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TECHNICAL AND ECONOMIC EFFICIENCY OF HITACHI EX-1200 EXCAVATOR BUCKET TEETH MADE OF TITANIUM-MODIFIED HIGH-MANGANESE 110G13L STEEL

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Abstract. This article analyzes the technical and economic efficiency of high-manganese 110G13L steel and titanium-modified 110G13L steel used in the production of bucket teeth for the HITACHI EX-1200 hydraulic excavator. In the study, steel variants containing 0.4%, 0.6%, and 0.8% titanium were compared with conventional 110G13L steel in terms of production cost, service life, annual operating time, and technical availability coefficient. The calculations considered raw material, energy, labor, heat treatment, and general production costs from melting 6 tons of metal in a DSP-6 electric arc furnace to the production of 30 bucket teeth. The results showed that the addition of titanium increases the production cost of bucket teeth to a certain extent; however, it improves their service life and the technical availability coefficient of the excavator. In particular, bucket teeth made of 110G13L steel modified with 0.8% titanium showed the highest result in terms of service life.

Keywords: 110G13L steel, high-manganese steel, titanium, ferrotitanium, HITACHI EX-1200, bucket tooth, production cost, service life, technical and economic efficiency.

Аннотация. В данной статье проанализирована технико-экономическая эффективность высокомарганцовистой стали марки 110Г13Л и стали 110Г13Л, модифицированной титаном, применяемых при производстве зубьев ковша гидравлического экскаватора HITACHI EX-1200. В исследовании варианты стали с добавлением 0,4 %, 0,6 % и 0,8 % титана были сравнены с обычной сталью 110Г13Л по таким показателям, как

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себестоимость, эксплуатационный срок службы, годовое рабочее время и коэффициент технической готовности. В расчётах были учтены затраты на сырьё, электроэнергию, рабочую силу, термическую обработку и общепроизводственные расходы — от плавки 6 тонн металла в электродуговой печи ДСП-6 до изготовления 30 зубьев ковша. Результаты показали, что добавление титана в определённой степени увеличивает себестоимость зубьев ковша, однако повышает их срок службы и коэффициент технической готовности экскаватора. Особенно высокие результаты по сроку службы показали зубья ковша, изготовленные из стали 110Г13Л, модифицированной 0,8 % титана.

Ключевые слова: сталь 110Г13Л, высокомарганцовистая сталь, титан, ферротитан, HITACHI EX-1200, зуб ковша, себестоимость, срок службы, технико-экономическая эффективность.

Annotatsiya. Ushbu maqolada HITACHI EX-1200 rusumli gidravlik ekskavator kovsh tishlarini ishlab chiqarishda qo‘llaniladigan 110G13L markali yuqori marganesli po‘lat hamda titan bilan modifikatsiyalangan 110G13L po‘latining texnik-iqtisodiy samaradorligi tahlil qilindi. Tadqiqotda 0,4 %, 0,6 % va 0,8 % titan qo‘shilgan po‘lat variantlari oddiy 110G13L po‘lati bilan tannarx, ekspluatatsion xizmat muddati, yillik ishlash vaqti hamda texnik tayyorgarlik koeffitsienti bo‘yicha taqqoslandi. Hisob-kitoblarda DSP-6 elektr yoy pechida 6 tonna metall eritishdan boshlab 30 dona kovsh tishi ishlab chiqarishgacha bo‘lgan xomashyo, energiya, ishchi kuchi, termik ishlov berish va umumishlab chiqarish xarajatlari hisobga olindi. Natijalar shuni ko‘rsatdiki, titan qo‘shilishi kovsh tishlarining tannarxini ma’lum darajada oshiradi, biroq ularning xizmat muddati va ekskavatorning texnik tayyorgarlik koeffitsientini yaxshilaydi. Ayniqsa, 0,8 % titan bilan modifikatsiyalangan 110G13L po‘latdan tayyorlangan kovsh tishlari xizmat muddati bo‘yicha eng yuqori natijani ko‘rsatdi.

Kalit so‘zlar: 110G13L po‘lat, yuqori marganesli po‘lat, titan, ferrotitan, HITACHI EX-1200, kovsh tishi, tannarx, xizmat muddati, texnik-iqtisodiy samaradorlik.

INTRODUCTION.

Excavator bucket teeth used in the mining industry operate under conditions of high impact loads, abrasive wear, and severe service environments. In particular, the bucket teeth of HITACHI EX-1200 hydraulic excavators are constantly exposed to friction with rock materials and impact forces; therefore, their strength, wear resistance, and service life are of great importance.

One of the widely used materials for manufacturing bucket teeth is high-manganese 110G13L steel. This steel has the ability to harden its surface layer

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under impact loads and is considered an effective material for cast parts operating under severe conditions. However, during production and operation, rapid wear of bucket teeth, the need for frequent replacement, and increased maintenance costs negatively affect the economic efficiency of the enterprise.[1]

One of the ways to reduce this problem is to modify the composition of 110G13L steel with titanium. Titanium forms carbides in the steel, restricts grain growth, stabilizes the microstructure, and improves the mechanical and operational properties of the material. Therefore, evaluating the technical and economic efficiency of bucket teeth made of titanium-modified 110G13L steel is a relevant issue.[2]

The purpose of this study is to compare conventional 110G13L steel and 110G13L steel modified with 0.4%, 0.6%, and 0.8% titanium in the production of HITACHI EX-1200 excavator bucket teeth in terms of production cost, service life, and technical availability coefficient.

MATERIALS AND METHODS.

The bucket teeth of the HITACHI EX-1200 hydraulic excavator were selected as the research object. High-manganese 110G13L steel and titanium-modified 110G13L steel variants were considered for the production of bucket teeth.

The calculations were based on the melting of 6 tons of metal in a DSP-6 electric arc furnace. It was assumed that 30 bucket teeth are produced during one melting process. Since 6 teeth are installed on one excavator bucket, 30 teeth were considered sufficient for 5 excavators.



1-rasm. 110G13L po‘latini eritish va quyish jarayonida olingan namuna stakanlari.

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The following variants were compared in the study:

1. Conventional high-manganese 110G13L steel;
2. 110G13L + 0.4% titanium;
3. 110G13L + 0.6% titanium;
4. 110G13L + 0.8% titanium.

FTi-35 ferrotitanium was considered for introducing titanium into the steel. In the calculations, the price of ferrotitanium was accepted as **65,808 UZS/kg**. Losses due to burning and material loss during the titanium addition process were also taken into account.[4]

The following cost types were considered in the economic evaluation:

- direct material costs;
- energy costs;
- direct labor costs;
- general production costs.



Figure 2. Sample cups taken during the casting process of 110G13L steel for mechanical testing.

Operational efficiency was evaluated by analyzing the average service life of the bucket teeth, the number of replacements per year, the annual cost for 5 excavators, and the technical availability coefficient.[5] Under enterprise operating conditions, the initial technical availability coefficient was accepted as **80%**.

The annual effective operating time was determined using the following formula:

$$T = 365 \cdot 24 \cdot KIO$$

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where:

T — annual effective operating time, hours;

KIO — technical availability coefficient.

RESULTS.

The total production cost of bucket teeth made of conventional 110G13L steel was 107.5 million UZS. When 30 bucket teeth were produced from 6 tons of metal melted in the DSP-6 furnace, the cost of one bucket tooth was 3.583 million UZS. Since 6 teeth are required for one excavator bucket, the cost for one bucket amounted to 21.498 million UZS.

The service life of bucket teeth made of conventional 110G13L steel for 5 excavators ranged from 157 to 161 motor-hours, with an average service life of 159 motor-hours. When the technical availability coefficient was accepted as 80% under enterprise operating conditions, the annual effective operating time was 7008 hours. The number of bucket tooth replacements per year for one excavator was 44 times.

For bucket teeth made of 110G13L steel modified with 0.4% titanium, the total production cost was 112.4 million UZS. In this case, the cost of one tooth was 3.75 million UZS, and the cost for one excavator bucket was 22.5 million UZS. According to the operational test results, the average service life of bucket teeth with 0.4% titanium was 173 motor-hours. This is approximately 9% higher compared to conventional 110G13L steel. The technical availability coefficient increased to 87%.

For the variant modified with 0.6% titanium, the total production cost was 113.7 million UZS. The cost of one tooth was 3.79 million UZS, and the cost for one bucket was 22.74 million UZS. In this variant, the average service life of the bucket teeth was 178 motor-hours. This is 11.9% higher compared to conventional 110G13L steel and also shows an increase in service life compared to the 0.4% titanium variant. The KIO value reached 89%.

Bucket teeth made of 110G13L steel modified with 0.8% titanium showed the highest service life. In this variant, the total production cost was 117.5 million UZS, the cost of one tooth was 3.92 million UZS, and the cost for one bucket was 23.52 million UZS. According to the operational results, the average service life of the bucket teeth reached 185 motor-hours. This is 16.4% higher compared to conventional 110G13L steel. The technical availability coefficient increased to 92%.

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Table 1

Comparison of bucket teeth made of 110G13L steel and titanium-modified 110G13L steel

Indicator	110G13L	110G13L + 0,4 % Ti	110G13L + 0,6 % Ti	110G13L + 0,8 % Ti
Total production cost, million UZS	107,5	112,4	113,7	117,5
Cost of one tooth, million UZS	3,583	3,75	3,79	3,92
Cost per one bucket, million UZS	21,498	22,5	22,74	23,52
Average service life, motor-hours	159	173	178	185
Increase in service life, %	—	9,0	11,9	16,4
Technical availability coefficient, %	80	87	89	92
Annual operating time of one excavator, hours	7008	7612	7832	8140

DISCUSSION.

The obtained results show that bucket teeth made of titanium-modified 110G13L steel have higher operational durability compared to bucket teeth made of conventional 110G13L steel. As the titanium content increased, the service life of the bucket teeth also increased consistently.

While the average service life of conventional 110G13L steel was 159 motor-hours, this value increased to 173 motor-hours with the addition of 0.4% titanium, to 178 motor-hours with 0.6% titanium, and to 185 motor-hours with 0.8% titanium. This indicates that titanium improves the microstructural stability of the steel and increases the wear resistance of the bucket teeth

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However, the addition of titanium also increases the production cost. The cost of one bucket tooth made of 110G13L steel was 3.583 million UZS, while it amounted to 3.75 million UZS for the 0.4% titanium variant, 3.79 million UZS for the 0.6% titanium variant, and 3.92 million UZS for the 0.8% titanium variant. Nevertheless, the increase in service life and the improvement of the technical availability coefficient make it possible to compensate for the additional production costs.

In particular, the variant with 0.8% titanium showed the highest technical result. In this variant, the service life increased by 16.4%, and the KIO reached 92%. However, when choosing the economically optimal variant, not only the service life but also the increase in production cost should be taken into account. The 0.4% titanium variant may be considered a practical solution in terms of the balance between cost and service life. The 0.6% and 0.8% titanium variants are more effective under conditions of high load and intensive wear.

Thus, titanium modification improves not only the mechanical and operational properties of bucket teeth but also the overall technical availability of the excavator. This makes it possible to reduce downtime during production, decrease spare parts consumption, and improve maintenance efficiency.

CONCLUSION.

The modification of high-manganese 110G13L steel with titanium in the production of HITACHI EX-1200 excavator bucket teeth is considered a technically and economically effective solution.

According to the research results, the average service life of bucket teeth made of conventional 110G13L steel was 159 motor-hours. With the addition of 0.4% titanium, this value increased to 173 motor-hours; with 0.6% titanium, it increased to 178 motor-hours; and with 0.8% titanium, it reached 185 motor-hours.

The increase in titanium content led to an increase in the production cost of the bucket teeth. However, the extension of service life, the reduction in the number of replacements, and the increase in the technical availability coefficient from 80% to 87–92% indicate the economic feasibility of titanium modification.

The 110G13L steel modified with 0.8% titanium showed the highest technical result. At the same time, considering the balance between production cost and operational efficiency, the variants with 0.4–0.6% titanium can be regarded as optimal options for application under production conditions.

The implementation of this technology in industrial practice makes it possible to increase the service life of HITACHI EX-1200 excavator bucket teeth, improve their wear resistance, reduce maintenance costs, and increase production efficiency.

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