pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

SUBSTITUTION OF PRODUCING EAT-RESISTANT STEEL FROM SECONDARY RAW MATERIALS (USED IN THE EXAMPLE OF EXCAVATOR SHOE)

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Abstract

This article discusses the scientific and technological foundations for obtaining wear-resistant steel from secondary raw materials. Particular attention is paid to the optimization of the chemical composition of steel for excavator buckets operating in conditions of intense abrasive wear. The economic and environmental advantages of using secondary metal resources are substantiated. Experimental studies have shown that the correct selection of alloying elements allows you to form a structure with high wear resistance. The use of this approach helps to reduce energy costs, reduce waste and improve product quality. The results obtained can be effectively used in mechanical engineering and the mining industry to increase the service life of equipment.

Keywords

wear-resistant steel, secondary raw materials, alloying, excavator bucket, abrasion, metallurgy, recycling, economic efficiency, ecology, hardness, strength, microstructure, martensite, austenite, carbon, manganese, chromium, heat treatment, resource saving, industrial waste

Introduction

The demand for metal products in modern industry and construction is increasing. In particular, wear-resistant steels are widely used in mining, construction and heavy machinery. Excavators, bulldozers and other heavy machinery parts, including excavators, are exposed to high abrasive loads during operation and wear quickly. Therefore, the steel material used for such parts must have high mechanical properties, be wear-resistant and have a long service life. In traditional metal production, natural ores are used as the main raw material, but this approach is expensive and environmentally harmful. Therefore, the use of secondary raw materials is becoming one of the important directions of modern metallurgy[1].

Secondary raw materials are raw materials obtained by recycling previously used metal products, which can be melted down and re-alloyed to produce new high-quality steel. This approach has several advantages: firstly, it allows you to save natural resources; secondly, it reduces waste; thirdly, it is economically efficient. At the same time, by precisely controlling the chemical composition of the recycled metal and adding alloying elements in optimal quantities, it is possible to create wear-resistant steel. Taking the example of an excavator bucket, its operating conditions are very severe: it is exposed to constant abrasive loading, shocks, vibrations and high mechanical stresses. Therefore, for such parts, it is important to scientifically select the steel composition, correctly carry out alloying and heat treatment [1].

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pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

The production of wear-resistant steel from secondary raw materials is also environmentally beneficial. Traditional steel production requires the extraction of large amounts of natural ores, which damages the earth's crust and requires a lot of energy resources. Recycled metal significantly reduces energy consumption, reduces waste, and makes the production process environmentally friendly. In addition, the quality and properties of wear-resistant steels are very important in modern industry and construction to extend the service life and increase the efficiency of equipment. Therefore, it is an urgent issue to study the scientific and technological foundations of obtaining high-quality steel from secondary raw materials and apply them to heavy-duty parts, such as excavator buckets.

Materials and method

Experimental studies were conducted to study the scientific basis for the use of secondary raw materials in the production of wear-resistant steel. The main goal of the study was to optimize the composition of high-abrasion-resistant steel for excavator undercarriage parts and determine the effectiveness of alloying elements. The study included several stages: the selection and preparation of secondary raw materials, the study and optimization of the chemical composition, melting and casting processes, heat treatment, microstructure analysis, and hardness and wear resistance tests. This allowed the structural properties and mechanical properties of the metal to be determined, which made it possible to develop the most optimal type of steel for excavator undercarriage parts.[2]

The first stage of the research involved the preparation of secondary raw materials. The used metal waste was separated, cleaned and brought to the required dimensions. Before processing, the chemical composition of the raw materials was measured using spectrometric analysis. Then, the amount of alloying elements such as carbon (C), manganese (Mn), chromium (Cr), silicon (Si), nickel (Ni) and molybdenum (Mo) in the main elements of the steel was optimized. The experimental results showed that the composition of secondary raw materials is close to natural ores, and by remelting and alloying them, it is possible to obtain high-quality corrosion-resistant steel. At the same time, determining the optimal ratio of constituent elements directly affects the microstructure and mechanical properties of the steel.

Figure-1. Secondary metals

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pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

The second stage involved the melting and casting process. The steel was melted in electric furnaces, and alloying elements were added at high temperatures. The molten steel was poured into special casting molds and then strengthened by heat treatment. Heat treatment included hardening and tempering processes. During the hardening process, the steel was heated to a temperature of 850–900°C and rapidly cooled in water, then during the tempering process, it was heated to 200–250°C to reduce internal stresses. As a result of this process, martensite and bainite structures were formed in the steel, which significantly increased the wear resistance of the material.

In the third stage, microstructure analysis and hardness tests were carried out. Using metallographic analysis, the martensite, bainite and ferrite phases of the steel were determined, and the effect of alloying elements was assessed. Hardness tests were carried out using the Rockwell method, and the results were tabulated. At the same time, abrasive wear resistance tests were carried out in laboratory conditions using special tribological devices. The results showed that the optimal amount of alloying elements and heat treatment directly affect the microstructure and wear resistance of the steel.

In the fourth stage, the research results were systematically analyzed and the optimal steel composition parameters for excavator undercarriage parts were determined.

Table-1. The composition of the steel tested during the experiment and its main properties

Element	Mass. %	Hardness HRC	Wear resistance (%)	Microstructure	Note
C	0.38	52	100	Martensite	Optimal carbon
Mn	1.0	52	100	Martensite + Bainite	Increases endurance
Cr	1.8	52	100	Martensite + Bainite	Abrasive wear resistant
And	0.45	52	100	hell	Increases strength
In	0.5	52	100	Martensite	Ensures structural stability
For	0.3	52	100	Bainit	Increases resistance to erosion
Fe	The rest	–	–	–	Base metal

These results show that by properly alloying and heat treating steel made from secondary raw materials, it is possible to obtain highly wear-resistant materials for heavy-duty parts such as excavator buckets. At the same time, the use of recycled metal resources increases the economic and environmental efficiency of the production process, reduces energy consumption and reduces waste.[3]The results of this research can be widely used in the production of wear-resistant steels in the fields of mechanical engineering, mining, and heavy construction.

Result and discussion

The results of the study showed that by optimizing the chemical elements of the steel composition and heat treatment parameters of secondary raw materials, it is possible to obtain a highly wear-resistant material for excavator undercarriage parts. In experimental studies, increasing the amount of carbon, manganese and chromium significantly increased the hardness and abrasive wear resistance of the steel. In particular, the high content of the martensite phase plays an important role in extending the service life of the material. The results of

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pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

microstructural analysis showed that the combination of alloying elements and heat treatment creates a uniformly distributed martensite and bainite phases in the steel, which maximizes the wear resistance of the material.[4].

Also, the mechanical properties of steel made from recycled secondary raw materials are close to those of steel made from traditional raw materials, and in some parameters, they are superior to it. Hardness tests were carried out using the Rockwell method, and the results showed that steel with an optimal composition has a hardness of 52–55 HRC. This value is sufficient for heavy-duty parts such as excavator shoes. Wear resistance was tested in laboratory conditions using a tribological device, and the results showed a direct dependence on the composition of the steel and alloying elements. Also, the bainite phase formed in the microstructure increases the elastic toughness of the steel and increases its impact resistance.

Table-2. The composition of the steel obtained during the experiment and its main resulting properties

Composition (wt. %)	Hardness HRC	Wear resistance (%)	Microstructural properties	Note
C 0.38, Mn 1.0, Cr 1.8, Si 0.45, Ni 0.5, Mo 0.3	52	100	Martensite + Bainite	Optimal combination
C 0.42, Mn 1.2, Cr 2.0, Si 0.5, Ni 0.5, Mo 0.3	54	105	Martensite + Bainite	Increased resistance to eating
C 0.35, Mn 0.9, Cr 1.5, Si 0.4, Ni 0.4, Mo 0.2	50	95	Martensite + Ferrite	The hardness is a little low, but the elastic tolerance is good
C 0.40, Mn 1.1, Cr 1.8, Si 0.45, Ni 0.5, Mo 0.3	53	102	Martensite + Bainite	Balanced properties

During the discussion, it is worth noting that the carbon content of steel is the main factor determining the formation of martensite. A high carbon content increases hardness, but also increases the risk of embrittlement of the material during processing. Therefore, the optimal value of carbon is recommended to be in the range of 0.35–0.42 wt. %. Manganese and chromium increase the resistance of the material to abrasive wear, and also ensure the stability of the bainite and martensite phases. Silicon and molybdenum are important for increasing the elastic toughness of the material and increasing impact resistance.[5]The results show that the optimal combination of alloying elements allows for the production of high-quality wear-resistant steel for heavy-duty parts such as excavator buckets.[6].

At the same time, the research results also showed the environmental and economic efficiency of steel made from secondary raw materials. The use of recycled metal resources reduces energy consumption, reduces waste and optimizes production costs. From an ecological point of view, such an approach reduces the demand for natural ores and minimizes the negative impact on the environment. Therefore, the production of wear-resistant steel from secondary raw materials is considered beneficial not only in terms of technical properties, but also economically and environmentally.[7]i.

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The results show that when optimizing the steel composition for excavator undercarriage parts, it is necessary to precisely control the alloying elements and heat treatment parameters. As a result of the optimal composition and heat treatment, the martensite and bainite phases are evenly distributed in the steel, and the hardness and wear resistance reach the maximum level. At the same time, the experimental results allow us to develop recommendations that can be practically applied in industry. The study showed that wear-resistant steel made from secondary raw materials not only extends the service life, but also reduces production costs and reduces the environmental load. On this basis, the widespread use of such steel in the fields of mechanical engineering, mining and heavy construction is of practical importance[8].

Conclusion

The results of the study showed that obtaining wear-resistant steel from secondary raw materials is an effective and economically viable approach in modern metallurgy and mechanical engineering. Experimental work on the example of an excavator casing confirmed that it is possible to maximize the hardness, microstructure and wear resistance of steel by optimizing alloying elements and heat treatment parameters.[9]. During the study, the optimal amounts of carbon, manganese, chromium, silicon, nickel and molybdenum were determined, and it was shown that the uniform distribution of martensite and bainite phases plays an important role in increasing the abrasive wear resistance of steel. In addition, the use of recycled metal resources provides advantages not only in terms of technical properties, but also in terms of energy saving, reducing production costs and reducing the environmental load. The results showed that wear-resistant steel prepared with optimal composition and heat treatment provides a long service life in heavy-duty parts such as excavator buckets, reduces technical failures and increases production efficiency[10]. At the same time, the research results allow us to develop recommendations that can be practically applied in the industrial production process. On this basis, wear-resistant steel made from secondary raw materials is considered a relevant and promising direction not only in the fields of mechanical engineering and construction, but also in ecological and economic terms.

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