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Research Article

DEVELOPMENT OF A NEW DESIGN OF CUTTING ELEMENTS FOR QUARRY EXCAVATOR BUCKETS AND RESULTS OF ITS EXPERIMENTAL RESEARCH

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ABSTRACT

An analysis of the performance of excavators shows that many hydraulic excavators used in mining companies operate at a lower efficiency than those specified in the technical description. This can be caused by unforeseen downtime, rapid failure of parts and unreliable operation of excavator workers.

This paper discusses the development of cutting elements with high service life to increase the efficiency of quarry excavators. In addition, the results of experiments on the proposed improved denture teeth and their analysis are presented.

KEYWORDS

Quarry, excavator, bucket, tooth, protective element, efficiency, service life, basic, improved, demolition.

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INTRODUCTION

The decrease in the operational efficiency of quarry excavators depends on the conditions of use (physical and mechanical properties of rocks, maintenance conditions, etc.) and climatic conditions under the influence of the external environment. In unfavorable weather and difficult conditions, the freezing, stickiness and poor quality of the rocks lead to the rapid erosion of the cutting elements (teeth) of the quarry excavators. This situation leads to a decrease in the efficiency of the excavation process in exchange for the creation of high loads on the power mechanisms of the working members of quarry excavators [1].

The main reason for the failure of quarry excavators currently used in the global mining industry is the failure of mechanical parts. The main factor in stopping excavations and cuts due to the failure of mechanical parts is the bucket teeth, which make direct contact with the rock.

MATERIALS AND METHODS

Defects in the cutting elements of quarry excavators depend on a number of factors, mainly the skills of the excavator driver during operation, non-compliance with service rules, adverse climatic conditions, variability of rock properties, poorly blasted large-sized rocks and a number of other technical factors [2].

Defects in the part of the bucket cutting element connected to the adapter of the quarry excavator are due to the fact that the adapter and the finger (palets) serving to connect the cutting element are not well tightened by service providers, special fasteners do not fit, the fastening finger widens the hole 3].

Figure 1 shows the faults of the HITACHI EX-1200 quarry hydraulic excavators connected to the cutting elements and the adapter part of the bucket.

Figure 1. Defective part of HITACHI EX-1200 excavator bucket connected with cutting element and adapter part

Fault 1, shown in Figure 1, results in additional resistance to cutting and drilling due to the fingers not being fastened to the required standard in the fastening part of the cutting element and the adapter part of the bucket. In case of failure 2, due to the poor quality of the cutting element and the adapter part, the tooth is in a cold state and as a result does not sink well into the rock [4].

In many cases, during the operation of quarry excavators, the allowable amount of bucket cutting elements is ignored. This can lead to tooth decay beyond the allowable level, which can eventually lead to tooth decay, and these defects are shown in Figure 2.

Figure 2. Perforation of HITACHI EX-1200 excavator bucket teeth due to erosion

Faults caused by untimely maintenance of teeth can lead to malfunctions in other systems, which are even greater. As a result of research and analysis in production, tooth perforation also leads to rapid wear of the adapter part, and these processes reduce the efficiency of quarry excavators and increase operating costs [5].

The size of the top and bottom of the excavator is shown in Figure 3, the size of the front and the length of the tooth L, as shown in Figure 3. studied [6].

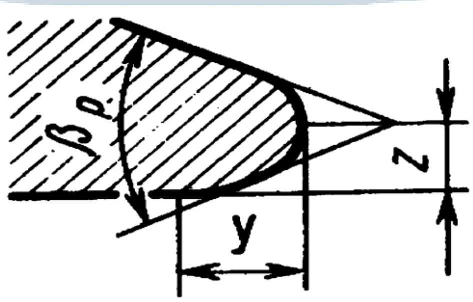

Figure 3 Scheme for determining the amount of erosion of the teeth of the excavator bucket

The study revealed that the working time of quarry hydraulic excavators is from 250 moto / h to 300 moto

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/ h, depending on the physical and mechanical properties of the rock, the working condition, the quality of the explosion.

Analysis of the results of the above studies shows that most of the faults in the teeth of quarry hydraulic excavators used in open pit mining are not able to work at the level required for the strength and durability of bucket teeth, ie different types of excavated rock quickly loses its properties when exposed to rocks, and as a result, the teeth quickly become impenetrable, leading to failure of other parts of the quarry excavators and a decline in operational performance.

In view of the above, during our research work we have made it one of our main goals to develop technical solutions to increase the wear resistance, service life and efficiency of the quarry excavator bucket cutting elements [7].

It has been proved that the energy intensity of the excavation process with collapsed cutting elements is 1.5-2 times higher than the new ones. The practice of using excavator buckets from 3.20 to 20 m3 has shown that the allowable erosion of the teeth increases the specific specific shear load by 50-100% relative to the cutting conditions with teeth of nominal shape and size. The breakdown of the cutting elements of excavators has a significant impact on their performance. In some cases, due to the wear of the working part, the productivity of the machine decreases by up to 40% and fuel consumption increases by up to 30% [3].

THE MAIN PART

There are several types of pit teeth of quarry hydraulic excavators, and these teeth are used as standard production teeth of pit hydraulic excavators used in all open pit mines of Navoi Mining and Metallurgical Combine (Figures 4 and 5).

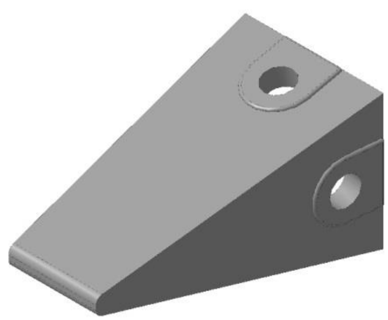

Figure 4. 3D view of standard bucket teeth

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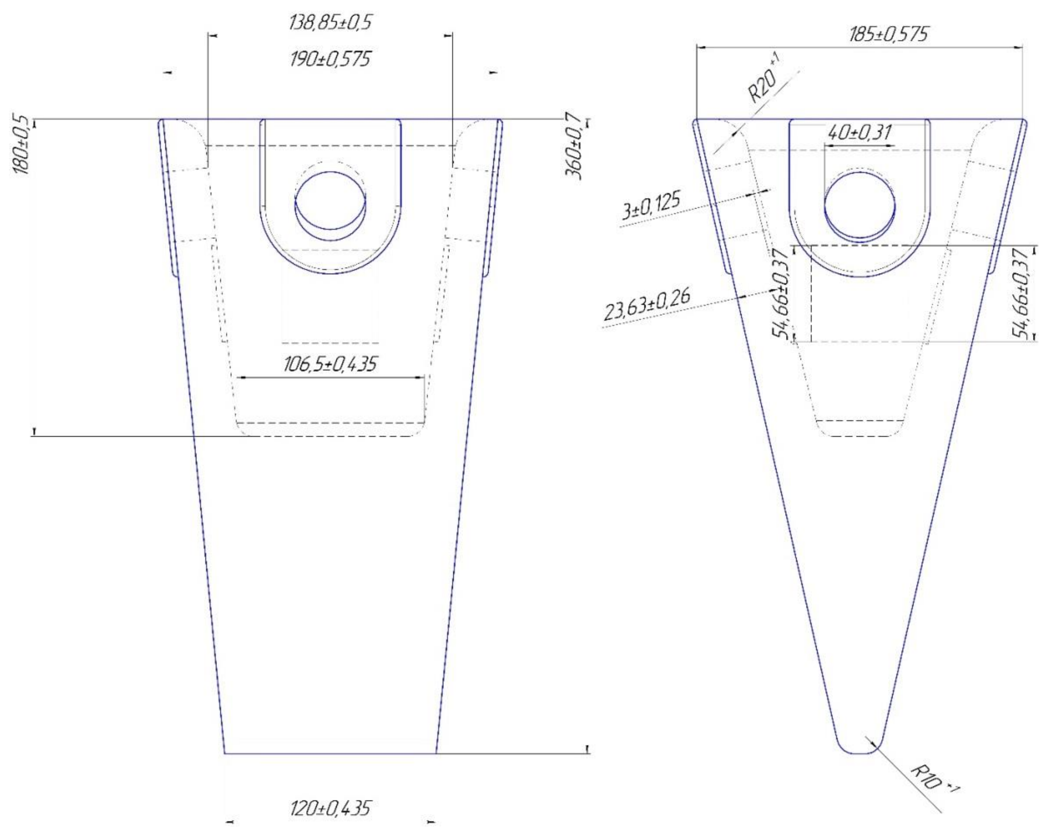

Figure 5. General appearance and dimensions of standard bucket teeth: a - top view and dimensions; b - side view and dimension

The average lifespan of this type of denture is currently 13-16 days. The time spent on each replacement leads to a decrease in the operational efficiency of the excavator and a long-term failure of the teeth leads to an increase in operating costs.

Thus, to increase the productivity of quarry hydraulic excavators, it is important to create wear-resistant tooth shapes, develop and select effective technological methods to increase their durability.

Theoretical research and observations of the use of cutting elements in production have revealed the need to increase the strength of the upper and lower surfaces of the bucket teeth, which make the most contact with the rock. To this end, special notches have been created on standard bucket surfaces, and an improved type of bucket tooth design has been developed to increase the efficiency of quarry excavators in order to increase their resistance to erosion.

In this project, an improved design of the tooth in the form of a sharp angled embossing relative to the center of the tooth, which is slightly different from the standard bucket teeth of quarry hydraulic excavators (Figures 6 and 7).

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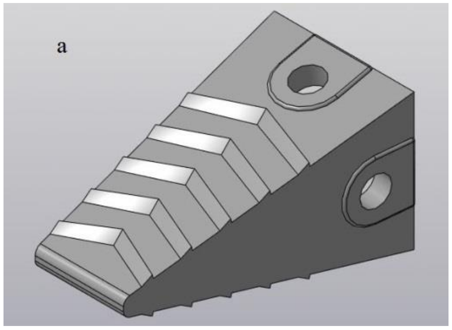


Figure 6. 3D view of advanced dentition teeth

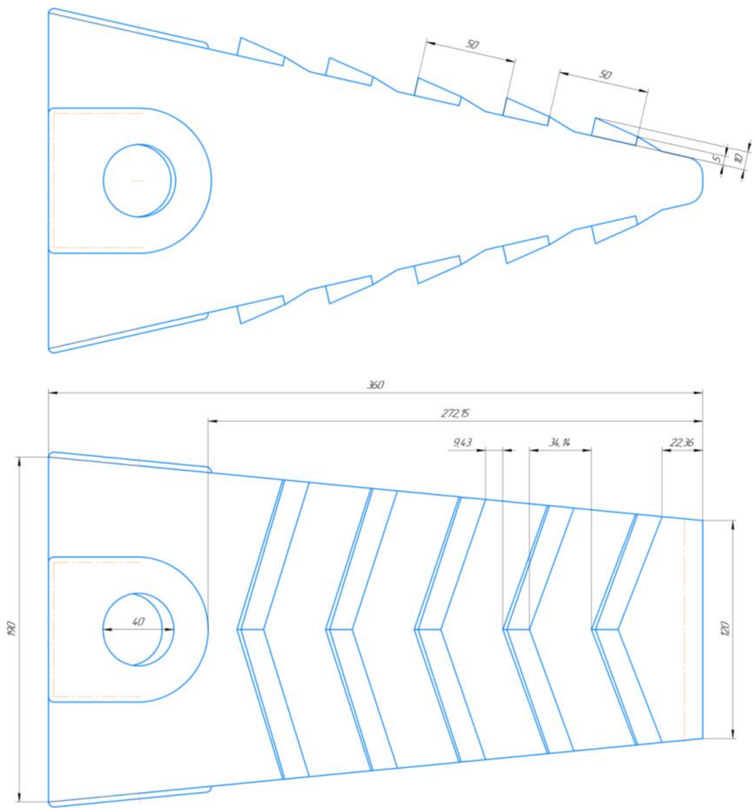


Figure 7. Appearance and dimensions of the tooth in the form of a sharp-edged bulge relative to the center of the improved tooth: a - top view and dimensions; b - side view and dimensions.

EXPERIMENTAL RESULTS

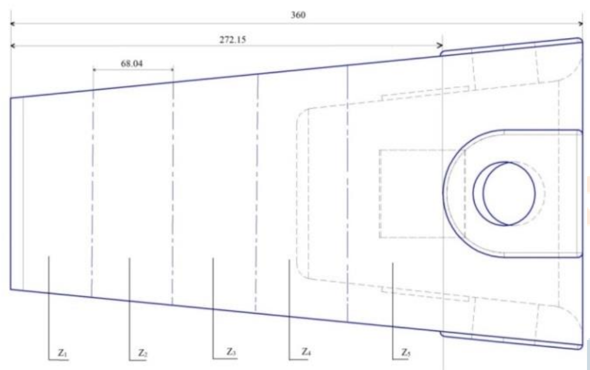
In the process of making this improved bucket tooth, special angular embossed patterns were created on the top and bottom of the whole case. The total length of the developed tooth is 36.0 cm. 'rtma patterns are created.

In order to determine the effectiveness of the new design of the developed excavator bucket teeth, they underwent experimental tests.

During the experimental work, the abrasive abrasion resistance of the teeth with a diamond-shaped bulge and a sharp-edged bulge, which developed the basic teeth of the excavator bucket, was studied, ie their service life.

Experimental work was carried out in the following stages:

In the first stage of the experimental test, with the installation of the basic teeth on the excavator bucket, excavation of loaded rock and semi-rock rocks with rock strength f = 12 ÷ 14 was carried out. During the experimental tests, the length of the bucket teeth and the average thickness of the 5 separated parts were determined during the operation over a period of time (Figure 8).



z_1, z_2, z_3, z_4, z_5 – the sequence number of sections on flat surfaces

Figure 8. Location of incisions to measure decay rates for base teeth

In experimental tests, one of the most effective ways to determine the change in the size of the teeth of the bucket due to friction due to friction along its length and separated parts during operation for a certain period of time is to allow an error of Δ=0.1 mm in the differential method. was carried out using a heat-resistant ШЦ-400 barbell compass, and these results are given in Table 1 of the applications.

Table 1
Over time, the size of the base bucket tooth changes due to friction due to friction along its length and separated parts

T, hours	L, mm	Δl, mm	Z_1, mm	Z_2, mm	Z_3, mm	Z_4, mm	Z_5, mm
0	360	0	40	81	103	143	174
30	332	28	33	79	102	142	173
60	308	52	-	76	100	140	171
90	286	74		70	98	137	168
120	264	96		64	95	134	165
150	249	111		-	91	131	162
180	235	125			85	128	159
210	221	139			78	124	156
240	210	150			72	119	153
270	196	164			65	114	150
300	180	180			-	108	147

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where, T – working time of the bucket tooth, hours; L – the length of the tooth at a given time, mm; Δl – a change in the length of a tooth over a period of time, mm; Z_1 – size on section 1, mm; Z_2 – Size on section 2, mm; Z_3 – Size on section 3, mm; Z_4 – Size on section 4, mm; Z_5 – Size on section 5, mm.

Experimental experiments were performed on the five sharp angular embossed teeth shown in Figure 9. The five sections shown in Figure 9 measured the amount of abrasion of sharp-edged embossed patterns and flat surfaces over time, and the results are presented in Table 2.

Table 2

The change in the size of a five-pointed convex tooth over time due to friction due to friction along its length and separation

T, moto-hours	L, mm	Δl, mm	1- cut		2- cut		3- cut		4- cut		5- cut	
			Z_1 mm	Z_{1b} mm	Z_2 mm	Z_{2b} mm	Z_3 mm	Z_{3b} mm	Z_4 mm	Z_{4b} mm	Z_5 mm	Z_{5b} mm
0	360	0	35	45	76	86	98	108	138	148	169	179
30	346	14	32	38	75	85	97	107	138	147	169	179
60	329	31	28	30	74	84	96	102	137	146	168	178
90	318	42	-	-	72	82	95	98	137	146	167	177
120	306	54			70	80	94	96	135	145	166	175
150	293	67			68	78	92	94	135	142	164	173
180	286	74			65	73	90	92	132	140	162	171
210	273	93			63	65	87	89	130	138	161	169
240	248	112			-	-	84	87	128	136	159	167
270	237	123					80	82	125	134	157	165
300	226	134					76	78	121	131	156	163
330	214	146					72	74	117	126	154	160
345	203	157					68	70	114	122	152	157
360	191	169					64	66	111	111	150	151
375	180	180					-	-	108	108	147	147

where, T – working time of the bucket tooth, hours; L – the length of the tooth at a given time, mm; Δl – a change in the length of a tooth over a period of time, mm; Z_1 – Flat surface size on section 1, mm; Z_{1b} – The size of the bulge on section 1, mm; Z_2 – Flat surface size on section 2, mm; Z_{2b} – The size of the bulge on section 2, mm; Z_3 – Flat surface size on section 3, mm; Z_{3b} – The size of the bulge on section 3, mm; Z_4 – Flat surface size on section 4, mm; Z_{4b} – The size of the bulge on section 4, mm; Z_5 – Flat surface size on section 5, mm; Z_{5b} – The size of the bulge on section 5, mm.

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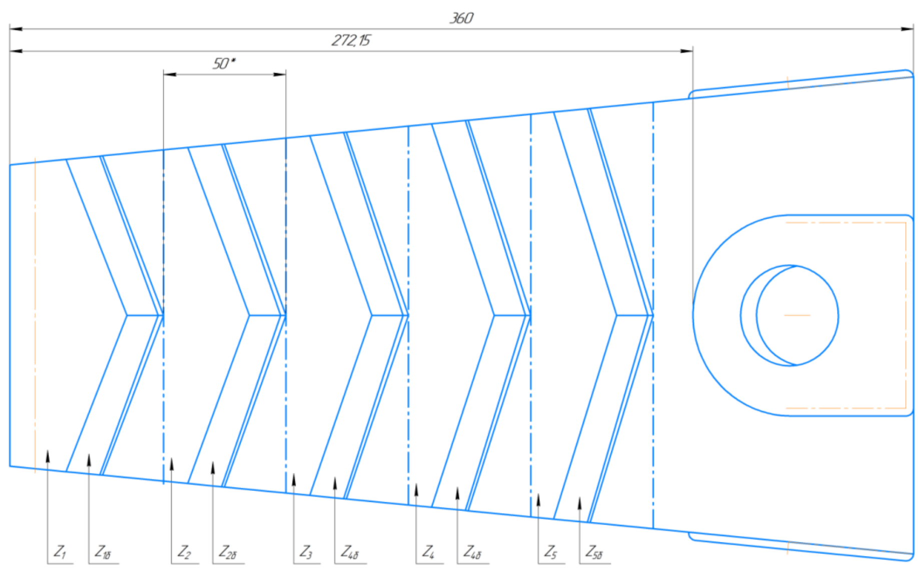

z_1, z_2, z_3, z_4, z_5 – the sequence number of the flat surfaces of the cuts;

z_{1b}, z_{2b}, z_{3b}, z_{4b}, z_{5b} – the sequence number in the location of the sharp corners with embossed patterns in the sections

Figure 9. Location of cuts for measuring the amount of erosion for improved five sharp angled convex teeth

Based on the analysis of the results of experimental tests conducted to determine the effectiveness of the improved design of the teeth of the excavator bucket, it was established that the service life of the bucket teeth depends on the magnitude of fractures.

CONCLUSION

Based on the results of the experimental studies, graphs of the dependence of the magnitude of the erosion on the length of the service life of the basic bucket tooth and the embossed bucket teeth with 5 sharp angular shapes were established and their a cross-correlation graph was developed and shown in Figure 10.

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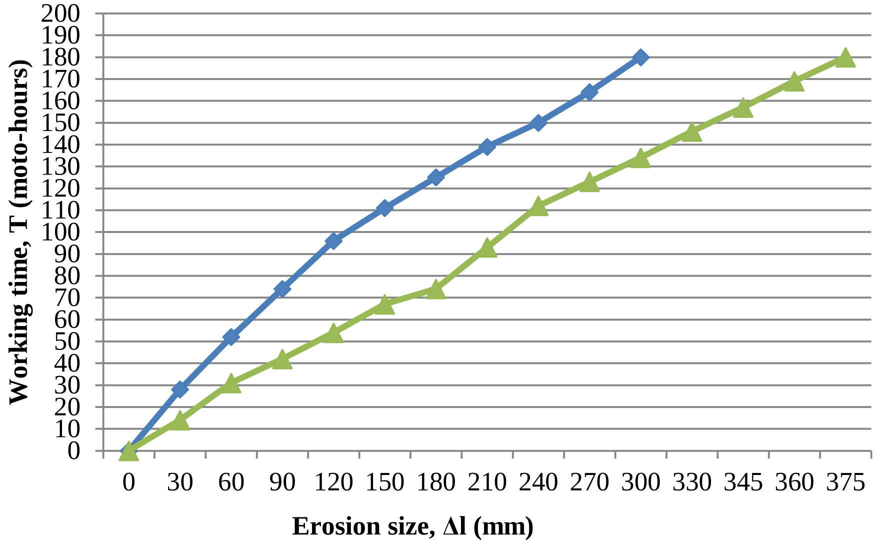

1 - basic tooth; 2 - five embossed teeth with sharp corners;

Figure 10 Graph of the corrosion rate of the basic and improved sharp-edged bucket teeth

As can be seen from the set graph of the dependence of the magnitude of the fracture on the length of the working life of the embossed bucket teeth with basic and improved 5 sharp angular shapes shown in Figure 10 above, The working life of the embossed bucket tooth, which has 5 sharp angular shapes, improved compared to the basic bucket tooth, was found to be 75 moto-hours, or 25% more.

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