

# Analysis of Producing and Using Complex Alloy Steels in Kazakhstan Based on Monitoring the World and Domestic Steel Market

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**Abstract.** The article analyzes the market of complex alloy steels produced both in the world and in Kazakhstan. Particular attention is paid to global trends in improving the properties of complex alloy steels. Factors influencing the increase in the production of complex alloy steels from the standpoint of new realities of producing competitive products in various sectors of the economy are noted. The main areas of use of these steels are highlighted. The purpose of the study based on the conducted monitoring of the steel market, is to determine the grades of complex alloy steels needed by the domestic industry, and to substantiate the technological capabilities of producing these steels at metallurgical plants in Kazakhstan. As a recommendation for one of the grades of such steels, steel type 40KhN3MF is determined.

**Keywords:** metallurgical industry, monitoring, alloy steel, competitiveness, microstructure, modification, properties, practical applicability.

## Introduction

The metallurgical industry for the Republic of Kazakhstan is one of the main industries that contribute to increasing the competitiveness of the national economy, as well as achieving sustainable development. According to various estimates, the share of ferrous metallurgy alone in Kazakhstan GDP is up to 8%, assent only to the oil and gas industry and non-ferrous metallurgy.

One of the problems of the ferrous metallurgy of the Republic of Kazakhstan is a fairly narrow range of steels currently smelted. Most of the steels are carbon or low-alloy. This is caused, first of all, by the presence of a certain type of fixed assets. Almost 90% of steel-making furnaces in Kazakhstan are converters, which are designed to smelt only carbon steels. The share of electric furnaces (arc/ induction) remains about 10%, and these furnaces have, as a rule, a small volume and belong to medium-sized businesses. The volume of steel they smelt does not make a significant contribution to the volume of steels produced in the country.

Such domestic giants as the Qarmet JSC,

the TEMC JSC have chromium, chromium-nickel steels and a number of others in their range, but the range is limited and the quality of the smelted steels does not yet allow competing in the world market.

The purpose of this study is to develop a technology of producing complex alloy steels with improved performance properties by affecting modifiers-inoculants and external factors. A distinctive feature is the «binding» to the existing range of smelted steels and fixed assets in the territory of the Republic of Kazakhstan, which will allow implementing the developed technology by potential consumers without significant investments and expansion of production areas.

To achieve this goal, monitoring of the world and domestic alloy steel market was carried out. Based on the monitoring and information analysis, grades of complex alloy steels that can be smelted at metallurgical enterprises of Kazakhstan were determined as the object of research. Steel 40KhN3MF is considered as one of the this type steel grades.

The studies were carried out in the accredited laboratory of Abylkas Saginov Karaganda

Technical University NJSC, at the production sites of the Parkhomenko KMZ LLP and the Marganets SPC to test smelting in furnaces of different types.

### Basic provisions

The main consumer of foundry products in Kazakhstan is mechanical engineering. Until 1990, there were approximately 1 800 large and medium-sized mechanical engineering enterprises in the Republic of Kazakhstan [1]. Kazakhstan had a fairly powerful foundry base with established production of cast iron, steel and non-ferrous castings using various technologies, including high-precision ones.

However, it is known that by the end of the 20th century, large machine-building enterprises in Alma-Ata, Karaganda, Pavlodar and the other cities were closed or were on the verge of stopping. This led to the fact that in 1999, in the total volume of industrial production of the Republic of Kazakhstan, the mechanical engineering and metalworking industries accounted for only 1,5%. The share of medium-sized enterprises slightly exceeds 1%. Small enterprises cannot maintain foundry production. Unfortunately, accurate statistics on the number and condition of foundries are currently not presented in open sources [1].

It is important to note that the leading sectors of the economy of Kazakhstan such as the mining and metallurgical complex, oil and gas industry, construction, chemical industry, medicine, space industry, etc. are in dire need of products made of high-alloy quality steels.

The analysis of Kazakhstan enterprises producing rolled steel showed a rather narrow range of steel they produce. These enterprises include the Qarmet JSC (Temirtau),

the National Mining Company Tau-Ken Samruk JSC (Astana), the TEMC JSC Temirtau Electro-metallurgical Plant, the KazTemir Trade LLP (Astana), the S. Kirov Machine-Building Plant JSC (Almaty), the Recom Company, the ARBC Aktobe Rail and Beam Plant LLP, the Temirtau Foundry LLP, the Parokhomenko KMZ LLP.

At the same time, only five plants smelt alloy steel. These are the Qarmet JSC, the Temirtau Foundry LLP, the ARBC Aktobe Rail and Beam Plant, the former Almaty heavy engineering plant, S. Kirov Machine-Building Plant and the Parkhomenko KMZ LLP.

The Almaty S. Kirov Machine-Building Plant uses casting in sand-clay and metal molds; centrifugal and chill casting [1]. The Temirtau Foundry LLP specializes in the production of 110G13L steel products; high-alloy, manganese and chromium steels up to 1,6 tons are smelted in the DSP furnace. The range of smelted steel at the Parkhomenko KMZ LLP includes carbon, alloyed types 40Kh, 40KhN, 110G13, and complex alloy types 30KhGS. The Aktobe Rail and Beam Plant LLP is an enterprise producing rolled products.

The output of the Qarmet JSC, the largest manufacturer in the RK market, is presented below (Table 1).

The monopolist in the steel market in Kazakhstan, the Qarmet JSC, produces along with such steel grades as ST08, ST3, ST20, reinforcing steel grade 35GS (5 mm and 10 mm), an extremely insignificant volume of low-alloy steel grades 09G2S, 17G1SU, 08YuR, 30KhN2M.

If to consider the volumes of production of metallurgical industry products in Kazakhstan by regions, it can be noted that the largest volume belongs to the Karaganda region, the Pavlodar and the East Kazakhstan regions,

**Table 1 – Range of products manufactured by the Qarmet JSC**

Products	Material	Dimensions	Amount, kg
Hot rolled flat products	Alloy steel 09G2S without coating	Sheet 10,00*1500*6000 MM	30690 (4 pallets)
Hot rolled flat products	Alloy steel 09G2S without coating	8,00*1500*6000 MM	31120 (4 pallets)
Hot rolled thick sheet products	Alloy steel 09G2S	10,0*1500*6000 MM	30690 (4 pallets)
Hot rolled products	Alloy steel 09G2S without coating	8,00*1500*6000 MM	38590 (5 pallets)
Hot rolled products	Alloy steel 09G2S without coating	5,00*1500*6000 MM	22410 (3 pallets)
Hot rolled products	Alloy steel 09G2S in coils, the silicon content from 0,60% to 0,63%	5*1250 MM	8 coils
Hot rolled thick products	Alloy steel 09G2S	5,00*1500*6000 MM	22410 (3 pallets)

which together make up about 80% of the total volume of production of the country's metallurgical industry [2].

### Research methods

To determine the current state and development prospects of the steel products market, comparative, information and graphical analysis methods, laboratory work, statistical analysis were used.

The analysis of the dynamics of the global steel market includes taking into account the effect of such factors as economic conditions, industry trends and technological advances that affect the supply and demand of the manufacturing industries.

Current trends in the special alloy steel market that manufacturers will face include the following:

- active implementing of advanced technologies to improve the qualities of special steel, making it more efficient, lightweight and sustainable for a wide range of applications;
- a growing trend towards the use of lightweight materials, as environmental sustainability and fuel efficiency are becoming increasingly important factors;
- increasing demand for special steel grades due to the growing need for materials with high strength, heat resistance and corrosion resistance;
- industries with special needs, such as

electronics, healthcare, space, defense, are expected to require customized formulations of high-quality steel.

Monitoring the global steel market shows that more than six million people are employed in ferrous metallurgy enterprises worldwide. For every 2 jobs in the steel sector, there are another 13 jobs in related industries that are the main consumers of steel (mechanical engineering, automotive industry, construction, etc.). Steel smelting is a low-waste production, since more than 96% of raw materials are converted into primary and secondary products [3]. To assess the prospects for the development of the industry, the analysis of the state and development of the global metallurgy market was carried out.

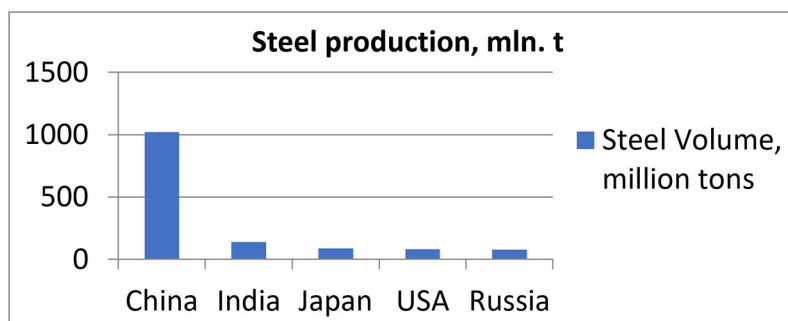
Table 2 presents the data on the volume of steel production by 5 countries that were top leaders among 71 countries in 2023. China ranks first, with the figure remaining the same as in 2022, at 1 019,1 million tons. In India that ranks next in the ranking of leaders, production reached 140,2 million tons, and in Japan 87 million tons. In 2023, the United States increased steel production from 80,5 million to 80,7 million tons in annual terms (Figure 1) [4].

It is obvious that, according to experts, the same current industry leaders will remain the world leaders in steel production in 2024 [4].

Current trends in the development of the

**Table 2 – Steel production in 2023**

Leading countries-steel producers	Steel production in mln. t
China	1019,1
India	140,2
Japan	87
USA	80,7
Russia	75,8



**Figure 1 – Steel production in 2023 in leading producing countries**

global steel market allow concluding that production of high-strength alloy steels is particularly developing among promising steel grades. For example, the share of these types of steel in the automotive industry is increasing. If in 2000 the share of high-strength steels in the automotive industry was only 13%, then in 2010 it was already 31%, and in 2020 this share exceeded 35%.

In the production of the latest car models, the share of high-strength steels is already significantly higher. Thus, at the Volkswagen plant, the share of high-strength steels in the production of the sixth Golf model is 66%, and in the production of the new seventh model it has already reached 80%, of which 28% are ultra-high-strength steels [5].

A 20% reduction in the cost of the new product was made possible by reducing the amount of expensive chromium and nickel used in the production of conventional stainless steel by 40% [6].

Complex alloying has become widespread abroad.

Alloy steels play the key role in industry. Large manufacturers not only dictate the market development trends but also set quality standards. A look at the TOP-20 global and Russian enterprises in this area allows us to better understand the dynamics and main trends of this important segment of the global

economy [7-8]. Table 3 presents data on some enterprises from this register.

The dynamics of demand for steel industry products significantly depends on the macro-economic situation. An economic downturn or recovery is always accompanied by decreasing or increasing the volume of new industrial, commercial, housing, railway construction, a reduction or increase in the production and sales of engineering products and other industries. By 2050, the world population is expected to increase by 2,7 billion people. The growth of the world population will be accompanied by its urbanization. In this regard, the need for buildings and infrastructure will increase, which, in turn, will lead to an increase in the need for high-quality durable steel [9, 10].

According to the International Organization of Automobile Manufacturers, 95,6 million cars were produced in 2018. On average, about 900 kg of steel is consumed per vehicle. At the same time, improved high-strength steel grades are used for the production of cars. They allow car manufacturers reducing the weight of a car by 25-40% compared to conventional steel (170-270 kg) and providing savings of 3 to 4,5 tons of greenhouse gases over the life cycle of a car [3, 11].

The structure of the range of products exported by Kazakhstan companies still has a raw materials focus. However, it continues to

**Table 3 – TOP-20 enterprises that produce special steels [8]**

No	Enterprise	Output per year	Enterprise profile in steel production
1	ArcelorMittal, India	90 mil. t	special steels, including automotive, marine and energy steels
2	Nippon Steel & Sumitomo Metal Corporation, Japan	49 mil. t	stainless and high-strength steels for aircraft, automotive and construction
3	Hebei Iron and Steel Group, China	47,8 mil. t	high-strength steels for construction and industry
4	Novolipetsk metallurgical plant OJSC, RF	17 mil. t	steel for the automotive and construction industrie
5	Severstal OJSC, RF	11,8 mil. t	steel for construction, automotive and shipbuilding
6	Baosteel Group, China	43 mil. t	high-quality steels for the automotive and construction industries
7	Wuhan Iron and Steel Group, China	30 mil. t	steels for heavy engineering
8	Posco, Korea	37,5 mil. t	construction, pipes, energy
9	Jiangsu Shagang, China	34,2 mil. t	steel for the automotive and energy industries
10	Tata Steel, India	28,5 mil. t	steels for construction, automotive and shipbuilding industries of household appliances
11	JFE Holdings, Japan	30 mil. t	automotive steels and steels for pipe production

be in demand on the external market, since it meets the need for semi-finished products and primary types of rolled products [9, 12].

Figure 2 shows a comparative diagram of the world market (average indicator for leading countries according to Table 3) and the Kazakhstan market, showing the share of complex alloy steels in the total volume of steel produced.

In this case, complex alloy steels mean steels alloyed with more than one element and having different effects on the formation of  $\alpha$ - and  $\gamma$ -regions.

In this Figure it is seen that, if the world market of leading steel producers is dominated by the production of alloyed and high-alloyed steels, then the market of Kazakhstan is mainly dominated by the share of carbon steels. This fact is explained by the fact that the main steel producer in Kazakhstan is the Qarmet JSC, which has only converter furnaces designed for smelting carbon and low-alloyed steels. The share of the other producers in the total amount of steel produced is small.

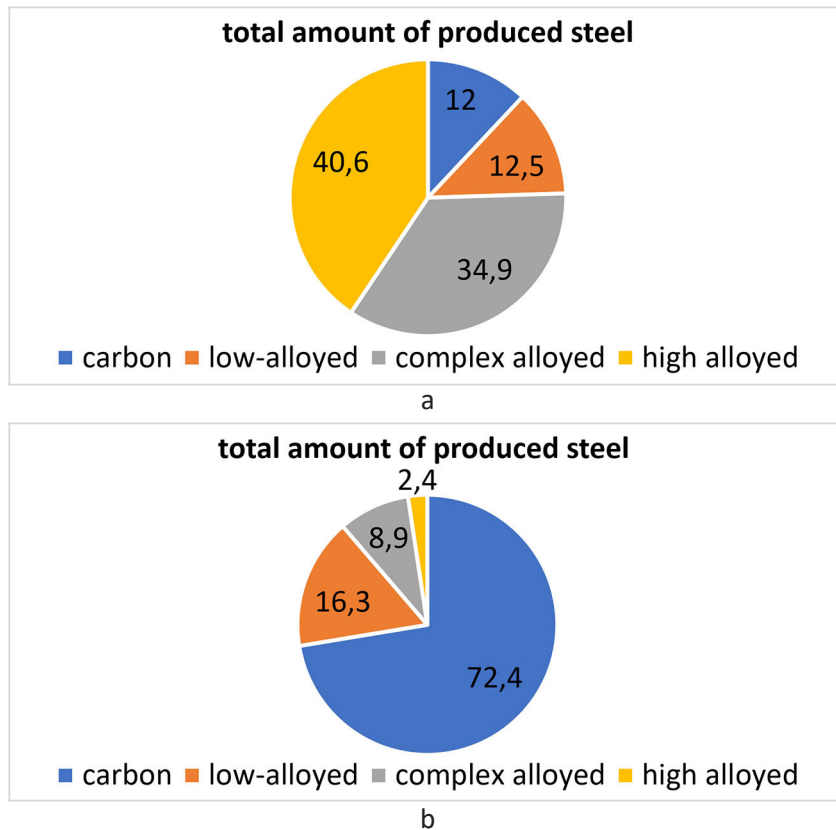
**Scientific results**

Based on the data of monitoring the world and domestic alloy steel market, the current

state of metallurgical enterprises of Kazakhstan, their technical equipment and technological capabilities for the production of complex alloy steels, as a modern direction in the field of improving the quality of cast blanks from complex alloy steels, it seems advisable to control the structure during the primary crystallization period using different processing methods, such as vibration, ultrasound, etc. [13-14].

With directional crystallization, controlling the cooling rate, modifiers are introduced in combination with the use of additional effects on the structure. This ensures high performance properties of complex alloy steel. The development of this area is caused by the fact that the other possibilities for improving properties (alloying, heat treatment, ingot modification, etc.) have almost exhausted their capabilities.

Thus, the use of modification-type processing is a good alternative for improving the properties of complex alloy steel compared to changing the composition of the steel. Steel grade 40KhN3MF was chosen as the subject of the study among various grades of complex alloy steels.



**Figure 2 – Comparative diagram of the shares of produced steel:  
a – world market; b – Kazakhstan market**

### Conclusions

1. Monitoring of the steel market shows that the world market of leading steel producers is dominated by the production of high-alloyed steels.

2. The metallurgical industry of the Republic of Kazakhstan is in dire need of developing production of alloy steels with improved performance properties for sustainable economic development. Currently, the metallurgical industry of the Republic of Kazakhstan does not have the basic means for developing production of alloy steels (electric arc/induction furnaces). In this regard, the most appropriate at this stage seems to be improving the properties of the already produced range of alloy steels, including various types of processing.

3. Based on the analysis, the object of re-

search was determined: steel grade 40KhN3MF. Steels of this class were chosen due to the following circumstances:

- steel of this class is widely used for producing parts for mining and metallurgical production, since it has a unique set of strength and ductile properties;

- steel is included in the range of smelted steels at many enterprises of the Republic of Kazakhstan. This means that implementing the developed technology will not require significant investments and changes in process regulations.

*This research was funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan, grant number BR24993020.*

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**Әлемдік және отандық болат нарығының мониторингі негізінде Қазақстанда күрделі қоспаланған болаттардың өндірісі мен қолданылуын талдау**

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**Аңдатпа.** Мақалада әлемде де, Қазақстанда да өндірілетін күрделі қоспаланған болаттар нарығына талдау берілген. Күрделі қоспаланған болаттардың қасиеттерін жетілдірудің әлемдік тенденцияларына ерекше назар аударылады. Экономиканың әртүрлі салаларында бәсекеге қабілетті өнім шығарудың жаңа шындықтары тұрғысынан күрделі қоспаланған болаттар өндірісінің ұлғаюына әсер ететін факторлар атап өтілді. Бұл болаттарды пайдаланудың негізгі бағыттары көрсетілген. Болат нарығына жүргізілген мониторинг негізінде зерттеудің мақсаты отандық өнеркәсіпке қажет күрделі қоспаланған болаттардың маркаларын айқындау және Қазақстанның металлургиялық зауыттарында осы болаттарды өндірудің технологиялық мүмкіндіктерін негіздеу болып табылады. Осындай болаттардың бір маркасының ұсынысы ретінде 40ХНЗМФ типті болат анықталды.

**Кілт сөздер:** металлургия өнеркәсібі, мониторинг, легирленген болат, бәсекеге қабілеттілік, микроқұрылым, модификация, қасиеттері, практикалық қолданылуы.

**Анализ производства и применения сложнелегированных сталей в Казахстане на основе мониторинга мирового и отечественного рынка стали**

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**Аннотация.** В статье дан анализ рынка сложнелегированных сталей, производимых как в мире, так и в Казахстане. Особое внимание уделено мировым тенденциям совершенствования свойств сложнелегированных сталей. Отмечены факторы, оказывающие влияние на увеличение производства сложнелегированных сталей с позиции новых реалий выпуска конкурентоспособной продукции в различных отраслях экономики. Выделены основные направления использования этих сталей. Целью исследования на основе проведенного мониторинга рынка стали являются определение марок сложнелегированных сталей, в которых нуждается отечественная промышленность, и обоснование технологических возможностей производства этих сталей на металлургических заводах Казахстана. В качестве рекомендации одной из марок таких сталей определена сталь типа 40ХНЗМФ.

**Ключевые слова:** металлургическая промышленность, мониторинг, легированная сталь, конкурентоспособность, микроструктура, модификация, свойства, практическая применимость.

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