UDC 541.118; 546.8

METALLOGRAPHIC ANALYSIS OF CARBON STEEL USING INTEGRATED FERROALLOYS

A.Kh. Nurumgaliev[1]**, A.R. Toleuova**[2]**, F.Zh. Bekkulina**[3]
[1] Doctor of Technical Sciences, Professor, Head of the Laboratory,
[2] PhD, engineer of the highest category,
[3] Master of Science, Engineer of the Highest Category
RSE on the basis of economic control rights Karaganda State Industrial University (Temirtau), Kazakhstan

Abstract*. The article suggests microstructure analysis of steel prototypes using the new integrated ferroalloys and considers impurities and nonmetallic inclusions, their influence on the structure and properties of the steel. The authors presented metallographic evaluation of steel prototypes.*

Keywords*: complex ferroalloys, deoxidizing, alloying, microstructure, properties*.

In recent years, in the world a clear tendency was designated to identify different methods for determining the properties of ferro-alloys, influencing the choice of rational structure. Some researchers choose the effect on the quality and characteristics of processed metal as the main criterion for optimizing the composition of the alloy, without taking into account the technological features of preparation and application properties of the alloy. The new integrated approaches to the definition of rational composition of ferroalloys are being developed now. They allow to consider in detail its characteristics and interact with the melt and more reasonably select elements and their ratio in the alloy [1].

In modern conditions the chemical composition of ferroalloys are strictly limited by State Standards or specifications. This creates the possibility of limiting use of different types of raw materials (often do not allow to use more affordable and cheap raw materials), and in some cases leads to a deterioration of consumer properties of ferroalloys.

To have a high content of the master element in ferroalloy in conventional general trends in some cases is advisable to change the composition including in the direction of reducing the content of the master element. This position is supported by studies of a large group of ferroalloys (molybdenum, tungsten, boron, aluminum, chromium alloys, etc.) [2].

The foreign plants in recent years use brands of high carbon ferrochrome with low chromium content, that is so-called "Charg crome" in addition to high-grade ferrochrome. This ferrochrome includes, %: > 45 Cr; 3-10 Si.

1. Effect of individual components on the properties of steel

The development and definition of rational structures of complex ferroalloys, allowing to give a full consideration of their characteristics and interaction with the melt processed, require more reasonably to choose each alloying element to take into account its impact on the structure and properties of the alloy. In our case, we analyzed the effect of manganese, silicon, aluminum, chromium and barium on the structure and properties of carbon steel 08KP and 08ps.

Alloying elements are introduced into the steel to increase its structural strength. The main structural component of the carbon steel is a ferrite structure occupying not less than 90 % by volume. Alloying elements reinforce the ferrite dissolving in it. Hardness of the ferrite (in the state after normalization) is most strongly increased by silicon, manganese and nickel - the elements with lattice that differs from the lattice α - Fe. Molybdenum, tungsten and chromium have a weaker effect.

Many of alloying elements solidifying the ferrite and having little effect on the ductility, reduce its toughness (except nickel). When the content is up to 1 %, manganese and chromium increase the toughness. Above this content, the toughness decreases after reaching the level of undoped ferrite with 3 % Cr and 1,5 % Mn.

Increasing the carbon content enhances the impact of the carbide phase which dispersion depends on the thermal treatment and the alloy composition. Largely the increase of steel hardenability contributes the increase of the structural strength at the steel alloying. The best result in improving of steel hardenability can be achieved by doping with several elements, such as chromium + molybdenum, chromium + nickel, chromium + nickel + molybdenum, and other combinations of different elements.

High structural strength steel is provided by rational content of alloying elements in it. Excess alloying (except for nickel) after achieving the necessary hardenability leads to reduction of the viscosity and facilitate brittle fracture of the steel.

Aluminium is used to remove oxygen and has an effect of increasing the strength and toughness. The high content of aluminum is the cause of congestion attachments in the manufacture of continuous casting.

Aluminum has also an effect of grain size reduction and it is the main alloying element of nitrided steel. In some types of microalloyed steel aluminum is used as the alloying element as nitride and carbonitride forming.

Chromium is the main alloying element of stainless steel. Chromium steel provides resistance to oxidation and corrosion processes. It increases the ability to calcination; it increases the wear resistance in the high-carbon steel. Chromium with carbon compound form $Cr_{23}C_6$, located at the grain boundaries. The formed compound reduces the ultimate level of the corrosion resistance of stainless steel up to 12 %. This compound is easily obtained due to acceleration of carbon spread at high temperatures and causes weld defects near welds, performed in the welded stainless steel.

Chrome has a beneficial effect on the mechanical properties of structural steel. It is introduced into the steel in an amount of up to 2 %, it is dissolved in the ferrite and cementite [3].

Manganese as a carbon is an element that already presents in the microstructure of the steel during manufacture and it has an effect of increasing the strength of steel. At the same time, it increase the ability to the hardness and weldability, it is a key element for the process of ausforminga. The most important is the ability of manganese to form compounds with sulfur MnS and prevent the formation of the iron-sulfur FeS. The compound FeS is causing brittleness. Manganese is introduced into the steel up to 1,5 %, it is distributed between ferrite and cementite. Manganese significantly increases the yield strength of steel, but it makes the steel susceptible to overheating. In this regard, carbide-forming elements are introduced in steel with manganese for grain refinement.

Thus, to determine the rational structures of ferroalloys it is necessary to use an integrated approach, allowing to give a full consideration of its characteristics and interact with the processed melt. To improve the stability and the degree of assimilation of the leading elements of the melt ferroalloys, in some cases, it is advisable to reduce the lead content of the element in the alloy, allowing significant differences of chemical compositions of ferroalloys from the existing requirements of the State Standards.

2. Experimental Procedure

2.1 Preparation of the alloys and samples for research.

Series of experiments on the use of silica-alumino-manganese, silica-alyumino-barium and silico-alumino-chromium as complex reductants for carbon steels was carried out on the basis of Karaganda State Industrial University (Laboratory of "Metallurgy and Materials Engineering" Department).

In accordance with the process of steelmaking instruction TI 38005 the calculation of the required number of complex ferroalloys, coke and aluminum wire, according to the weight of metal, assimilation of elements was made to obtain a desired steel composition [4]. Calculating the composition of the charge degree of intoxication for the major alloying elements was taken into account: silicon waste is 10–15%; barium – 50 %; aluminum – 50 % [5].

For the treatment of ferroalloys, the samples steel were placed in a corundum crucible and they were heated slowly. After the molten steel at 1600 ^{o}C ferroalloys were added through an alumina tube in the center of boiling metal complex. The liquid metal was held for no more than 7–8 minutes. Preparation to macrosection (of templates) began after cooling and crystallization.

The chemical composition of complex ferroalloys for steel deoxidation of 08ps is listed in Table 1.

Table 1

The chemical composition of complex ferroalloys

Type of steel	Comprehensive deoxidizer	Chemical elements, %								
		Cr	Al	Si	Fe	Mn	Ba	P	S	C
08PS	Si – Al – Cr	9,29	15,8	59,3	14,2	-	-	0,134	0,033	0,4
08PS	Si – Al – Mn	-	14,5	21,6	12,7	27,0	-	0,092	0,035	0,38
08PS	Si – Al – Ba	-	8,50	45,5	20,7	-	13,6	-	-	0,45

The study of the microstructure was performed on the Leica optical microscope. The microstructure was investigated on specially prepared microsections. The preparation of microsections was carried out in the following sequence: tenderloin of templates from the study area of the blank; grinding of a flat surface of the sample; polishing the sample plane; etching; study of the microstructure. Clipping of templates was carried out on the cutting machine Labotom-3 of the company Struers (Switzerland). In the process of cutting sample and cutting disc were cooled with water with a special lubricant that would prevent from oxidation of the sample.

Grinding and polishing were carried out on the machine TegraForce / TegraPol of the Struers firm (Switzerland) by the standard method for steel materials. When grinding special wheels on magnetic base coolants firm Struers were used. After grinding, the sample was finely polished to remove any remaining small defects after sanding, scratches, etc.

The samples were etched on optical microscope for studying. Rzheshotarsky reagent was used as an etchant for steel materials (solution of 4 % of nitric acid in alcohol).

2.2 Analysis of the microstructure of the samples

In the analysis of the microstructure samples in the optical microscope Leica microscope was used. Magnification was x100, x200, x500 and x1000 fold. All samples were examined in the bright field. The study of the microstructure under an optical microscope allowed to identify various structural elements, colored by etching in different colors, sizes and location of the character of phase components. Studying ща microsections in non- etching condition let to evaluate the distribution of inclusions in the cross section of the sample and their shape.

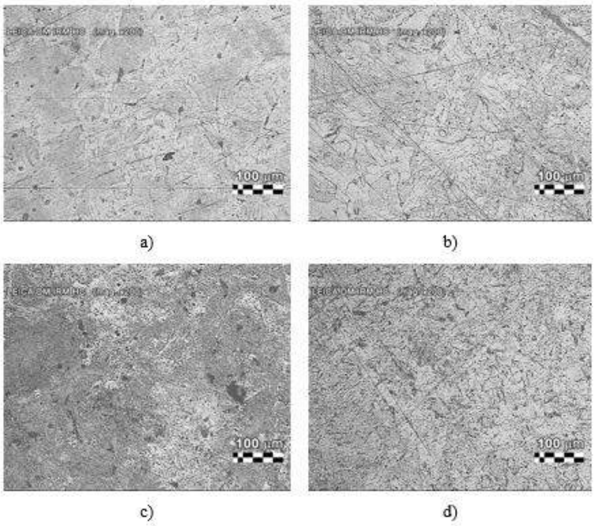

Fig. 1. Moulded alloy structure, x200

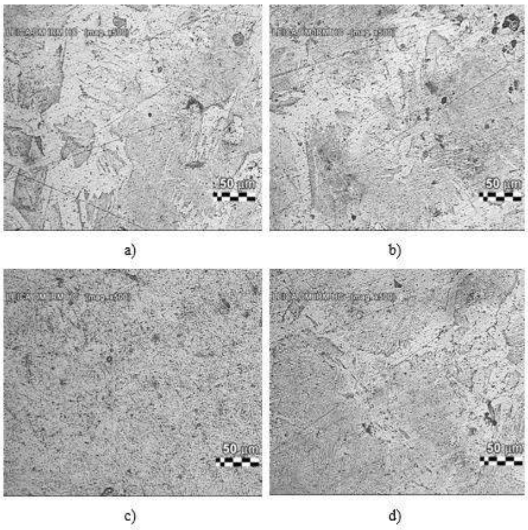

Fig. 2. Moulded grain structure in the area of large equiaxed crystals, x500

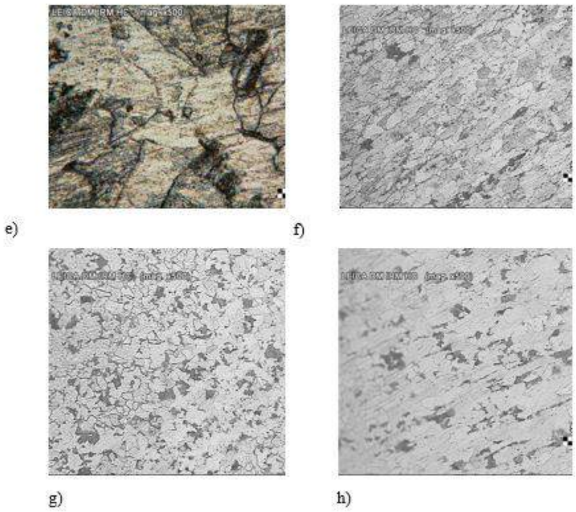

Fig. 3. Microstructure of steel 08ps, deoxidized by FeSiAlMn

Figure 2 demonstrates the conventional carbon steel deoxidized by ferro-silico-alumino-chrome, it has a cast structure with large equiaxed crystals. Upon further cooling of the sample after complete solidification the primary grain structure formes, which is revealed by etching with 4 % acid in alcohol. This structure is a widemanstatten ferrite decorated with cast grain on the bounds with ferrite allotriomorphic grid. We can see that the grain when moving from the edge of the ingot varies considerably from large elongated grains of transcrystallization area whose boundaries extend beyond the sample up to equiaxial grains in their center.

Addition of ferro-silico-alumino-manganese to 08ps steel ensures the formation of ferrite-pearlite structure (Figure 3, e-h). The structure of the melted brand samples 08ps present grains of pearlite and ferrite. Ferrite grains are painted in a light color and pearlite in the dark. Perlite is a plate type, i.e. alternating layers of ferrite and cementite, which orientation means that they represent a single whole grain.

The structure consists of a mechanical mixture of pearlite and ferrite. Ferrite and pearlite cementite layers of grain are converted into fine grains of ferrite and cementite, respectively.

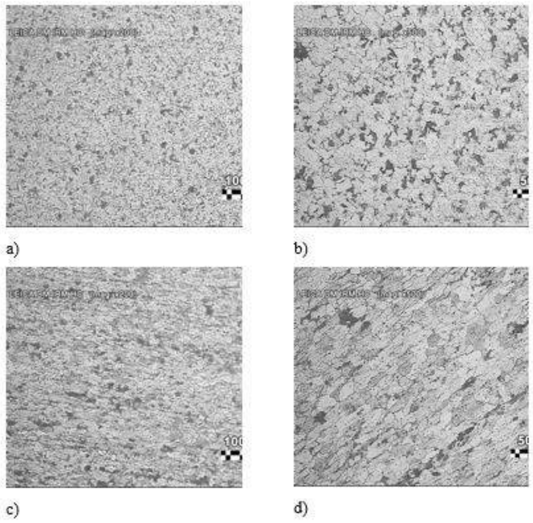

Fig. 4. Microstructure of steel 08ps: a–b) transverse direction, x200, x500; c–d) longitudinal direction, x200, x500

Alloying of ferrite is accompanied by hardening. Manganese and chromium affect most significantly on its strength. Moreover, the smaller the ferrite grains, the higher the strength. Many alloying elements contribute to grain refinement of ferrite and pearlite in the steel, which considerably increases the toughness of the steel. Alloyed paramagnetic austenite has a large coefficient of thermal expansion. Alloyed austenite is the main component of many corrosion-resistant and non-magnetic alloys. He quickly and strongly hardened under the influence of cold deformation.

Alloying elements improving the stability of austenite, reduce the critical speed of hardening and hardenability. For many austenitic alloys critical speed of hardening is reduced to 20 °C/s or lower, which is of great practical importance.

Carbide forming elements: Fe – Mn – Cr – Mo – W – Nb – V – Zr – Ti (except manganese) inhibit austenite grain growth during heating. Steels alloyed with these elements, at the same temperature retains a higher dispersion of carbide particles and correspondingly higher strength.

Conclusions:

– Methods of quantitative metallography helped to investigate dispersion and density of dendritic structure of conventional carbon steels deoxidized by FeSiAlCr, FeSiAlMn. It is shown that the dispersion and the density of the sample in different structural zones differ from each other. The heterogeneity of the dendritic structure reflects its corresponding chemical heterogeneity across the sample.

– The absence of a clear correspondence between the visual and the cast dendritic grain structure is demonstrated. Primary and secondary dendrite axes arranged irrespective border or grain cast body: several dendritic axis may intersect one or more of cast grains.

– It has been established that the ferrite is formed on the most "dirty" areas of interdendritic space solidified last, then the body has grain segregation on widemanstatten ferrite formed from dendrites of the axes, and the boundaries of the cast grain decorated with allotriomorphic ferrite formed by interdendritic space with moderate amounts of segregation. The last ones were formed from interdendritic space of an earlier stage of solidification, presumably between the axes of the second order.

– It has been established that the axes of the dendrites formed on the mechanism of cellular growth are inhomogeneous in their structure.

The determining the rational structures of ferroalloys requires an integrated approach, allowing full consideration to its characteristics and interaction with the processed melt. To improve the stability and the degree of assimilation of the leading elements of the melt ferroalloys, in some cases, it is advisable to reduce the lead content of the element in the alloy, allowing for significant differences chemical compositions of ferroalloys from the existing requirements of the State Standards.

The study has showed the feasibility of a reducing ability of complex ferroalloys usage for steel deoxidation. Introduction of these steel alloys, due to their high deoxidizing ability, provides a more complete transfer of dissolved oxygen into the oxide phase. This decreases the amount of inclusions formed during solidification of steel.

СПИСОК ЛИТЕРАТУРЫ

1. Жучков, В. И. Разработка рациональных составов ферросплавов для обработки стали и чугуна / В. И. Жучков, М. И. Гасик, О. Ю. Шешуков Сборник докладов Литейного консилиума № 2 «Теория и практика металлургических процессов при производстве отливок из чёрных сплавов» - Челябинск : Челябинский Дом печати, 2007 – с. 88.
2. Жучков, В. И. Растворение ферросплавов в жидком металле / В. И. Жучков, А. С. Носков, А. Л. Завьялов. – Свердловск: УНЦ АН СССР, 1990. – 134 с.
3. Жучков, В. И. Основные принципы определения оптимального состава ферросплавов / В. И. Жучков // Материалы III Республ. науч. тех. совещ. : Совершенствование технологии марганцевых сплавов – Тбилиси, 1983.– С. 109–114.
4. Друинский, М. И., Жучков, В. И. Получение комплексных ферросплавов из минерального сырья Казахстана / М. И. Друинский, В. И. Жучков // - Алма-Ата : Наука, 1988. – 208 с.
5. Толымбеков, М. Ж. Прямое легирование стали марганцем. / М. Ж. Толымбеков, Т. Д. Такенов, А. Б. Ахметов – Алматы : НИЦ «Ғылым», 2003. – 304 с.

Материал поступил в редакцию 25.11.14.

МЕТАЛЛОГРАФИЧЕСКИЙ АНАЛИЗ УГЛЕРОДИСТЫХ СТАЛЕЙ С ИСПОЛЬЗОВАНИЕМ КОМПЛЕКСНЫХ ФЕРРОСПЛАВОВ

А.Х. Нурумгалиев[1], А.Р. Толеуова[2], Ф.Ж. Беккулина[3]
[1] доктор технических наук, профессор, руководитель лаборатории, [2] PhD, инженер высшей категории,
[3] магистр естественных наук, инженер высшей категории
РГП на ПХВ Карагандинский государственный индустриальный университет (Темиртау), Казахстан

Аннотация. *Проведен микроструктурный анализ опытных образцов стали с использованием новых комплексных ферросплавов. Рассмотрены примеси и неметаллические включения, их влияние на структуру и свойства стали. Дана металлографическая оценка опытных образцов стали.*

Ключевые слова: *комплексные ферросплавы, раскисление, легирование, микроструктура, свойства.*