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IMPROVING THE PERFORMANCE OF ROTARY EXCAVATORS USING DIFFERENT BUCKET DESIGNS

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Annotation. *Sticky soil or mud slows down the soil-digging process. It clogs rotary excavator buckets, making it difficult to dig. It sticks to the bucket body and wheels, which calls for an intensive cleaning job thereafter. This requires a lot of time, and a lot of time means a lot of wasted money in the cleaning and maintenance process. Dealing with sticky soil may not be as easy, but then it's not too difficult to handle if the process is backed up with the proper equipment and advanced designs of the tools that come into contact with the sticky soil first.*

Keywords: *soil sticking, bucket with ellipse form, volume, productivity.*

One of the biggest problems for excavator operators is sticky and clay soils that cling to the back or inside of the buckets every time you are digging with a rotary excavator. They gather on the edges of the attachments, preventing them from doing their tasks smoothly.

To avoid the soils sticking to different sides of the bucket and making the movement of the rotor heavy, one must delve more into the details of how to design the parts that directly affect the excavating process.

Practice in the operation of earth-moving machines shows that during the development of wet soils, freezing and sticking of the soil to the working bodies significantly reduces the productivity of the machines. At the same time, the decrease in productivity occurs due to a decrease in the useful capacity of the buckets due to incomplete unloading.

An increase in the resistance of the bucket to entering, and an increase in the machine downtime due to the need to clean the working bodies. In addition, energy losses increase due to the increase in friction forces, and the quality of work performed decreases. The friction force during digging and leveling is 30...70% of the total digging resistance, and productivity is reduced by 1.2...2 times or more [1].

The successful operation of digging is ensured by the release of products that must clearly meet specific needs, scope or purpose, meet consumer requirements. This method is very simple: the standard bucket is substituted with a bucket in the form of sphere or ellipse. It leads to avoiding the sticking of the soils to the corners and teeth of proposed bucket. Its basic principle is also very simple. While the standard bucket uses the teeth to dig and shovel the soils, the bucket of the ellipse form can avoid the dense fusion and adhesion of the soil by digging in radial directions [2].

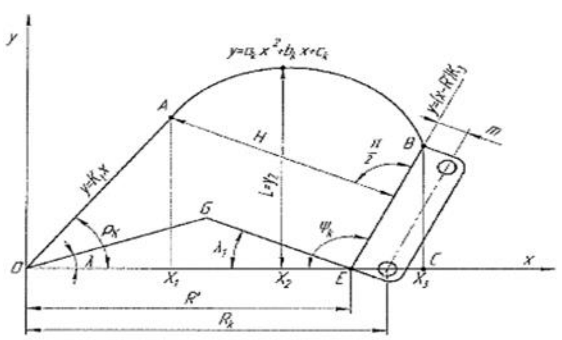
Standard buckets (Table 1), also known as general purpose buckets, are versatile. They are typically used for digging or loading materials such as topsoil or loam. They are typically the lightest of all bucket types due to the lack of any reinforcement in the bucket itself. Thus, standard buckets can usually lift large volumes of material because the mass of the bucket is small and the excavator does not waste additional energy [3].

Technology development is currently proceeding in two directions: the creation of large-scale units with high efficiency and the creation of compact mobile models.

Table 1

Estimated dimensions of buckets

Size, мм	Bucket capacity q, м^3				
	0,15	0,25	0,4	0,65	1,0
Bк	700	800	900	1100	1400
Rк	750	900	1080	1250	1370
m	50	80	120	180	230
R'	750	830	960	1070	1140
L	550	640	750	855	940
X_1	270	314	341	341	300
X_2	450	570	595	840	996



The most promising are rotary excavators with a round or ellipsoidal bucket, shown in Fig. 1. During forward movement, soil digging is carried out by part of the spherical segment of the bucket, forming the front cutting blade of the bucket. If the bucket movement occurs along a horizontal circle, then the digging of the soil is carried out by the spherical segment of the bucket, forming the side cutting blade of the bucket. In both cases, the lengths of the cutting blades of the buckets are approximately the same and the filling of the buckets will be approximately the same. If the feed movement is not circular or radial, but diagonal, then the length of the cutting blade will still be almost the same as in the above cases. Thus, the coefficient of filling the buckets with soil will be the same for any direction of feed, and with the appropriate choice of feed amount it will always be maximum.

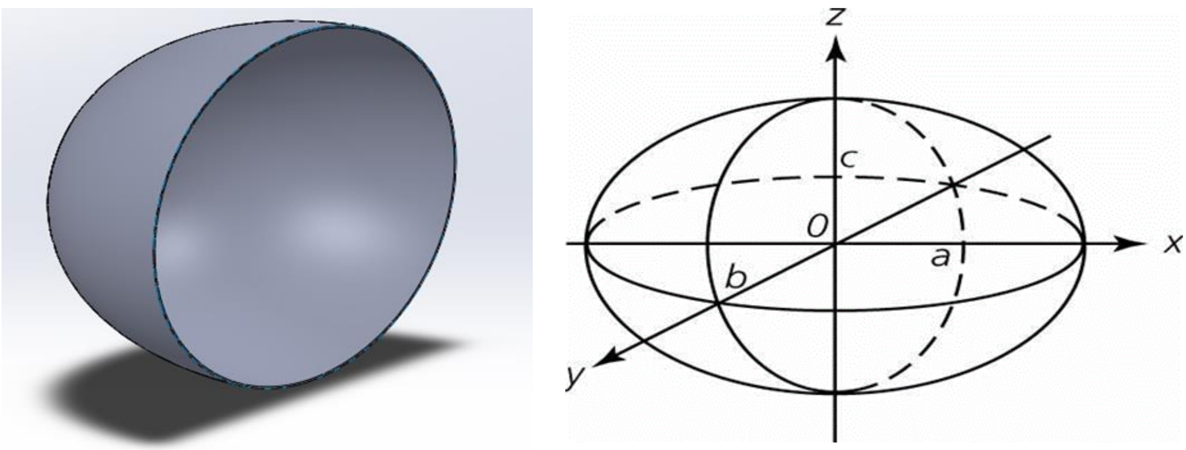


Fig. 1. Bucket which could with ellipsoid form

The ellipsoid has three pairwise perpendicular axes of symmetry (a, b, c), which intersect at the center of symmetry (the center of the ellipsoid). The segments limited on the symmetry axes by the ellipsoid are called the main axes of the ellipsoid [4]. It is easier to calculate the volume of an ellipsoid using generalized spherical coordinates [5].

$$x = a\rho\cos\varphi\sin\theta, y = b\rho\sin\varphi\sin\theta, z = c\rho\cos\theta.$$

Since the absolute value of the Jacobian for transformation of Cartesian coordinates into generalized spherical coordinates is

$$|I| = abc\rho^2\sin\theta,$$

hence,

$$dxdydz = abc\rho^2 \sin\ \theta d\rho d\varphi d\theta.$$

The volume of the ellipsoid is expressed through the triple integral:

$$V = \iiint_U dxdydz = \iiint_{U'} abc\rho^2 \sin\ \theta d\rho d\varphi d\theta.$$

By symmetry, we can find the volume of $\frac{1}{8}$ part of the ellipsoid lying in the first octant $(x \geq 0, y \geq 0, z \geq 0)$ and then multiply the result by 8 . The generalized spherical coordinates will range within the limits:

$$0 \leq \rho \leq 1, \qquad 0 \leq \varphi \leq \frac{\pi}{2}, \qquad 0 \leq \theta \leq \frac{\pi}{2}.$$

$0 \leq \rho \leq 1$ means that the sphere has radius 1. $0 \leq \varphi \leq \frac{\pi}{2}$ and $0 \leq \theta \leq \frac{\pi}{2}$ means that we have only one quarter of the half-sphere in the figure - the part limited by the planes *xz* and *yz*. In contrast, the conventions (ρ, φ, θ) *or* (r, φ, θ) give the naming order differently as: radial distance, «azimuthal angle», «polar angle» [5]. Then the volume of the ellipsoid is

$$V = \iiint_{U'} abc\rho^2 \sin\ \theta d\rho d\varphi d\theta = 8abc\int_0^{\frac{\pi}{2}} d\varphi \int_0^1 \rho^2 d\rho \int_0^{\frac{\pi}{2}} \sin\ \theta d\theta = 8abc\int_0^{\frac{\pi}{2}} d\varphi \int_0^1 \rho^2 d\rho \cdot \left[(-\cos\ \theta)|_0^{\frac{\pi}{2}}\right]$$
$$= 8abc\int_0^{\frac{\pi}{2}} d\varphi \int_0^1 \rho^2 d\rho \cdot \left(-\cos\frac{\pi}{2} + \cos\ 0\right) = 8abc\int_0^{\frac{\pi}{2}} d\varphi \int_0^{\frac{\pi}{2}} \rho^2 d\rho = 8abc\int_0^1 d\varphi \cdot \left[\left(\frac{\rho^3}{3}\right)\Big|_0^1\right]$$
$$= \frac{8abc}{3}\int_0^{\frac{\pi}{2}} d\varphi = \frac{8abc}{3} \cdot \left[\varphi|_0^{\frac{\pi}{2}}\right] = \frac{8abc}{3} \cdot \frac{\pi}{2} = \frac{4}{3}\pi abc.$$

Buckets of spherical or ellipsoidal shape have a smooth inner surface, without sharp corners where soil can stick, therefore the useful volume of the bucket will remain maximum (Fig. 2).

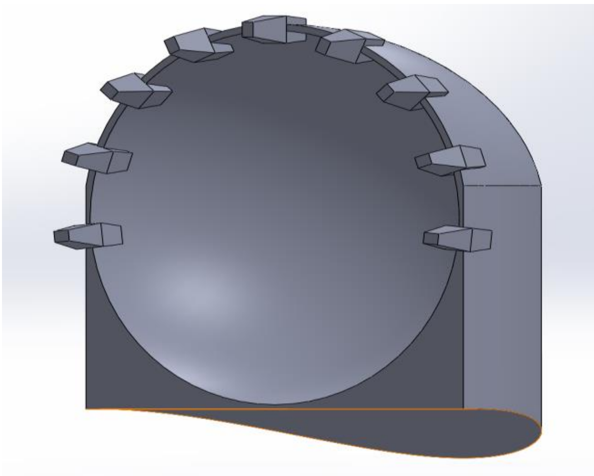


Fig. 2. Rotary bucket wheel with the new combination design

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