# NEW TRENDS IN TECHNOLOGY OF FeSiAl – «KAZAKHSTANSKYI» ALLOY

N.A. Nazarbaev

President of the Republic of Kazakhstan

## ABSTRACT

*It is noted that there remains a steady interest in production and using of new complex ferroalloy - ferrosilicoaluminum («Kazakhstanskyi» alloy) produced by a single-stage slag-free carbothermal method. Due to the increasing demand for ferrosilicoaluminum there are plans to build plants in Karaganda (Karaganda plant of complex ferroalloys) in the territory of Special Economic Zone «Sary-Arka» and in Tash-Kumyr (Kyrgyz Republic). Development of production technologies for complex ferroalloys containing Al, Si, Mn and Cr is beneficial in terms of combining the processes of smelting secondary aluminum, ferromanganese, ferrochrome and ferrosilicon together.*

***KEYWORDS:*** *Complex alloys, carbothermal, SAF, steelmaking.*

Modern steelmaking is based on consumption of standard grades of ferroalloys, secondary aluminum, and their mechanical mixtures. The standards and requirements for a number of basic ferroalloys were developed in the 70-80th years of the last century and remain practically unchanged since the early 90th.

Production of common ferroalloys is based on consumption of rich mono-mineral concentrates (e.g., chrome, manganese, nickel, ilmenite, etc.). Reserves of such minerals are steadily depleting, while the demand grows, matching increased steel production (forecasted global production reaches 2 billion tons per year). Depletion and degradation of rich ores creates global trend in increasing cost of production of basic ferroalloys. Given such conditions, the ferroalloy industry of Kazakhstan, currently holding noticeable position in the global ferroalloy production (annual capacity 1.4 million tons), can be displaced over time by more dynamically developing countries producing ferroalloys (China, South Africa and others).

Kazakhstan scientists of the National Center on Integrated Processing of Minerals (NC CPMRM) are developing a new direction in ferroalloy production oriented to production of new types of ferroalloys from subgrade raw materials and industrial wastes, such as high-ash coal, coaly rocks, substandard ores and dumping slags.

Most noticeable distinctions of these ferroalloys are:

1. Presence of several active components (silicon, aluminum, manganese, chromium, etc.) significantly increases their combined deoxidizing and alloying effect. It ensures a deeper deoxidizing of steel or better reduction of elements during metallothermy.
2. Higher density and lower melting point of such ferroalloys in contrast to aluminum and silicon ferroalloys promote more complete absorption in liquid steel during deoxidation.
3. Use of high-ash coals or coaly rocks and subgrade ores as raw materials considerably reduces their production cost and allows to expand the mineral resources base of ferroalloy production.
4. Development of complex ferroalloys production in Kazakhstan allows to organize production of highly-active deoxidizers such as barium and calcium that are not produced in the Republic at the moment.

Complex alloys are sufficiently uniform in chemical composition, have relatively low melting temperature and high density, which promotes faster and complete absorption in metal during deoxidation. At the same time combined use of several elements greatly increases their deoxidizing ability due to formation of fusible oxide inclusions, easily coalescing and floating.

Ferrosilicon and aluminum are often used in steelmaking in the form of mechanical mixture.

Smelting of these ferroalloys requires deficit materials: quartz, metal shavings, bauxite and others. At the same time their production technologies are energy intensive and involve costly presmelting preparation. For example, energy consumption for smelting of aluminum and ferrosilicon FS75 is 8-10 MWt·h 15-20 MWt·h per 1 ton of product, respectively.

Since the deoxidation of steel is done with mechanical mixture of ferrosilicon and aluminum, a significant share of Si and Al is oxidized on the surface of liquid steel with low efficiency. This problem has led to the search for effective and cheap ways to process industrial waste (coal ash, tailings of coal mining and cleaning, etc.) into the alloy of FeSi and Al with composition similar to that of mixture used in steelmaking. Availability of such alloy along with its low cost would ensure low loss of aluminum and silicon, deeper refining of steel from nonmetallic inclusions, because interaction of fused ferrosilicon and aluminum with oxygen in the liquid steel results in formation of low-melt aluminosilicates. Use of ferrosilicon and aluminum, on the contrary, leads to formation of refractory inclusions (silica and corundum) that are hard to remove from the steel.

According to steelmaking requirements new alloy should contain: 50-60% Si, 15-25% Al.

Multicomponent ferroalloys can be divided into two groups:

1. Standard or bulk – widespread and produced on a commercial scale (ferrosilicon manganese, silicochrome, silicocalcium and ferrosilicon with barium).

2. Non-standard - ferrosilicoaluminum, alumosilicomanganese (alloy AMS), alloy ACS (aluminum-chrome-silicon), alloy CAMS (calcium-aluminum-manganese-silicon), etc., produced in small batches by fusion of pure metals. These group of alloys is not widespread in the industry due to high cost and absence on smelting technology.

Complex ferroalloys of second group are less prevalent, except ferrosilicoaluminum and alumosilicomanganese that are produced in small volumes by fusion of secondary aluminum, ferrosilicon and ferromanganese. However, there are good prospects of distribution, provided their cost reduction by means of e.g. implementation of single-stage slag-free carbothermal smelting from low-quality raw materials and or/and industrial wastes. Unlike for common ferroalloys production, where resources base may be depleted in the coming decades, the resource base will be available for tens or even hundreds of years.

However, such large industrial enterprises, as Aksu Ferroalloy Plant (who served in the Soviet period second place in the world by ferroalloy production after Nikopol Plant) now prefer to melt bulk ferroalloys (ferrochrome, ferrosilicon and silicomanganese), with annual capacity reaching 1 million tons. Therefore producing of complex ferroalloys is more promising direction for smaller plants and will contribute to development of medium-sized steel enterprises requiring comparatively small investments.

At present, a steady interest towards production and application of complex ferroalloy - ferrosilicoaluminium (FSA) is observed. Russia, Kazakhstan, Georgia and Ukraine are working on the creation of technology of single-stage carbothermal smelting of FeSiAl. Until recently, the alloys of this composition not produced globally by direct carbothermal smelting . The reason for this was very low performance of all tested methods for SAFs which is in turn caused by uncertainty of nature of the processes occurring in system Fe-Si-Al-OC in high-temperature conditions.

Currently, ferrosilicoaluminum (alloy «Kazakhstanskyi») is produced in Kazakhstan in Ekibastuz (AiK Ltd. and FSA-group Ltd.) with annual capacity of 2-3 thousand tons [1].

Due to the increasing demand for FSA a new project was initiated in Karaganda (Karaganda plant of complex ferroalloys - KZKS). New plant will consist of four 45 MVA submerged arc furnaces. The project is currently under design, special electricity tariffs are approved. Located on the territory of Special economic zone «Sary-Arka», the project is subject to tax and customs preferential for the next 20 years. Furnaces will be supplied and installed by SMS Siemag AG (Germany).

In March 2011, construction of a new plant for «Kazakhstanskyi» alloy production was begun in Tash-Kumyr, the Republic of Kyrgyzstan. Planned capacity of new plant is 50 000 tons per year. The founders of plant are the Republican State Enterprise "National Center on Complex Processing of Mineral Raw Materials" and the International Corporation of Metal and Alloy Development.

Approximate consumption of ferrosilicoaluminum for steel and cast iron making, production of explosives and other fields exceeds 3 million tons per year, including 1.25 million tons in China, 400 tons in the CIS countries (Kazakhstan more than 100 thousand tons per year). Foreign customers - steel producers (Germany, Turkey and Japan) and magnesium metal (Korea) are interested in purchasing bulk amounts of FeSiAl.

Another interesting application for FeSiAl is production of energy-accumulating materials (EAM). The necessity of long-distance energy transportation and long-term and safe storage leads to a problem of energy preservation. One of possible and promising solutions is storing energy in solid state in the form of EAM.

Synthetic or non-fossil kinds of fuel including hydrogen is going to become inevitable and vital problem in the future due to the gradual depletion of the fossil fuel. Scientific and technological progress would allow wider use of nuclear (water splitting and nuclear fusion), solar (in direct and indirect forms the latter includes wind and wave power) and geothermal energy sources. Energy can be used directly in the form of electricity but its storage and transportation represent a problem.

Energy can be stored and transported as gases of which hydrogen has highest energy capacity. There are several ways of hydrogen production such as electrochemical methods, solid and liquid fuel gasification, water steam recovery, etc.

Consumption of hydrogen in its usual fields of use (metallurgy, transport, chemical technology) is growing steadily and currently reaches $80\text{-}100 \cdot 10^6$ tons per year. Traditional ways of hydrogen mass production, such as thermochemical decomposition with electrolysis and photolysis, photocatalytic and microbiological water decomposition are expensive, ineffective and sometimes dangerous.

It is known that metal hydrides have highest hydrogen yield but expensiveness and risk of explosions and fire limit their use severely.

Recent researches by Kazakhstan scientists confirm that FeSiAl can be considered one of efficient kinds of EAM. FeSiAl containing 25-30% of aluminum and 55-65 % of silicon is suitable for decomposition of water in alkaline medium with subsequent emission of hydrogen. The end products of interaction are pure oxides or hydroxides of aluminum and silicon that can easily find application in chemical industry.

After certain treatment such alloys evolve large quantities of hydrogen. The hydrogen combustion product is water, which is environmentally friendly substance.

The chemistry of hydrogen emission from FSA is concluded in the following: in usual conditions silicon and aluminium show weak interaction with water and water steam and can be oxidized by the latter only at high temperature. It is caused by the passivating film formation on the surface of metal ($SiO_2$, Si-O-Si, Si-O, $Al_2O_3$). During the interaction with alkaline solution (KOH, NaOH) the film dissolves resulting in intensive interaction accompanied by hydrogen emission.

Unlike hydrides, FeSiAl is stable under any environmental conditions, has long shelf life in lumps and is fire-safe. Use of FSA in mobile devices and in transport can reduce the energy cost.

Production of complex ferroalloys – one of the most promising trends in mining and metallurgical industry of the Republic of Kazakhstan as it offers complex resolution of a number of crucial issues:

- utilization of great amounts of industrial wastes (coaly rocks, poor and off-grade ores, dump slags, ore dressing tailings) accumulated by present;
- simplification of existing ferroalloys production schemes accompanied by loss of valuable elements;
- energy saving and increasing the efficiency of production and processing compared to conventional technologies;
- obtaining materials with unique properties (due to the combined action of several components or precisely selected composition) for steelmaking complex and related industries.

Organization of production complex ferroalloys for the Republic of Kazakhstan is particularly relevant because there are all necessary conditions:

- Availability of necessary mineral resources which are often not suitable for ferroalloys smelting by known methods;
- Availability of scientific developments and specialists with extensive experience in the field;

- High competitiveness of developed technologies and new alloys;
- Availability of interested consumers for products;
- Availability of domestic sales market and unexplored global market.

One of the decisive factors strengthening the necessity of complex ferroalloys production is the availability of efficient technologies along with experience in their implementation.

Implementation of described projects on new alloys production has strong social effect as it will create thousands of new workplaces both in metallurgical and mining enterprises in steel companies and in mining companies.

Development of this direction in ferroalloy industry will ensure the competitiveness of products, increase the export potential of the country and become an innovative achievement in the field of ferrous metallurgy in Kazakhstan.

## REFERENCES

1. Patent19649. Alloy «Kazakhstanslyi» for deoxidation and alloying of steel, N. Nazarbaev, V. Schkolnik, A. Zharmenov et.al., published 16.06.2008, bull. No. 6 – 5 p.