Conference Paper

Density of Chrome–Nickel Ferroalloys

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Abstract

The density of a new group of chrome–nickel ferroalloys was investigated. Picnometric method was applied for the density measurements of alloys samples. The influence of chromium content on the density was assessed for the alloys containing 10–12% of Ni; 0.2–0.4% of Si; Fe to the balance. It was established that the density values are decreased from 7750 to 7320 kg/m^3 at considered chromium concentration range. These alloys have the density values above optimal one (5000–7000 kg/m^3) and they correspond to a heavy alloys group. Addition of 40.1% silicon against 0.2% to chrome–nickel ferroalloys (10–12% Ni, 26–29% Cr) at constant Cr/Ni ratio causes a sharp decrease of the alloy density from 7670 to 5120 kg/m^3. The alloys with increased silicon content (20–40%) have optimal density values (5000–7000 kg/m^3). The density of the alloys with low silicon content (0.2–13%) are higher than the optimal one. From the obtained data, it was concluded that the efficient way to decrease the density of chrome–nickel ferroalloys up to the optimal values is silicon content increasing up to 20% or higher.

Keywords: metallurgy, complex ferroalloys, physicochemical properties, density, chromium, nickel

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1. Introduction

Density is important physicochemical and structure-sensitive property of the alloys. Degree and stability of digestion of main ferroalloy component as well as melting rate and distribution uniformity in the liquid metal are influenced by the alloy density [1]. If there is no motion in iron-carbon melt, the piece of light-weight ferroalloy come to the surface and undergo severe oxidation (Figure 1). When ferroalloy piece with high-density is added into steel melt, it sinks to the bottom of bucket and dissolves smoothly [2]. Apart from this, the density has great impact on the process of ferroalloys production. Similar density values of alloy and slag causes their weak separation, i.e. slag divides metal in some proportion. This leads to high losses of metal, hence technologies of melting and pouring becomes more complicated [3]. The requirement to such alloys is to have higher density than slag to provide their close-cut separation. According to practice this requirement is fulfilled when the alloy density is 3200 kg/m^3 or higher.

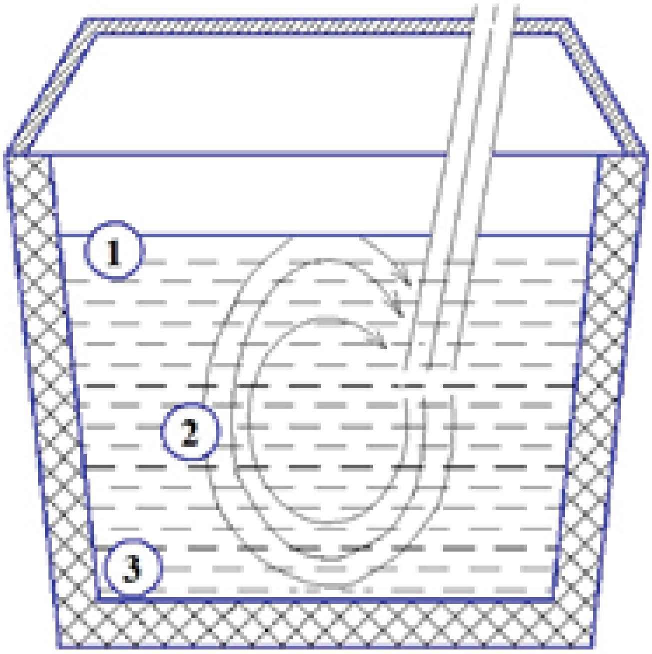

Figure 1: Schematic picture of ferroalloy piece location in iron-carbon melt during pouring in bucket depending on ferroalloy density: 1 – 5000 kg/m^3 or less; 2 – 5000–7000 kg/m^3, 3 – more than 7000 kg/m^3. (Source: Author's own work.)

From the point of view of ferroalloy and steel melt interaction, there are contradictory opinions concerning optimal ferroalloy density. Authors [4] believed that the optimal ferroalloy density should be a bit higher than the density of liquid steel. According to [5, 6] the value of ferroalloy density should be close to steel melt one, otherwise the alloy will be mixed with the slag or sink on the bucket bottom. Authors [7] evidences that "froze" solid steel shell [8] preventing direct contact between ferroalloy and iron-carbon melt enables one to select alloy with lower density than the steel melt density. In the reference [9] in terms of ferroalloy pieces' motion in a bucket the assessment of optimal ferroalloy density was carried out. Using an appropriate hydraulic model, it was found the relationship of the stay probability of a pieces in melt depending on their diameter, and densities ratio of pieces and melt. Optimal values of ferroalloys density were defined for ferroalloy pieces of various diameter. The recommended values of ferroalloys density taking into account the processes of melting, size refinement, oxidation of less dense ferroalloys, and freezing of steel solid shell on the piece surface are 5000–7000 $kg/m^3$for piece fraction of 0.10–0.15 m; 6300–7000 kg/m^3- for 0.05–0.10 m. Thereby, all types of ferroalloys might be divided in the three groups: heavy, optimal, and light-weight (dense). Heavy alloys have the density more 7000 kg/m^3, i.e. higher than the density of melt. Light-weight alloys have the density 5000 kg/m^3 or less, and optimal one is 5000–7000 kg/m^3[10]. The alloys having optimal values of the density are more involved in hydrodynamic motion by steels melt flows in a bucket and as a consequence they have time to become a melt, hence they have the highest digestion degree in iron-carbon melts.

Our research team investigated the Fe-Ni-Cr-Si alloy system, with various chromium and silicon content (Table 1, alloys 1–5 and 2, 6–9, respectively). Topicality of complex chrome-nickel ferroalloy production and their physicochemical properties study was reasoned in number of papers [11–13]. Ferroalloy samples were obtained by synthetic melting of low-carbon ferrochrome - FeCr70C03LP grade (ISO 5448-81), metallic nickel, technical silicon and chemically pure iron.

For theoretical calculation the additive method which takes into account the influence of every component on the density depending on its content was applied. Picnometric method was applied for the density measurements at 23°C [14]. Typically, ferroalloys in solid form are added to the metal melt, hence the data about the solid phase density are the most valuable [15].

The experimental results are presented in Table 1 and Figures 2 and 3.

Table 1: Chemical composition and density of studied ferroalloys.

Alloy numbers	Chemical composition*, %			Density, kg/m3	
	Ni	Cr	Si	Calculated	Experimental
1	11.2	0.5	0.2	7857	7750
2	11.0	27.5	0.2	7672	7540
3	10.8	36.7	0.4	7599	7450
4	9.6	45.6	0.4	7521	7370
5	10.0	55.0	0.2	7476	7320
6	12.2	27.4	5.8	7479	7240
7	11.9	28.7	13.0	7068	7000
8	12.1	26.3	20.4	6678	6450
9	11.7	25.5	40.1	5584	5120
Note: * Iron and admixtures to the balance.					
Source: Author’s own work.					

In the alloys (1–5) the influence of chromium content on the density was assessed. Chromium content in the alloy was changed from 0.54 to 55%. It was established that in considered chromium concentration range the density values are decreased from 7750

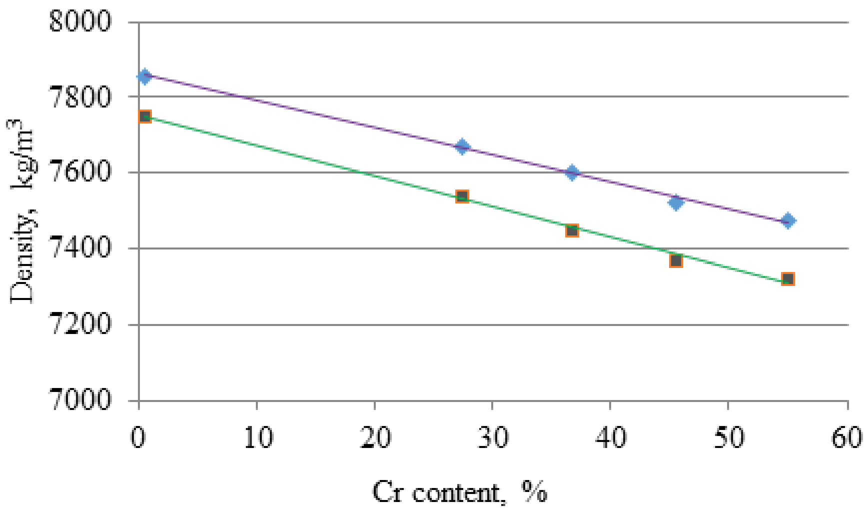

Figure 2: Influence of chromium content on alloys density. (Source: Author's own work.) ◆ - calculated values; ■ - experimental values.

to 7320 kg/m^3 (Figure 2). So the alloys (1–5) have the density values above optimal one and they correspond to a heavy group.

In samples 2,6–9 the silicon content is varied at constant ratio of chromium to nickel. It was found that the increase of silicon content from 0.2 to 40.1% causes a sharp decrease of the alloy density from 7672 to 5120 (Figure 3) kg/m^3. Such dependence might be explained by relatively low silicon density (2329 kg/m3) in comparison with other main constituents of chrome-nickel ferroalloys i.e. chromium, nickel and iron [16].

In general, the calculated results correspond well to experimental ones.

The alloys (8 and 9) with increased silicon content (20–40%) have optimal values of the density 5000–7000 kg/m^3. The density of alloys with low silicon content (0.2–13%) are higher than optimal one.

Hence it might be concluded that the efficient way to decrease the density of chrome-nickel ferroalloys to optimal values is increase of silicon content. Complex ferroalloys having 20–40% of Si have optimal value of the density (5000–7000 kg/m^3).

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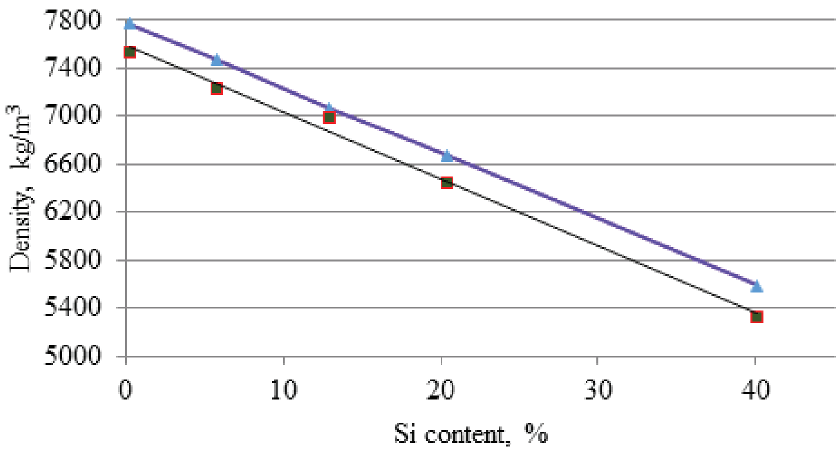

Figure 3: Influence of silicon content on alloys density. (Source: Author's own work.) ◆ - calculated values; ■ - experimental values.

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