = m_c.g = 19.5 \text{ kN} \quad (4)$$

$$G_o = m_o.g = 50 \text{ kN} \quad (5)$$

$$G_n = 0.001.m_n.g = 3.5 \text{ kN} \quad (6)$$

$$l_m = L.cos\beta - e + 0.3 = 8.1 \text{ m} \quad (7)$$

$$l_c = 0.5.L.cos\beta - e = 3.3 \text{ m} \quad (8)$$

e [m] - distance between the suspension point of the boom and the axis of rotation (fig.2) (e=1,15m - it is checked by the drawing of the slewing platform).

Arm of the resultant vertical force toward the axis of rotation at *L*=9m, *β*=75° and *Q*=0t (without load)

$$l'_p=\frac{G_o.l_o+G_n.l_n-G_c.l'_c}{G_c+G_o+G_n}= 0.98 \text{ m}, \quad (9)$$

where:

$$l'_c = 0.5.L.cos\beta - e = 0.01 \text{ m} \quad (10)$$

Determination of the loads acting on the slewing support

The slewing supports are selected via graphs (Fig. 3) according to the resultant vertical force, acting on the support V [kN], the resultant horizontal force, acting on the support R [kN], and the unbalanced moment of the forces, acting on the slewing part of the crane toward the centre of the slewing support M [kN.m] (Fig. 1, Fig. 2). Four cases are considered for the fourth endmost positions of the load. The calculation results are given in a table.

In the formulae up to the end of the calculations, the values for the case for L = 9 m, β = 5° and Q_1 = 6.35 t are substituted, and for the leaving three cases only the results will be given in the table.

Resultant vertical force acting on the slewing support

$$V = G_m + G_{рб} + G_c + G_o + G_n = 135 \text{ kN}, \quad (11)$$

where:

$$G_m = Q_1.g = 62.3 \text{ kN} \quad (12)$$

Resulting horizontal force acting on the slewing support

$$R = P_m + P_c + P_o = 1.2 \text{ kN}, \quad (13)$$

where: P_m, P_c, P_o [kN] - wind forces over the load, the upper wall of the boom and the back surface of the slewing platform (Fig. 2) (they are determined by formulae (14÷16));

$$P_m = A_m.q.k_3.c.k_h = 0.9 \text{ kN} \quad (14)$$

$$P_c = A_c.q.k_3.c.k_h = 0.03 \text{ kN} \quad (15)$$

$$P_o = A_o.q.k_3.c.k_h = 0.2 \text{ kN}, \quad (16)$$

where: A_m [m^2] - wind-beaten area of the load (it is assumed from table 1 according to the crane capacity). At Q = 6,35 t I check A_m = 8 m^2;
q [kPa] - wind pressure at normal loading in working condition (case of loading I) (q = 0.09 kPa);
k_3 - filling coefficient of the construction (for loads and whole-wall constructions k_3 = 0.2÷0.6). For the calculated truck crane k_3=1;
c - aerodynamic coefficient (c=1.4 for the boom; c=1.2 for the load);
k_h - height coefficient (it is assumed from table 2 according to the height of the position of the load). At h_m=0.9m I check k_h=1;
A_c [m^2] - wind-beaten area of the upper wall of the boom (it is determined by formula (17));
A_o [m^2] - wind-beaten area of the back surface of the slewing platform (it is checked by the drawing of the platform, A_o=2.1m^2);

Table 1. *Wind-beaten area of the load A_m according to the crane capacity Q*

Q [t]	5	6,3	8	10	12,5	16	20	25
A_m [m^2]	7.1	8	9	10	12	14	16	18

Table 2. *Height coefficient*

h_m [m]	0÷10	10÷20	20÷40	40÷60
$k_в$	1	1.25	1.55	1.75

h_m [m] (fig.1) - see the explanations in formula (18)

$$S_c = L.b_c.sin\beta = 0.3\ m^2\ , \quad (17)$$

where: b_c [m] - width of the boom (it is checked by the drawing of the boom, b_c=0.43m).

Unbalanced moment of the forces acting on the slewing part of the crane toward the centre of the slewing support

$$M = (G_m+G_{рб}).l_m + G_c.l_c - G_o.l_o - G_n.l_n + P_m.h_m + P_c.h_c + P_o.h_o = 498\ kN.m\ , \quad (18)$$

where: h_m [m] - arm of the wind force over the load P_m in relation to the centre of the slewing support (Fig. 2) (it is determined by formula (19));
h_c [m] - arm of the wind force over the boom P_c in relation to the centre of the slewing support (Fig. 2) (it is determined by formula (20));
h_o [m] - arm of the wind force over the platform P_o in relation to the centre of the slewing support (Fig. 2) (it is checked from the drawing of the platform, h_o=0.8 m);

$$h_m = h + L.sin\beta - 1 = 0.9\ m \quad (19)$$

$$h_c = h + 0.5.L.sin\beta = 1.5\ m\ , \quad (20)$$

where: h [m] - distance between the suspension point of the boom and the horizontal plane, passing through the middle of the slewing support (figr.2) (it is checked from the drawing of the platform, h=1,1 m).

Selection of a slewing support

In table 3 the calculation results for V, R and M for the fourth positions of the load are given.

Table 3.*Calculation results for the vertical force V, horizontal force R and the unbalanced moment M of the forces acting on the slewing platform for the fourth positions of the load*

	L [m]	β [°]	Q [t]	A_m [m²]	k_h	V [kN]	R [kN]	M [kN.m]
1	9	75	25	18	1.25	318	3.4	315
2	9	5	6.35	8	1	135	1.2	498
3	21	75	6.35	8	1.25	135	2.4	270
4	21	5	0.9	2.5	1	82	0.3	286

The toughest case of loading is at position 2, because the unbalanced moment M is determinative for the selection of the slewing support. According to the graphs in Fig. 3 a slewing support size 04 is chosen, which at V = 135 kN and R = 1.2 KN ≈ 0 kN has a permissible unbalanced moment M = 620 kN.m > 498 kN.m.

A single row ball support type KC size 04 with externally generated teeth (Fig. 1) is selected from Table 4 with the following parameters:

- number of the teeth z=123;
- module of the teeth m=12 mm;
- centre diameter of the crown D_z=$m.z$=12x123=1476 mm;
- outer diameter (to the top of the teeth) D_a=$mz+2xm$=12x123+2x12=1500 mm;
- inner diameter d=1175 mm;
- diameter of the circuit over which the balls are rolling D=1320 mm=1.32 m;
- height H_o=100 mm;
- maximum permissible speed of rotation n_{max}=2,5 min^{-1};
- maximum permissible radial loading R_{max}=59 kN;
- material of the rings - steel 50 Mn;
- mass – 460 kg.

Table 4. *Characteristic of the single row ball slewing supports with externally generated teeth* (Kolarov, 1986)

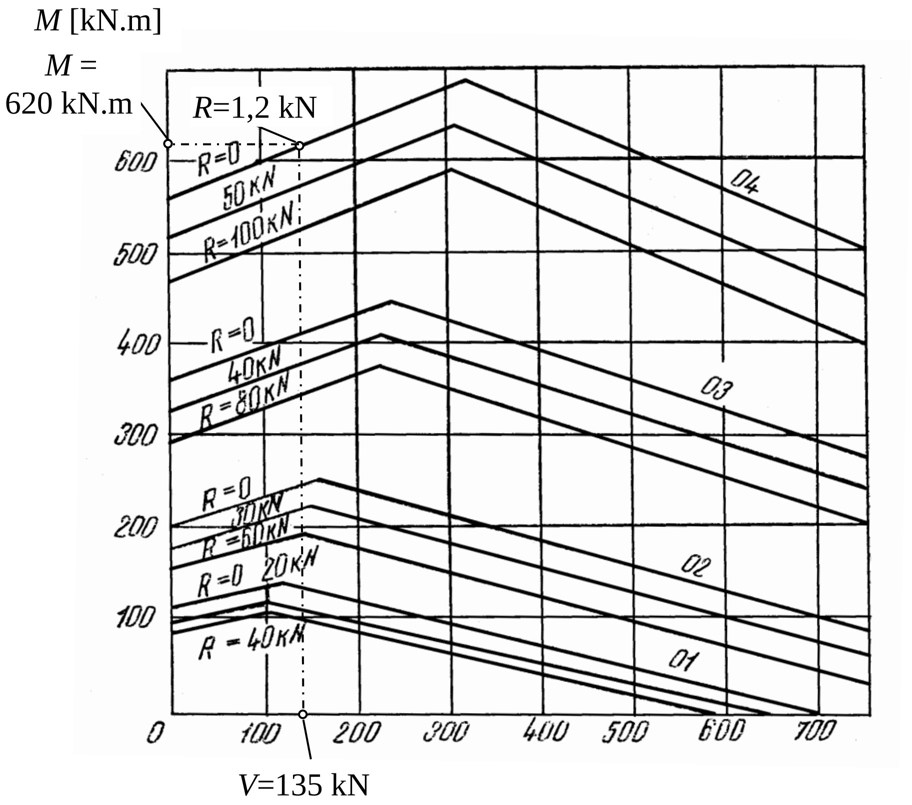
№	1	2	3	4
D_a [mm]	1000	1150	1300	1500
D [mm]	880	1012	1144	1320
m [mm]	6	8	8	12
z	164	142	160	123
D_z [mm]	984	1136	1280	1476
H_o [mm]	60	80	90	100
Mass [kg]	145	210	345	460

№	5	6	7	8
D_a [mm]	1900	2250	2650	3150
D [mm]	1672	1980	2332	2772
m [mm]	12	12	16	16
z	156	184	163	194
D_z [mm]	1872	2208	2608	3104
H_o [mm]	130	145	170	195
Mass [kg]	900	1320	2200	3700

D_a - outer diameter; D - diameter of the circuit, over which the balls are rolling; m - module of the teeth of the crown; z - number of the teeth of the crown; $D_z = m.z$ - centre diameter of the crown; H_o - height

Conclusions

1. From the calculations for the fourth endmost positions of the load the greatest resultant vertical force V, acting on the slewing support, is obtained at position 1 (minimum range of the crane, i.e. minimum boom length L and minimum angle of inclination of the boom β). The smallest vertical force is obtained at position 4 (minimum range of the crane, i.e. maximum boom length and minimum angle of inclination of the boom).
2. The greatest resultant horizontal force R, acting on the platform, is obtained at position 1, and the smallest - at position 4.
3. The greatest unbalanced moment M toward the centre of the slewing support is obtained at position 2 (minimum boom length and minimum angle of inclination of the boom). The smallest unbalanced moment is obtained at position 3 (maximum boom length and maximum angle of inclination of the boom).



M - unbalanced moment of the forces acting on the platform toward the centre of the slewing support; *V, R* - resultant vertical and horizontal forces acting on the slewing support

Fig. 3. Graphs for the selection of the slewing support

4. The toughest case of loading of the slewing support is at position 2 (minimum boom length and minimum angle of inclination of the boom), because the unbalanced moment is determinative in the selection of the slewing support.

5. For the calculated truck mounted crane the slewing support is correctly selected, because the dimensions of the mounted support coincide with the dimensions of the selected support.

References

Gohberg, M. M. 1988. *Spravochnik po kranam. Tom 2.* Mashinostroenie, Leningrad, 453 p. (in Russian)

Kolarov, I. G., M. N. Prodanov, P. D. Karaivanov. 1986. *Proektirane na tovaropodemni mashini*. Tehnika, Sofia, 386 p. (in Bulgarian)

Kran strelovoy avtomobilnyiy KS45717K-1. Rukovodstvo po ekspluatatsii (in Russian).