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TECHNOLOGICAL EFFICIENCY BY CHANGING THE CRANE EQUIPMENT

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Abstract: The paperwork includes some considerations regarding the way of establishing the constructive and functional main parameters needed to adapt a crane equipment on a tire excavator. Using a crane equipment on tire excavator is an advantage both for the economy of a service rendering company and for meeting many requirements from various customers. The work equipment on multipurpose excavator is obtained by replacing the work equipment on dragline or grab crane by single hook. Adapting the crane equipment, in case the excavator is provided with dragline equipment, is only the suitable choice of single hook. Specific for such equipment are load lifting – lowering, boom slewing together with excavator platform, boom inclining and travelling function of base machine which, according to load, amplifies the equipment working area. By adapting a crane equipment to tire excavator, a new equipment is got, which, in my opinion, can be part of tire cranes family. Changing the work equipment – hydraulic excavator bucket with crane equipment – shows some advantages like: high maneuverability and mobility, access in narrow spaces, occasional use of crane equipment, equipment cost price is much lower than for a tire crane, only specialized for loads lifting, slewing and travelling.
Key words: crane equipment, tire excavator, boom, mobility.

1. INTRODUCTION

The use of crane equipment at the tire excavator is an advantage, both for the economy of a service provider and for meeting a very large number of requirements from different beneficiaries.

The work equipment on multipurpose excavator is obtained by replacing the work element from dragline or grab crane equipment by single hook. Adapting the crane equipment when excavator is provided with dragline equipment, is reduced to suitable choosing of the single hook, [1].

Specific to this equipment are load lifting-lowering, boom slewing together with excavator platform, boom inclination and, obviously, travel function of the basic machine which, amplify the machinery working area according to the load.

2. MATERIALS AND METHODS

Lifting installations are work equipment with cyclic functioning in intermittent mode, serving for loads movement between points located at different heights. Depending on machinery complexity, the load can be vertically moved, on plane or special trajectories. In the first situation, the machine performs only one work, and in the other situations, two or more movements can simultaneously or successively take place. Lifting machines are used in the most various sectors of economy, as usually, all material assets, raw materials, intermediate and finite products, under excavation, fabrication, transport, assembly, installation, sale processes, etc., undergo multiple lifting-lowering operations.

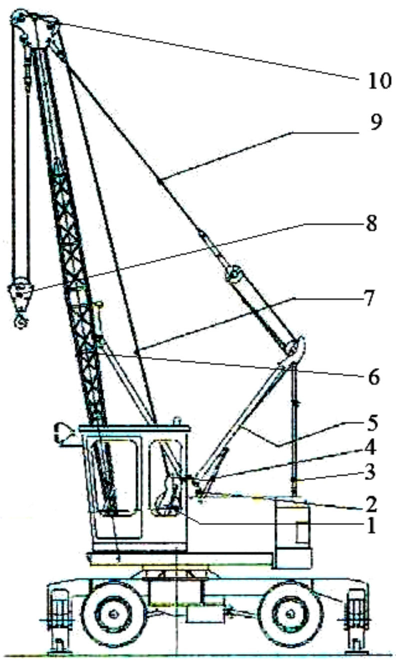

Fig. 1. Constructive sketch of the crane equipment adapted to hydraulic tire excavator

Figure 1 shows the constructive structure related to the manner of adapting the crane equipment, with boom of lattice beam type, to a tire hydraulic excavator. The main components are: load lifting trolley (1), trolley (2), rocker arm for boom (3), hydraulic cylinder for boom tilting (4), support (5), boom (6), tilting load lifting cable (7), single hook (8), boom positioning and sustaining cable (9), and deviation rollers (10). The machinery includes the load and moment limiters, limit switch, as well as other safety devices. To establish the technical parameters of crane equipment, it is necessary to know the technical features of basic machine. The main features of the tire hydraulic excavator are presented hereinafter (table 1):

Table 1. Technical features of the hydraulic tire excavator

Motor	Power: 40.4/55 [kw/CP]
	Speed: 2400rev/min
Drive	Hydrostatic for variable flow pump group with powers summing adjustment
	Maximum flow: 2X82l/min
	Maximum adjusted pressure: 28Mpa
	Auxiliary circuit: two gear pumps, maximum flow 24l/min
Travel mechanism	Two stages gearbox; two drive axles
	Travel speed [km/h]: Speed I (0....5km/h); II-nd speed (0....18km/h);
	Service brakes on all wheels; Normally closed parking brake on rear wheels.
Slewing mechanism	Platform slewing speed: (0....9rot/min)
Weights	Operating weight of machine with depth equipment (bucket with V=0.4m3), 141.12kN

Constructive parameters of basic machine – hydraulic tire excavator, are indicated in the below figure (figure 2):

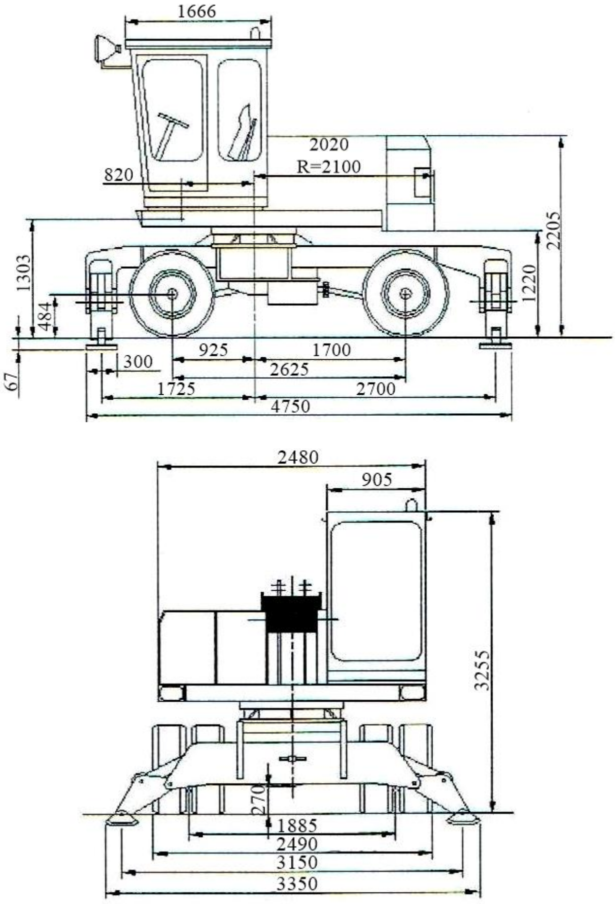

Fig. 2. Constructive parameters of the basic machine – hydraulic tire excavator, [1]

The main technical parameters of the crane equipment are those sizes determining its performances (figure 2). The functions of work equipment, needed for achievement of various stages of technological process, will be established in relation with functions of the basic machine: equipment maneouvring, slewing and travelling. Travelling system of crane equipment should ensure reaching speeds and forces for load lifting – lowering function, as well as boom inclination angle. Establishing the performance level for each type of parameter, featuring functionality within working area, is a study stage to elaborate technical structure of the work equipment. When adapting the crane equipment, requiring optimum performances for it, consideration should be given to the fact that, knowing the thermal power of the engine on the basic machine and its characteristics, the definition parameters possibly to achieve for the work equipment will be determined and adapted, [2].

3. CRANE EQUIPMENT ADAPTED TO HYDRAULIC TIRE EXCAVATOR

The mass of work equipment, operating mass of the excavator Mex, with empty bucket, is given by relation:

$$M_{ex} = M_{mb} + M_e \cong (1.22 \div 1.27) \qquad (1)$$

where: M_{mb} is the mass of basic machine; Me is the mass of standard equipment (backhoe equipment), [3]. Preliminary setting of crane equipment constructive mass supposes to know the constructive mass of the basic machine M_{mb}. On the basis of experimental and statistical data related to hydraulic tire excavators, of analogous types, with similar features and performances, calculation relations were set for each type of equipment, as follows (table 2).

Figure 3 shows a tire excavator with crane equipment. The constructive mass of crane equipment includes: total mass of crane boom (M_{tb}), trolleys mass (M_t), the mass of support for sag suspension (M_s) and single hook mass (M_m).

Table 2. Calculation relations for various work equipment

For basic equipment-standard-consisting of adjustable boom, handle and backhoe work element	$M_e = (0.20 \div 0.25) \cdot M_{mb}$
For basic equipment-standard-consisting of single boom, handle and backhoe work element	$M_e = (0.18 \div 0.21) \cdot M_{mb}$
For grab equipment-standard-consisting of specific single boom, handle and polyp grab work element	$M_e = (0.16 \div 0.25) \cdot M_{mb}$
For crane equipment consisting of lattice space beam type boom (base section, peak section and intermediate section resulted from load diagram)	$M_e = (0.16 \div 0.20) \cdot M_{mb}$

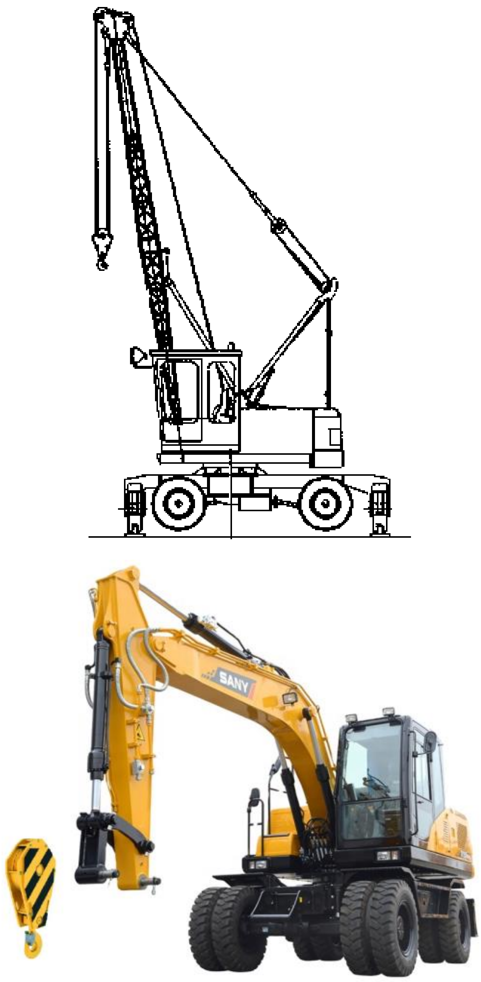

Fig. 3 Tire excavator with crane equipment, [1]

$$M_e = M_{tb} + M_t + M_s + M_m \quad (2)$$

Total constructive mass of the boom is calculated with the following relation:

$$M_{tb} = M_b + M_i \cong 0.5 \cdot M_e \quad (3)$$

where: M_b- mass of the boom consisting of base and peak sections; M_i – mass of intermediate sections;

$$M_b = (0.52 \div 1.00) \quad (4)$$

Intermediate values are adopted for a big quantity of intermediate sections. When there are no intermediate sections, M_b=M_{tb}.

Depending on the basic machine mass, the total mass of the boom is calculated with the following relation:

$$M_{tb} = (0.063\ldots\ldots0.105) \quad (5)$$

The values greater than 0.055, are adopted for a section quantity among 1÷5 pcs.

Maximum value of the load mass, admitted to be lifted under normal operation conditions (defined by functioning group), is named nominal load Q and is expressed in [kg] or [t]. The mobile single hook and the hook are not included by nominal load. Nominal moment is the maximum value of the multiplication result between load mass Q and outreach R, and expressed in [m].

$$M = \max(Q \cdot R) \quad (6)$$

The value of this result is limited, either by condition of crane stability to roll-over, or by its structural components strength condition. For cranes with variable outreach, the Q·R result is not constant, this having unfavorable impact on stability and stress conditions. This disadvantage is removed by reducing the load value related to the load resulting from Q·R= constant.

By this reason, dependency of load on outreach Q = Q(R), with Rv [R_{min}, R_{max}], is indicated by engineer on a diagram named crane load characteristic, or numerically indicated as a table. Crane's stability to roll-over is evaluated by stability coefficient requiring the condition that the moment of forces aiming to maintain stability and the moment given by the load to be at least greater or equal to the value of required coefficient:

$$\frac{M_s}{M_r} \geq c_s \geq 1.35 \quad (7)$$

where: M_s – moment of stability forces; M_r – moment of roll-over forces.

In case of crane equipment mounted on hydraulic tire excavator the variation of outreach is provided by boom tilting so, the lifting height is variable [4]. Therefor variation of lifting height per outreach will also be included in load characteristic field. For crane equipment subject to this paperwork with nodular construction boom, and different supporting nodes), nominal characteristics are those corresponding to work configuration that determine maximum load values (figure 4), [5].

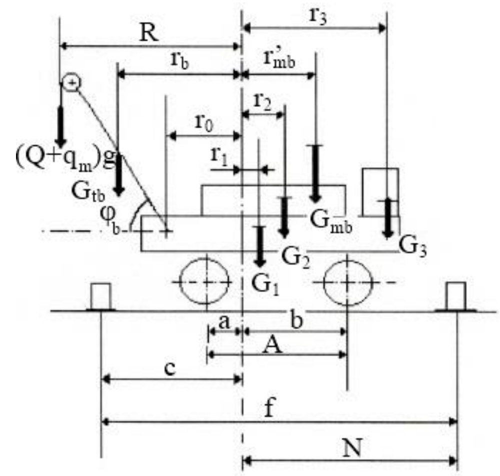

Fig. 4. Position I Boom works in diametral plan

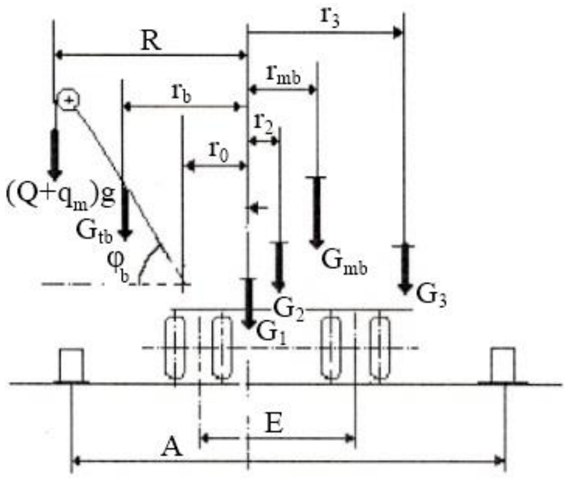

Fig. 5. Position II Boom works in transverse plan

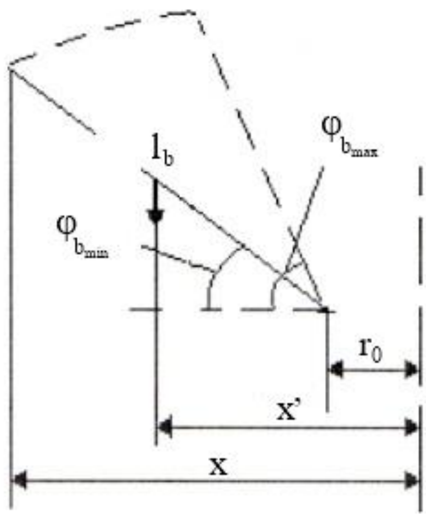

Fig. 6. Simplified calculation scheme for position II

Load diagram calculation is performed for the situation when excavator platform is rotated so that its longitudinal axis to be perpendicular to the most unfavorable roll-over axis and the boom be inclined by φ_b angle from horizontal (figure 5 position II). In figure 6 represent simplified calculation scheme for position II.

In the figure are noted: G_1- undercarriage weight G_2- platform weight, G_3- counterweight weight, G_{mb}- basic machine weight, G_{tb}- Boom weight, Q- load mass, q_m- single hook mass, N- platform length, A- wheel base, φ_b- boom inclination angle, E – track gauge, e-distance between pressing-on earth points in transverse plan and f- distance between pressing-on earth points in diametral plan. Considering the critical situation in position II (for platform angular rotating space of 360°), e < f, we obtain:

$$M_s = 0.5 \cdot M_1 \cdot e + M_2 \cdot (0.5 \cdot e + r_2) + M_3 \cdot (0.5 \cdot e + r_3) \tag{8}$$

$$M_r = (Q + q_m) \cdot (R - 0.5 \cdot e) + M_{tb} \cdot (r_b - 0.5 \cdot e) \tag{9}$$

In the end we reach the relation:

$$Q = \frac{\Gamma - M_{tb} \cdot (r_b - 0.5 \cdot e)}{R - 0.5 \cdot e} - q_m \tag{10}$$

$$\Gamma = \frac{0.5 \cdot M_1 \cdot e + M_2 \cdot (0.5 \cdot e + r_2) + M_3 \cdot (0.5 \cdot e + r_3)}{c_s} = \frac{M_{mb} \cdot (r_{mb} + 0.5 \cdot e)}{c_s} \tag{11}$$

$$M_{mb} = M_1 + M_2 + M_3 \tag{12}$$

where: M_1- constructive mass of undercarriage; M_2- platform mass; M_3- counterweight mass.

Distribution of basic machine own mass on the three subassemblies is recommended to be the following:

- For short platforms (N < 2500 mm): $M_1 = 0.48 \cdot M_{mb}; M_2 = 0.36 \cdot M_{mb}; M_3 = 0.20 \cdot M_{mb}$;
- For long platforms (N ≥2500 mm): $M_1 = 0.48 \cdot M_{mb}; M_2 = 0.39 \cdot M_{mb}; M_3 = 0.13 \cdot M_{mb}$

$$r_{mb} = \frac{0.5 \cdot M_1 \cdot e + M_2 \cdot (0.5 \cdot e + r_2) + M_3 \cdot (0.5 \cdot e + r_3)}{M_1 + M_2 + M_3} \tag{13}$$

Based upon presented relations and technical characteristics of the excavator supposed known and emphasized, the load characteristic of crane equipment is set up, according to calculation schemes in figures 5 and 6. Crane equipment characteristics are shown in table 3.

Table 3. Crane equipment characteristics

No.	Subassembly	Parameters	Symbol	M.U.	Value
1	Basic machine	Undercarriage mass	M_1	kg	5469
		Platform mass	M_2	kg	4475
		Counterweight mass	M_3	kg	2486
		Distances	r_1	mm	1015
			r_2	mm	446
			r_3	mm	1785
			r_{mb}^1	mm	975
			r_{mb}	mm	528
2	Work equipment	Boom total mass	M_{tb}	kg	783
		Boom mass (base section+peak section)	M_b	kg	660
		Intermediate section mass	M_i	kg	123
		Boom total length	l_b	m	12
		Intermediate section length	l_i	mm	3000
		Base section length	l_1	mm	4400
		Peak section length	l_2	mm	4600
3	Calculation elements for load characteristic	Stability coefficient for four calculation points	c_s	-	2,0
		Stability coefficient without pressing-on earth	c_s	-	2,5
		Stability moment	G	Kgm	13070
		Preliminary mass of single hook	q_m	kg	250

Working radius R is determined, depending on angle φb, by performing the following table calculation (table 4):

Table 4. Working radius depending on φ_b

Short boom					Long boom				
$R = l_b \cdot \cos\varphi_b + r_0 ; x = l_b \cdot \cos\varphi_b$									
φ_b[o]	l_b[m]	cos φ_b[-]	r_0[m]	R[m]	φ_b[o]	l_b[m]	cos φ_b[-]	r_0[m]	R[m]
80	9	0.17365	0.82	2.38	80	12	0.17365	0.82	2.9
70	9	0.34202	0.82	3.98	70	12	0.34202	0.82	4.92
60	9	0.50000	0.82	5.32	60	12	0.50000	0.82	6.82
50	9	0.64279	0.82	6.6	50	12	0.64279	0.82	8.53
40	9	0.76604	0.82	7.71	40	12	0.76604	0.82	10.01
30	9	0.86603	0.82	8.61	30	12	0.86603	0.82	11.2

Distance from the gravity point of the boom until platform slewing axis, noted with rb, is determined by performing the following table calculation (tabel 5):

Table 5. Determination of the arm action radius (r_b)

Short boom l_b=9m			Lomg boom l_b=12m		
$r_b = 0.5 \cdot l_b \cdot cos\,\phi_b + r_0 ; x = 0.5 \cdot l_b\, cos\,\phi_b$					
$\varphi_b^{[0]}$	x' [m]	r_b [m]	$\varphi_b^{[0]}$	x' [m]	r_b [m]
80	0.78	1.6	80	1.04	1.86
70	1.53	2.35	70	2.05	2.87
60	2.25	3.07	60	3	3.82
50	2,89	3.71	50	3.85	4.67
40	3.44	4.26	40	4.59	5.41
30	3.89	4.71	30	5.19	6.01

Using the data determined in tables 4 and 5 we perform the following table calculation to determine the load Q depending on inclination angle φ_b. Known are: G=13070[kgm]; e=3.15[m]; M_{tb}=783[kg] for long boom; M_{tb}=660[kg] for short boom; q_m=250[kg]. The data in table 6 result.

Lifting mechanism is dimensioned as follows:

a) From load diagram the following elements are kept:

Maximum load Q; Maximum working radius R_{max}, for each boom length; Minimum working radius R_{min}, for each boom length; Maximum lifting height, for each boom length; Minimum lifting height for each boom length.

Table 6. Values for short and long boom

Short boom				Long boom			
$Q = \frac{\Gamma - M_{tb} \cdot (r_b - 0.5 \cdot e)}{R - 0.5 \cdot e} - q_m$							
φ_b [o]	r_b [m]	R [m]	Q [t]	φ_b [o]	r_b [m]	R [m]	Q [t]
80	1.6	2.38	15.96	80	1.86	2.9	9.44
70	2.35	3.98	4.52	70	2.87	4.92	3.35
60	3.07	5.32	2.95	60	3.82	6.82	1.9
50	3.71	6.61	2.32	50	4.67	8.53	1.26
40	4.26	7.71	1.59	40	5.41	10.01	1.19
30	4.71	8.61	1.31	30	6.01	11.2	0.74

Table 7. Load characteristics

Boom without intermediate section (length = 9m)			Boom with intermediate section (length = 12m)		
Boom inclination angle [o]	Working radius [m]	Maximum load [t]	Boom inclination angle [o]	Working radius [m]	Maximum load [t]
80	2.38	15.96	80	2.9	944
70	3.98	4.52	70	4,92	3.35
60	5.32	2.95	60	6,82	1.9
50	6.6	2.32	50	8,63	1.26
40	7.71	1.59	40	10,01	1.19
30	8.61	1.31	30	112	0.74

b) Establishing operational characteristics: Load lifting/lowering speed v_r [m/min]; Rotating speed of the excavator platform n_{pi} [rot/min]; Time for changing the boom inclination angle t_b [s]; Machinery travel speed with load without pressing-on earth system v_d [km/h].
c) Establishing the work conditions: Place of work; Technically admitted temperature: +40°; -20°C; air relative humidity: 65%; Admitted wind speed (in operational condition, v=20 m/s and in pause condition, v=40 m/s); Field declivity, α [grade]; Maximum slope when machinery travels without load [%].
d) Establishing safety criteria: Stability coefficient at maximum load c_s =2.0; Stability coefficient in pause condition with maximum boom length c_s =2.75; Operating conditions for mechanisms and steel structure are given in the table below (table 8):

Table 8. Operating conditions for component mechanisms including steel structure

Mechanism	Class of use	Stress status	Operating group	STAS no.
Lifting	T5	L2	M4	STAS 4662-79
Slewing	T5	L2	M4	STAS 4662-79
Travelling	T5	L2	M4	STAS 4662-79
Steel structure	B	2	IV	STAS 8290-83
Crane	-	-	IV	STAS 8290-83

There are calculated: load hoist (simple hoist with four active branches), drum (drum diameter $D_T=D_{STAS}$=290mm, drum length L_T=912mm, drum wall thickness δ=16mm, hook size 15), power neede to drive the hydraulic motor (P_r =30kW), calculation of boom steel structure (taking into account the construction solution adopted, only the chekcing calculation was performed for boom under the most unfavorable work conditions), and the hook cross beam, so the chosen hook resists to maximum load).

4. CONCLUSIONS

This paperwork brings together some considerations regarding how to establish the main constructive and functional parameters needed to adapt a crane equipment on a hydraulic tire excavator. The crane equipment adapted on a hydraulic tire excavator performs similar activity as special lifting machinery and therefor, its development should reach performances of the same to the same power available for drive. Therefore, it should achieve the following parameters and characteristics to the same level: lifting capacity – load to lift [t]; lifting capacity-load moment

[tm]; lifting radius [m]; lifting height [m]; specific installed power, representing reversed ratio- [1/kw (installed power)/t (capacity)]-between installed power and lifting capacity, appreciating that, as quality is concerned, a crane equipment is superior to a special equipment, if, overall, a reduction of installed power is obtained for the same capacity t, consequently a reduction of fuel consumption; Load lifting-lowering speed [m/min]; slewing speed [rev/min]; specific mass [1/Mu (equipment mass)/t (capacity)]; average productivity [t/h]; useful work surface [m2]; constructive possibilities of the work equipment, as being the ratio between maximum boom length consisting of sections (Lbmax) and minimum boom length (Lbmin)-[Lbmax/Lbmin]-criterion which emphasize machinery operational limits. Use of crane equipment on the hydraulic tire excavator is an advantage both for economy of a service rendering company and for satisfying a very large number of requests from various beneficiaries.

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