DETERMINATION OF THE WHEEL DIAMETER OF SMALL CROSS OPEN-PIT EXCAVATORS

Yu. I. Berezhnoi

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The basic original linear parameters determining the production possibilities of a wheel excavator are the diameter of the wheel and the length of the boom [1]. In the Ukrainian Scientific-Research and Design Institute for the Coal, Ore, and Gas Industry an algorithm has been developed for solution of the problem of searching for the range of rational combinations of the diameter of the wheel and the length of the boom.* Any value of the length of the wheel boom from this range corresponds to the minimum unit adjusted costs and may be taken as the optimum in designing a wheel excavator [1]. However, the wheel diameter for open-pit excavators used in digging refractory raw material exceeds the minimum allowable value.

A correctly selected wheel diameter for small class open pit excavators, in addition to conformance to known conditions [2], must provide the minimum losses in digging minerals, such as refractory clays and kaolins, from a stratum with a complex structure. The minimum losses are provided with the minimum allowable wheel diameter. In [2] for approximate calculations an empirical relationship is proposed for determining the wheel diameter of excavators of different classes obtained on the basis of a statistical analysis made in the Ukrainian Scientific-Research and Design Institute for the Coal, Ore, and Gas Industry.

Let us introduce the coefficient $k_Q = Q_{tb}D_W^{-1}$. For small class open pit wheel excavators doing selective digging the relationship

$$(D_W \to D_{W\min}) \to \left(\frac{Q_{tb}}{D_W} \to k_{Q\max}\right), \tag{1}$$

where D_W is the wheel diameter on the cutting edges of the buckets and Q_{tb} is the theoretical productivity calculated with a base calculated digging force of 1 MPa.

According to condition (1) if D_W tends toward the minimum allowable then the expression $Q_{tb}D_W^{-1}$ tends toward the maximum value.

To use the wheel diameter determined from the empirical relationship of [2] as the base service index for small class open pit wheel excavators without checking compliance with condition (1) is unacceptable.

For the contemporary small class wheel excavators listed in Table 1 the expression $Q_{tb}D_W^{-1}$ varies from the minimum (41 m^2/h) for the SRs 65, K 40, and SR 60 excavators to the maximum (160 m^2/h) for the ÉRP-470 excavator. Therefore the empirical relationship for determining the wheel diameter of small class open pit wheel excavators was obtained for the ÉRP-470 excavator. The maximum thickness of a cut within the limits of a revolution of the wheel and the length of a block (advance per cycle) were measured in the open pit mine of Velikii Anadol Refractory Combine in the excavation by horizontal cuts of frozen and non-frozen kaolin. Two series of measurements were made.

The values obtained of the maximum thickness of a cut within the limits of a revolution of the wheel fell within a confidence interval of 0.07-0.178 m with a fiducial probability of the measurement of 0.9. The average value of the maximum thickness of a cut within the limits of a revolution of the wheel h_o is 0.124, which is

$$\bar{h}_0 = 0.0326 D_W \tag{2}$$

The length of a block, equal in this case to the width of the layer being excavated, was measured in the direction of the axis of movement of the machine. The values obtained of the width of a block (advance per cycle) fell within a confidence interval of 2.28-3.51

*Done by G. T. Sitkarevyi.

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TABLE 1. Wheel Diameter of Contemporary Small Class Excavators

Excavator model	Theor. productivity m³/h: according to the technical characteristic	Theor. productivity m³/h: with a digging force of 1 MPa	Wheel diam., m: according to the technical characteristic	Wheel diam., m: determined from Eq. (7)
SRs 65	320	123	3	2,6
SRs 130	500	182	4	3,2
SRs 220	770	636	5,1	4,0
SRs 240	1150	636	5,1	4,9
SRs 280	1150	298	5	4,9
K 40	250	123	3	2,3
K 60	400	224	3,5	2,9
K 150	630	222	4	3,6
K 250	1250	593	5,5	5,1
SH 250	1170	398	5	5,0
SH 400	1800	782	6,3	6,2
SchRs 85	460	151	3,1	3,1
SchRs 430	1320	437	5,2	5,3
T_{ur}-100	690	274	4,2	3,8
C-300	1300	633	5,4	5,2
SchRs $\frac{175}{0,5}$ 10	840	439	4,8	4,2
SR 60	150	123	3	1,8
SR 100	250	183	3,4	2,3
SR 150	380	222	4	2,8
SR 250	650	359	4,8	3,7
SR 400	1050	628	6	4,7
ÉR-100	625	222	3,9	3,6
ÉRG-120 $\frac{12}{0,8}$ 400	880	404	4	4,3
ÉRP-470	670	607	3,8	3,8
ÉR-630 $\frac{10,5^*}{1}$	630	528	4,6	3,6

*Test model.

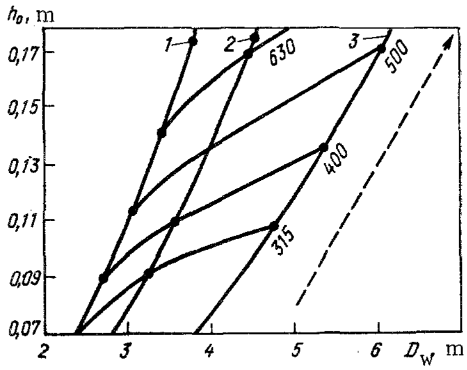

Fig. 1. Curves of the empirical relationships between the maximum thickness of cut h_0 within the limits of a wheel rotation and the wheel diameter D_W. The arrow shows the direction of increase in the theoretical productivity.

with a fiducial probability of the measurement of 0.9. The average value of the length of a block T_0 is equal to 2.895 m, which is

$$\bar{T}_0 = 0{,}76 D_W \tag{3}$$

According to the data of [3] the productivity of excavation in a dense mass Q_e in m^3/h is determined from the equation

$$Q_e = 60 \bar{h}_0 \bar{T}_0 V_{rot}, \tag{4}$$

where V_{rot} is the rate of rotation of the wheel excavator (for the ÉRP-470 V_{rot} = 15.1 m/min)

Let us substitute in Eq. (4) the relationships (2) and (3) and the value of V_{rot} for the ERP-470. Then

$$Q_e = 22.45D_w^2 \tag{5}$$

Solving Eq. (5) relative to D_w, we obtain

$$D_w = 0.21\sqrt{Q_e} \tag{6}$$

As a rule the technical characteristics of open pit wheel excavators include the theoretical productivity Q_t, equal to the product of the capacity of a bucket (sometimes taking into consideration the space beneath the bucket) by the number of discharges of the buckets per unit of time. Between the productivity of excavation and the theoretical productivity there exists a mutual relationship: $Q_e = Q_t\frac{k_f}{k_L}$, with taking into consideration of which Eq. (6) acquires the form

$$D_w = 0.21\sqrt{\frac{Q_t k_f}{k_L}}, \tag{7}$$

where k_L is the average coefficient of looseness of material in the excavator buckets and k_f is the coefficient of filling of the calculated capacity of the bucket.

According to the data of [4] the coefficient k_L is equal to 1.4. From the results of measurements the coefficient k_f was determined as the ratio of the productivity of excavation to the theoretical in a dense mass: $k_f = Q_e Q_t^{-1} k_L$. The values obtained of the coefficient of filling of the calculated capacity of the bucket fall within a confidence interval of 0.26-0.9 with a fiducial probability of measurement of 0.9 and the average value of k_f is 0.58. In excavation of unfrozen kaolin $k_f = 0.67 \pm 0.3$.

For contemporary small class wheel excavators Table 1 gives, in addition to the actual wheel diameter on the cutting edges of the buckets with side gravitational unloading, the results of calculations using Eq. (7) with $k_f = 0.67$ and $k_L = 1.4$. Agreement of the results of calculations using empirical relationship (7) with the actual values is observed for open pit machines of the SN series of the Orenstein-Koppel company and the SchRs series of the Mannesman—Demag—Lauchhammer company. For construction and open pit-construction small class wheel excavators and those used as loaders the calculated values of D_w are less than the actual, that is, the results of calculations using Eq. (7) correspond to condition (1). To determine the adequacy of Eq. (7) to the actual data we will use the Romanovskii dispersion criterion [5]. The calculated value of the criterion R is equal to 2.64. Taking into consideration that the calculated value of the criterion R < 3, the empirical relationship (7) is assumed to be adequate to the actual data.

Figure 1 shows curves of the empirical relationships between the maximum thickness of a cut within the limits of a wheel rotation and the wheel diameter. Curve 1 corresponds to the minimum values of the thickness of the cut and the length of a block and curves 2 and 3 to the average and maximum values of the confidence intervals established by measurements. Figure 1 also shows lines connecting the values of the maximum thickness of a cut within the limits of a rotation of the wheel with the same theoretical productivity (315, 400, 500, and 630 m^3/h).

In all cases $k_L = 1.4$ and $k_f = 1$ (values established by the plant standard "A Composite System of Control of Production. Equipment for Mechanization of Basic Mining Work. Standards of Productivity" [4]). The curves of the empirical relationships in Fig. 1 give approximate values of the thickness of cuts for small class open pit wheel excavators.

Therefore on the basis of the results of measurements of the parameters of operation of an ERP-470 small class wheel excavator in an open pit in mining of refractory raw material Eq. (7) was obtained for the wheel diameter in relation to the theoretical productivity. The relationship is adequate to the actual data on the wheel diameter of contemporary excavators of domestic and foreign production. Relationship (7) may be used as a base service index in determining the possibility of use of specific models of wheel excavators in mining of refractory raw material.

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