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IMPROVING THE PRODUCTION TECHNOLOGY OF EX-1200 EXCAVATOR BUCKET TEETH BASED ON TITANIUM MODIFICATION OF 110G13L HIGH-MANGANESE STEEL

Salimjonov Xazrat Akramjon o‘g‘li
Independent Researcher, Engineer-Technologist, Production Department of “NMZ”, JSC “NMMC”
Rasulov Islam Baxodirovich
Independent Researcher, Deputy Chief Engineer of the Production Department of “NMZ”, JSC “NMMC”
Okhunjon Sayfidinov
Department of Mechanical Engineering, Navoi State University of Mining and Technologies, Navoi, Uzbekistan
Oripov Dostonjon Rustamjon o‘g‘li
Department of Mechanical Engineering, Navoi State University of Mining and Technologies ,Navoi, Uzbekistan

Annotatsiya. Ushbu maqolada 110G13L markali yuqori marganesli po‘latni titan bilan modifikatsiyalash asosida EX-1200 ekskavatori kovshi tishlarini ishlab chiqarish texnologiyasini takomillashtirish masalasi IMRAD talablari asosida tahlil qilingan. Tadqiqot “Navoiy kon-metallurgiya kombinati” AJ “Navoiy mashinasozlik zavodi” ishlab chiqarish birlashmasining quymachilik sexi sharoitida olib borilgan. 110G13L po‘lat yuqori zarbli yuklamalar, abraziv yeyilish va og‘ir ekspluatatsiya sharoitlarida ishlovchi quyma detallar uchun qo‘llaniladi. Tadqiqotda titan elementi po‘latning mikrostrukturasi, donalar maydalanishi, qattiqligi, zarbga chidamliligi va yeyilishga bardoshliligini oshiruvchi modifikatsiyalovchi element sifatida ko‘rib chiqildi. Amaliy tajribalar uchun eritmaga 0,3% va 0,4% miqdorda titan qo‘shish belgilandi. Sof titan o‘rniga tarkibida 35% titan mavjud bo‘lgan FTi-35 markali ferrotitan qo‘llanildi. Natijada 0,3% titan miqdorini ta’minlash uchun 51 kg, 0,4% titan miqdorini ta’minlash uchun esa 68,5 kg ferrotitan qo‘shildi. Maqolada EX-1200 ekskavatori kovshi tishlarini loyihalash, metallni eritish, qolip tayyorlash, titan bilan modifikatsiyalash, quyish, tozalash, mexanik ishlov berish, termik ishlov berish va sifat nazorati bosqichlari tizimli yoritilgan. Olingan natijalar titan bilan modifikatsiyalangan 110G13L po‘latdan tayyorlangan kovsh tishlarining ekspluatatsion xossalarini yaxshilash imkonini berishini ko‘rsatadi.

Kalit so‘zlar: 110G13L po‘lat, yuqori marganesli po‘lat, titan, ferrotitan, modifikatsiyalash, EX-1200 ekskavatori, kovsh tishi, quymachilik, yeyilishga chidamlilik, termik ishlov berish.

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Abstract. This article analyzes the improvement of the production technology of EX-1200 excavator bucket teeth based on the titanium modification of 110G13L high-manganese steel in accordance with IMRAD requirements. The research was carried out under the foundry shop conditions of the Navoi Machine-Building Plant Production Association of JSC Navoi Mining and Metallurgical Company. 110G13L steel is used for cast parts operating under high impact loads, abrasive wear, and severe service conditions. In this study, titanium was considered as a modifying element that improves the microstructure of steel, promotes grain refinement, and increases hardness, impact resistance, and wear resistance. For practical experiments, it was determined to add titanium to the melt in amounts of 0.3% and 0.4%. Instead of pure titanium, FTi-35 ferrotitanium containing 35% titanium was used. As a result, 51 kg of ferrotitanium was added to provide 0.3% titanium, while 68.5 kg was added to provide 0.4% titanium. The article systematically describes the stages of designing EX-1200 excavator bucket teeth, metal melting, mold preparation, titanium modification, casting, cleaning, machining, heat treatment, and quality control. The obtained results show that bucket teeth made of titanium-modified 110G13L steel can have improved operational properties.

Keywords: 110G13L steel, high-manganese steel, titanium, ferrotitanium, modification, EX-1200 excavator, bucket tooth, foundry, wear resistance, heat treatment.

Аннотация. В данной статье на основе требований IMRAD проанализирован вопрос совершенствования технологии производства зубьев ковша экскаватора EX-1200 на основе модифицирования высокомарганцовистой стали марки 110Г13Л титаном. Исследование проводилось в условиях литейного цеха производственного объединения «Навоийский машиностроительный завод» АО «Навоийский горно-металлургический комбинат». Сталь 110Г13Л применяется для изготовления литых деталей, работающих в условиях высоких ударных нагрузок, абразивного износа и тяжёлой эксплуатации. В исследовании титан рассмотрен как модифицирующий элемент, способствующий улучшению микроструктуры стали, измельчению зёрен, повышению твёрдости, ударной вязкости и износостойкости. Для практических экспериментов было предусмотрено введение титана в расплав в количестве 0,3% и 0,4%. Вместо чистого титана применялся ферротитан марки FTi-35, содержащий 35% титана. В результате для обеспечения содержания титана 0,3% было добавлено 51 кг ферротитана, а для обеспечения содержания титана 0,4% — 68,5 кг ферротитана. В статье системно освещены этапы проектирования зубьев ковша экскаватора EX-

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1200, плавки металла, подготовки форм, модифицирования титаном, заливки, очистки, механической обработки, термической обработки и контроля качества. Полученные результаты показывают, что зубья ковша, изготовленные из стали 110Г13Л, модифицированной титаном, обладают улучшенными эксплуатационными свойствами.

Ключевые слова: сталь 110Г13Л, высокомарганцовистая сталь, титан, ферротитан, модифицирование, экскаватор EX-1200, зуб ковша, литейное производство, износостойкость, термическая обработка.

INTRODUCTION.

Excavator bucket teeth used in the mining, metallurgical, and heavy machinery industries operate under high impact loads, intense friction, abrasive wear, and complex service conditions. During operation, such parts are in direct contact with rocks, ore, gravel, and other hard materials. Therefore, the strength, wear resistance, impact resistance, and durability of the bucket tooth material directly affect production efficiency.

110G13L high-manganese steel is widely used for manufacturing cast parts that operate under such conditions. The high manganese content in this steel stabilizes its austenitic structure and contributes to the hardening of the surface layer under impact loads. At the same time, during the casting of 110G13L steel, grain coarsening, structural heterogeneity, gas pores, microcracks, and other casting defects may occur. This reduces the operational properties of the finished part.

One of the effective ways to eliminate this problem is to modify the chemical composition of the steel.[1] Modifying elements influence the formation of the steel microstructure, ensure grain refinement, increase structural homogeneity, and improve mechanical properties. In particular, titanium is of great importance in high-manganese steels as a microalloying and modifying element. Titanium reacts with carbon and forms titanium carbides. [2]These dispersed particles restrict the growth of crystal grains, refine the microstructure, and increase the hardness and wear resistance of the material.

The purpose of this study is to improve the production technology of EX-1200 excavator bucket teeth based on the titanium modification of 110G13L high-manganese steel.[3] The study analyzes the effect of titanium content on the technological process under production conditions, the possibility of using ferrotitanium, the stages of casting and heat treatment, and the factors influencing the quality of the final product.

MATERIALS AND METHODS.

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The bucket tooth of the EX-1200 excavator was selected as the object of the study. Since this part operates under conditions of high impact loads and abrasive wear, 110G13L high-manganese steel was used for its production. The research work was carried out under the foundry shop conditions of the Navoi Machine-Building Plant Production Association of JSC Navoi Mining and Metallurgical Company.



Figure 1. General view of the EX-1200 excavator, its bucket, and bucket tooth.

110G13L steel's chemical composition was evaluated based on the requirements of the GOST 977–88 standard. According to this standard, the steel contains 0.9–1.5% carbon, 0.3–1.0% silicon, 11.5–15.0% manganese, up to 1.0% nickel, up to 0.05% sulfur, up to 0.12% phosphorus, and up to 1.0% chromium.

The metal melting process was carried out in a DSP–6 electric arc furnace with a capacity of 6 tons. The metal charge was melted at a temperature of 1550 °C and brought to the required molten state.[4] After the melt had completely reached the liquid state, titanium was added as a modifying element. To determine the effect of titanium content in the study, two compositions were selected: 0.3% titanium and 0.4% titanium.

According to the calculations, 18 kg of pure titanium is required to provide 0.3% titanium in a 6-ton metal melt, while 24 kg of pure titanium is required to provide 0.4% titanium. Under production conditions, FTi-35 ferrotitanium containing 35% titanium was used instead of pure titanium. Therefore, 51 kg of

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ferrotitanium was added to the melt to obtain 0.3% titanium, and 68.5 kg was added to obtain 0.4% titanium.

The production technology of EX-1200 excavator bucket teeth consisted of the following main stages:

1. Designing the bucket tooth;
2. Developing the production technological process;
3. Melting the metal and preparing the molds;
4. Modifying the melt with titanium;
5. Pouring the molten metal into the molds;
6. Cleaning and machining the cast parts;
7. Heat treatment;
8. Technical inspection and evaluation of the finished product quality.

The molds were prepared in the modeling section based on drawings developed by design engineers. Three bucket teeth were placed in each mold. In total, 30 bucket teeth were cast in one melting cycle using 10 molds. The weight of one finished bucket tooth was 135 kg.

The casting process was carried out at a temperature range of 1380–1410 °C. This temperature was selected to be approximately 15 °C lower than the conventional casting temperature in order to reduce metal burning onto the mold surface and to decrease the probability of gas pores and other casting defects. The cast parts were naturally cooled under workshop conditions for 8–10 hours.

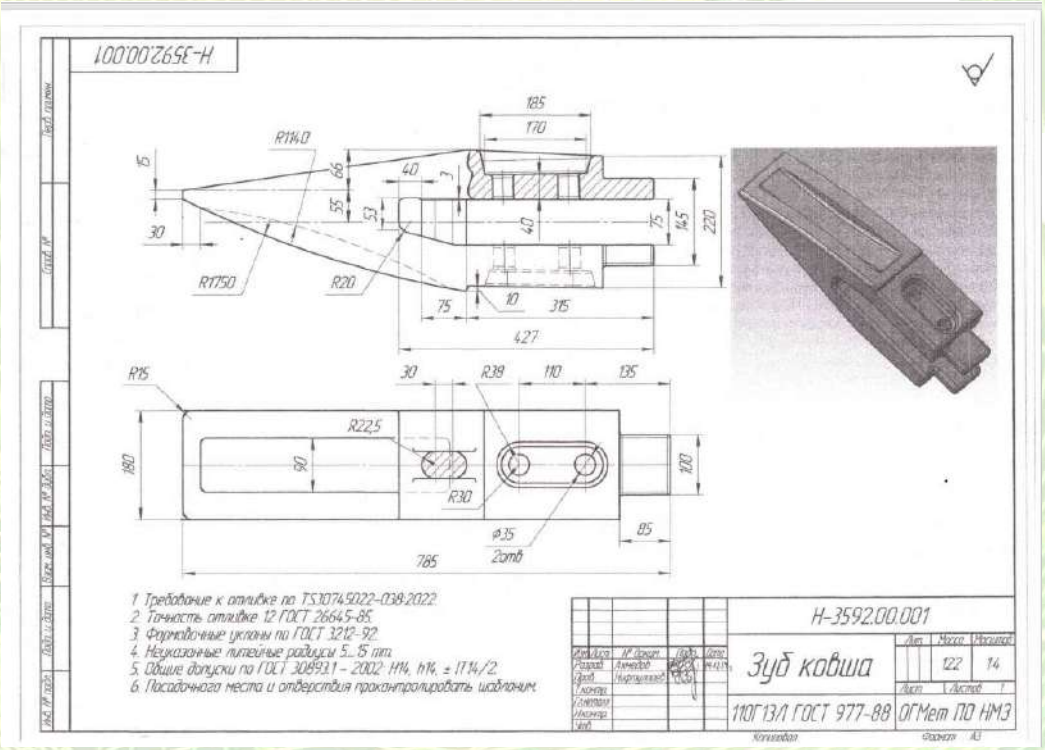


Figure 2. Design drawing of the EX-1200 excavator bucket tooth.

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After the cooling process was completed, the molds were broken, and the cast parts were removed. In the next stage, excess metal, gating system elements, and slag residues were removed using mechanical methods.



Figure 3. Model of the EX-1200 excavator bucket tooth.

After that, the bucket teeth were subjected to heat treatment. During heat treatment, the metal was heated to 900 °C and then naturally cooled under workshop conditions. At the final stage, the geometric dimensions, surface quality, and overall quality of the finished bucket teeth were inspected by the technical control department.

RESULTS.

The research results showed that the titanium modification of 110G13L high-manganese steel has significant technological importance in the production of EX-1200 excavator bucket teeth. When titanium is introduced into the melt, it has a positive effect on the formation of the steel microstructure, promotes grain refinement, and makes it possible to improve the mechanical and operational properties of the finished part.

It was determined that the use of FTi-35 ferrotitanium instead of pure titanium is technologically convenient under production conditions. For a 6-ton melt, 51 kg of ferrotitanium was used to provide 0.3% titanium, while 68.5 kg of ferrotitanium was used to provide 0.4% titanium. This made it possible to obtain the required amount of pure titanium in the melt.

The selection of the casting temperature in the range of 1380–1410 °C had a positive effect on the production process. Choosing a temperature approximately 15 °C lower than the conventional value reduces metal burning onto the mold surface and decreases the probability of gas pores and casting defects. This contributes to improving the quality of the finished bucket teeth.[5]

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The possibility of casting 30 EX-1200 excavator bucket teeth in one melting cycle ensured production efficiency. The weight of each finished bucket tooth was 135 kg, and 10 molds were used in the production process. The placement of 3 teeth in each mold made it possible to organize the casting process efficiently.

At the heat treatment stage, the internal microstructure of the bucket teeth was stabilized. Heating up to 900 °C and natural cooling helped reduce internal stresses in the material, improve its mechanical properties, and increase operational reliability.

Overall, it was found that EX-1200 bucket teeth made of titanium-modified 110G13L steel are suitable for operation under high impact loads and abrasive wear conditions. The addition of titanium contributes to increasing the hardness, strength, impact resistance, and wear resistance of the steel.

DISCUSSION.

The obtained results showed that adding titanium to 110G13L high-manganese steel is an effective method for improving its microstructure and operational properties. Although high-manganese steels have the ability to harden their surface layer under impact loads, structural heterogeneity and grain coarsening that occur during the casting process may limit their performance. Titanium modification helps reduce these shortcomings.

Titanium reacts with carbon in the steel and forms titanium carbides. These particles restrict grain growth, refine the microstructure, and improve the homogeneity of the steel. As a result, the working part of the bucket teeth can operate more stably in impact and abrasive environments.

The titanium content of 0.3–0.4% selected in this study was evaluated as a suitable range for production conditions. A very small amount of titanium may not provide a sufficient modification effect, while excessive titanium may lead to the formation of undesirable phases in the steel. Therefore, the 0.3–0.4% range is considered technologically optimal.

The use of FTi-35 ferrotitanium is also an important practical result. The use of pure titanium may be economically and technologically inconvenient in the production process. Ferrotitanium containing 35% titanium allows the required amount of titanium to be introduced into the melt and is convenient for use under plant conditions.

The selection of the casting temperature in the range of 1380–1410 °C is also technologically justified. Excessively high temperatures increase the risk of mold surface burning, gas pores, microcracks, and other defects. Therefore, selecting the optimal casting temperature is important for improving the quality of the finished product.

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The research results show that the titanium modification of 110G13L steel is not limited only to changing the chemical composition of the metal. This process requires a comprehensive technological approach that includes design, molding, melting, casting, cooling, machining, heat treatment, and quality control. The correct implementation of each stage directly affects the service life and reliability of the final product.

CONCLUSION.

Titanium modification of 110G13L high-manganese steel is an effective method for improving the production technology of EX-1200 excavator bucket teeth. The research results showed that titanium has a positive effect on the formation of the steel microstructure, promotes grain refinement, and improves the mechanical and operational properties of the material.

Under production conditions, the use of FTi-35 ferrotitanium was found to be appropriate for providing 0.3% and 0.4% titanium content. It was determined that 51 kg of ferrotitanium is required to obtain 0.3% titanium in a 6-ton melt, while 68.5 kg of ferrotitanium is required to obtain 0.4% titanium.

The production technology of EX-1200 excavator bucket teeth consisted of the stages of design, development of the technological process, metal melting, mold preparation, titanium modification, casting, cooling, cleaning, machining, heat treatment, and technical inspection. Each stage directly affects the quality of the finished product.

The selection of the casting temperature in the range of 1380–1410 °C helped reduce the probability of casting defects, decrease metal sticking to the mold surface, and improve the quality of the bucket teeth. During heat treatment, heating up to 900 °C and natural cooling reduced internal stresses in the material and increased its operational stability.

Overall, bucket teeth made of titanium-modified 110G13L steel can be considered an effective material for operation under high impact loads and abrasive wear conditions. The industrial application of this technology makes it possible to extend the service life of EX-1200 excavator bucket teeth, increase their wear resistance, and improve production efficiency.

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