EVALUATION OF GASEOUS DYNAMIC BEHAVIOR OF RAW MATERIALS AND CHARGE FOR HC FERROCHROME PRODUCTION

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ABSTRACT

HC ferrochrome smelting process in submerged arc furnace is accompanied by generation of gaseous product of reaction (carbon monoxide). For normal evolution of process good conditions for even gas escape should be provided. Layer of charge creates resistance for gaseous throughout, which depends on same factors. This paper reports data of resistance by layer of chromium sources (lamp ore, fine ore, brick and pallets), three types of coke with different size and mixes, which used for HC FC smelting. Key factors which depend on gas permeability of the material were founded. Obtained data allow to more rationally selecting needed participle size of raw material thereby to improve the efficiency of ferroalloys production.

KEYWORDS: *Gas velocity, charge, reductant, ferroalloy, chromite, lumpy ore, pellet, fines, coke, special coke, temperature, SAF furnace.*

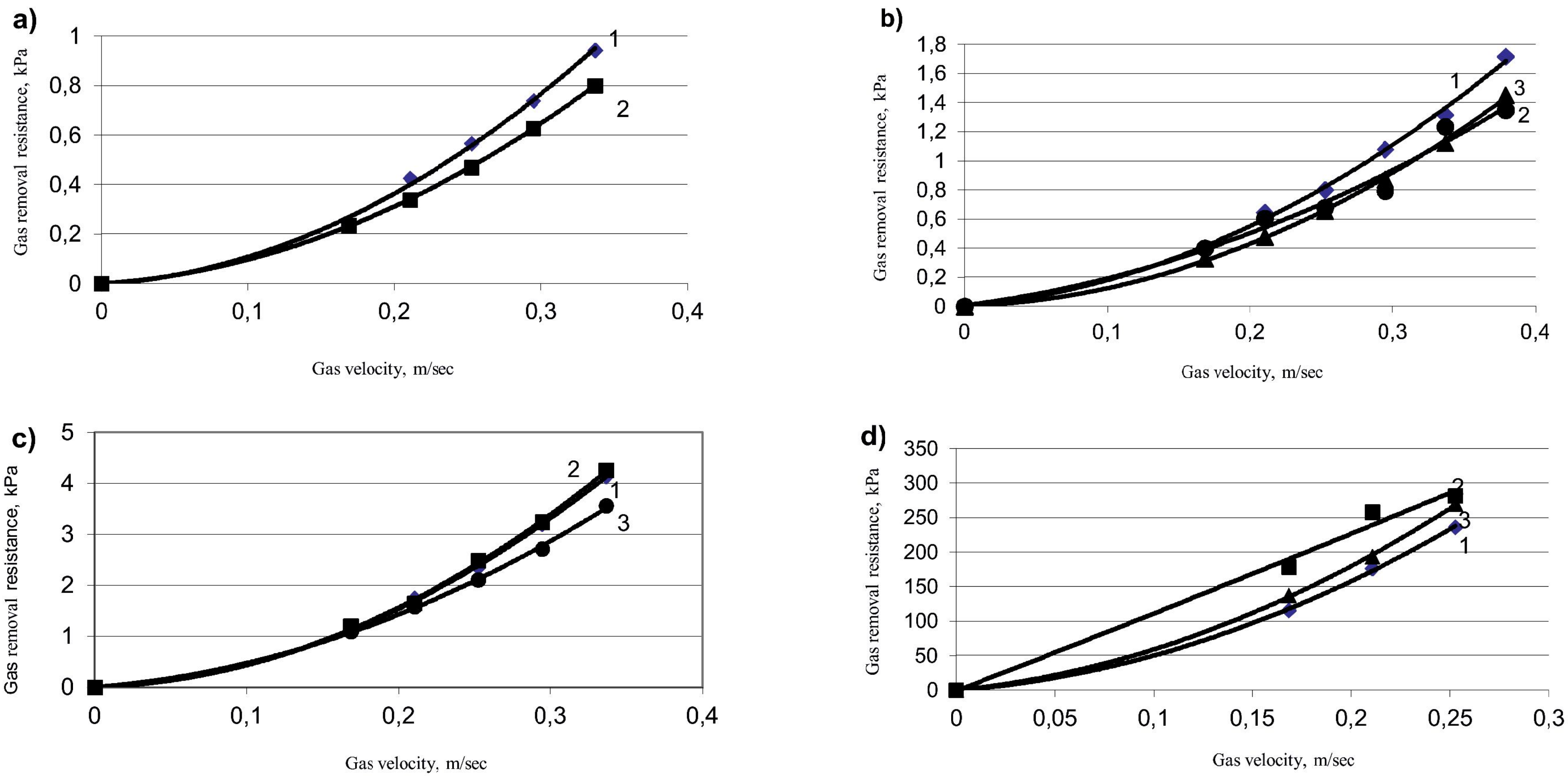
INTRODUCTION

A carbothermic ferroalloys smelting is accompanied, by gaseous carbon monoxide (CO) generation. To provide successful process evolution even CO escape conditions are required.

In submerged arc furnace (SAF) burden creates gas passage resistance which is determined by different classes coarseness ratio, nature and shape of material and other factors. Excessively high resistance causes raw materials discharge and gas escape in the form of over pressed gases. Charge consumption is accompanied by charge downslides and discharges. Furnace electrical mode is featured by capacity drops and in general unstable operation which results in labor conditions deterioration and all metallurgical parameters. Despite its urgency ferroalloy smelting gasodynamic behavior investigation matter is reported by a few works [1-3] and the matter still needs to be investigated. In reality gas permeability adjustment is just limited by fines screening and their agglomeration ,which is not always possible, also top handling. Currently there are no charge materials size proven demands in particular reductants. The more charge materials size increases the less their specific area becomes which causes reductant velocity decrease and raw materials leave furnace unreacted with melt. Evaluation of hydraulic resistance offered by coarseness different classes and their ratio allows reasonably choosing required size and adjusting overburden thickness. Correct choice of these parameters provides gas escape conditions without excessive consumption decrease.

SAMPLING AND METHODOLOGY

Raw materials and charge gaseous dynamic behavior experimental evaluation have been performed at a laboratory facility according to [2-4]. Investigation has covered raw materials used in ferrochrome production: lumpy and fine chromite, briquettes and pallets, coke produced in China and Russia and special coke.



1 - Coke produced in China, 2 – Shubarkol special coke, 3 - Coke produced in Russia

Figure 1: Relationships between gas blowing velocity and the resistance of reductants +20 mm (a), 10-20 mm (b), 5-10 mm (c) and 0-5 mm (d) large

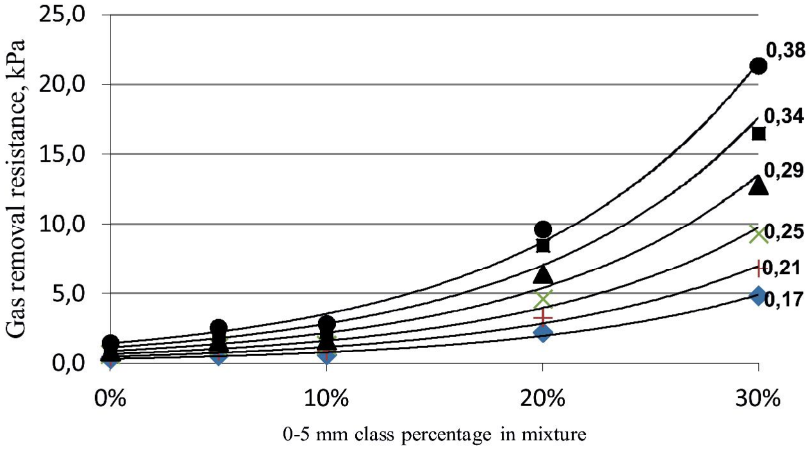
Special coke is a product of noncoking coal (Shubarcol deposit, Kazakhstan) charred in a shaft furnace. Before testing start the reductants had been divided into some fractions: 0-5 mm, 5-10 mm, 10-20 mm and +20 mm.

TEST RESULTS

As can be seen from figure 1 coke type affects on gas removal resistance. However the most important properties which affect on gas permeability are gas velocity and sample size. Within in the range of 0.17-0.34 m/sec, the relationship between gas velocity and pressure drops is linear. Gas velocity increasing from 1.25 to 2.25 times leads to pressure drops growth from 1.4-1.6 to 3.4-5.4 times.

Reductants size is a key factor which determines layer gas permeability. With coke size increasing from 10-20 mm to +20 mm, gas permeability increased by 1.5 times and with coke size decreasing to 5-10 mm, gas permeability decreased by 3-4 times and size minimization (0-5 mm) lead to fast (300-400 times) resistance growth.

Figure 2 shows results of reductant layer resistance measuring with mixing two coarseness classes: 0-5 and 10-20 mm. Since the results of different types of coke resistance measuring had been the same, the further experiments have been carried out using Russia coke. As it can be seen relationship between 10-20 mm reductant resistance and 0-5 mm class percentage within the range 0-30% is exponent, i.e. if carbon mix concentration is 0-5 mm and more than 10 % rapid growth of resistance can be seen. Thus, with increasing fines concentration in 2 times (from 10 to 20%), resistance increases by 3,4-3,9 times, and with increasing fines concentration in 3 times resistance increases by 7,2-7,9 times. Obviously fine materials and extremely small particles cause gas permeability drops however fines concentration up to 10 % is sufficient for gas permeability.



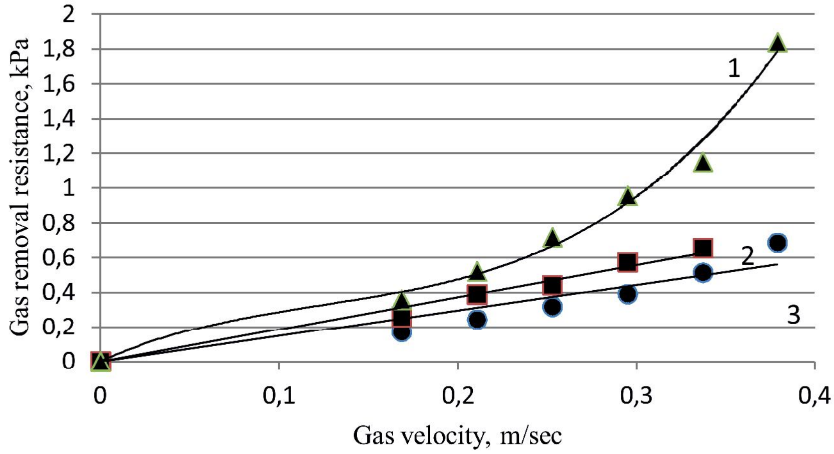
Numbers under the curves – gas velocity, m/sec

Figure 2: The relationship between the reductant resistance, gas velocity and 0-5 mm class percentage in mixture

Figure 3 shows the relationships between gas blowing velocity and the resistance of chromite materials. It can be seen that gas permeability decreases in the following sequence: lamp, briquette and pallets i.e. with material size decreasing. Evaluation of 0-5 mm chromite gas permeability was impossible due to the excessive high resistance. It should be marked, relatively large-sized materials (lamp ore and briquettes) have linear trends while pallets trend is exponent, like reductants. By comparing the chromite and carbon materials resistances, it can be seen that materials size is the most important property which determines gas permeability, while another factors as nature, type and shape of materials are less significant.

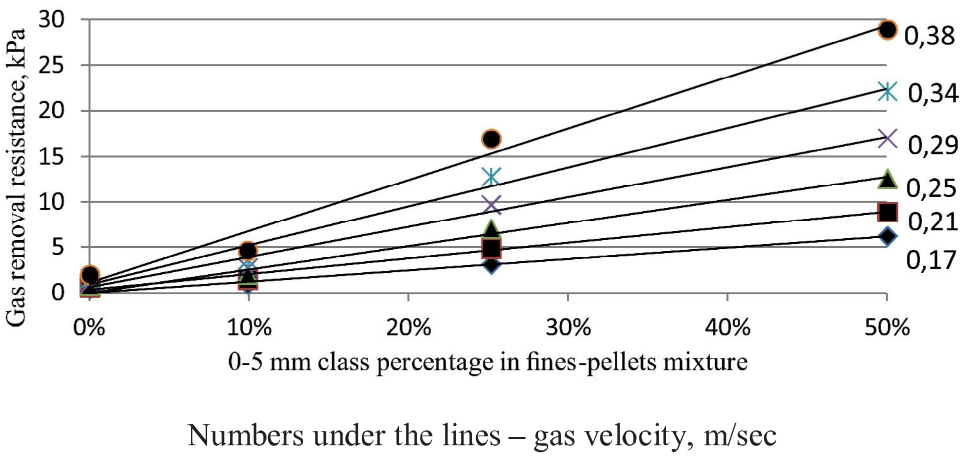
Figure 4 shows results of chromite materials mixes resistance measuring. 33% concentration of lump ore in the experiment mixes was constant. Pallets were substituted by fines in range of 0-50%. The relationship between chromite mixes resistance and fines concentration in mixes has a linear trend. The next stage of experiments has measured resistance of HCFC charges, using various materials. Three types of reductant 5-10 and 10-20 mm large have been used. It should be marked that China and Russia coke mixtures of both coarseness class had same results; therefore experiments only with coke produced in Russia have been considered. It may be resulted from the fact that both cokes have similar levels of bulk weight and fixed carbon concentration and take equal amount in the charge.

The experiment had started by measuring resistance of the mixture consisting of lumpy chromite ore and fines of 10-20 mm class (mixture 1) previously used at Kazchrome plant in Aktobe. This mixture is revealed to have maximum gas passage resistance (figure 5 a-g). Pellets usage instead of fines (mixture 2) enables to decrease resistance by 4, 2-4, 5 times.



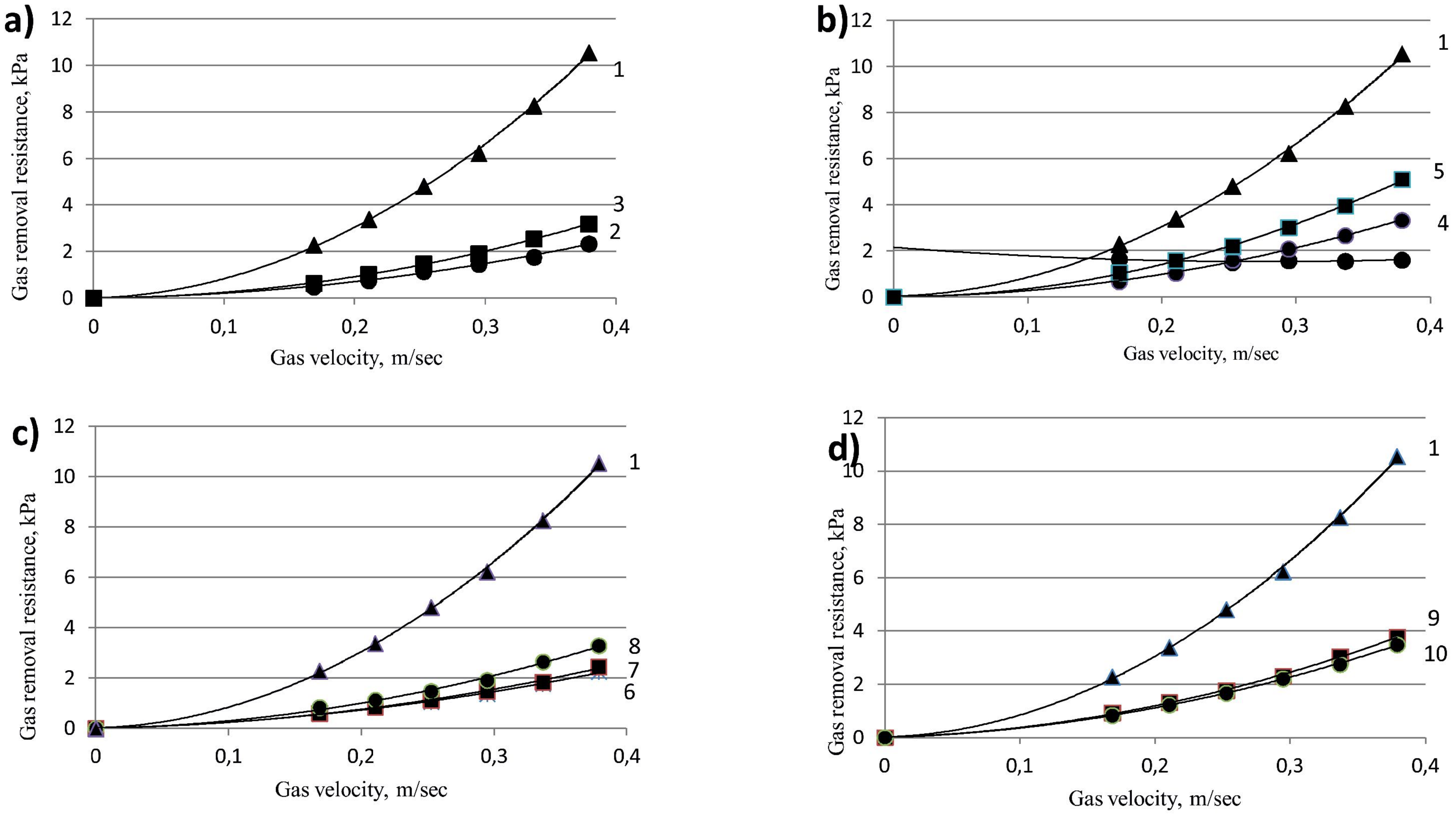
1- pellets, 2 - briquettes, 3 - lamp ore

Figure 3: Gas velocity affecting on the chromite materials resistance



Numbers under the lines – gas velocity, m/sec

Figure 4: The relationship between the chromite materials resistance, gas velocity and 0-5 mm class percentage in mixture



Numbers under the lines – No. of mixture

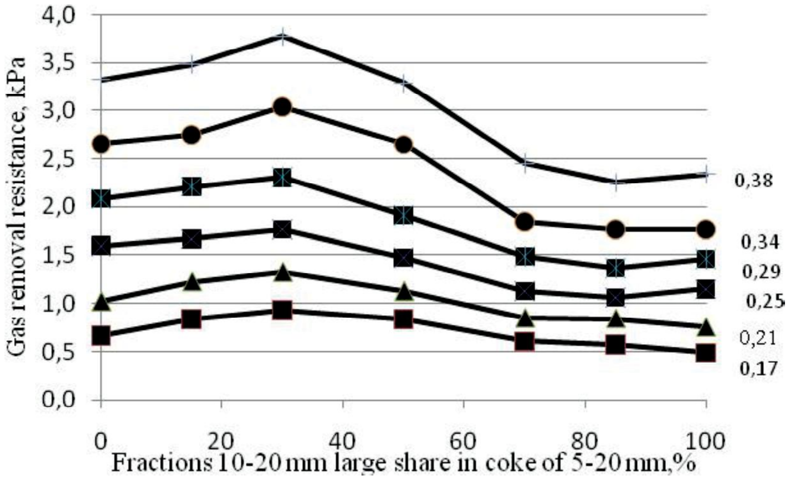
Figure 5: The relationship between gas velocity and HCFeCr mixture resistance

Coke substitution to special coke (mixture 3) causes gas permeability decreasing, but this mixture resistance is 3.2-3.6 times less than one of mixture 1 (figure 5a). Since there are no big differences between coke and special coke own gas permeability (figure 1b), mixture 2 advantage can be explained as follows: coke`s less bulk weight causes predominance of the volume of 10-20 mm large materials (pellets and coke) over the volume of large-sized materials (lamp), so it leads to porosity improvement and gas permeability increase.

As expected, reductant size reducing up to 5-10 mm increases mixture resistance (figure 5b). However compared to mixture 1 the resistance level of coke mixture (mixture 4) and special coke (mixture 5) are, respectively, 3.0-3.2 and 2.1-2.2 times less. With decreasing reductant size in 2 times resistance increases not so much: by 1.4 times for mixture 4 and by 1.5-1.6 times for mixture 5.

Since reducing agent 5-20 mm large is be of frequent use in practice, mixture resistance, with various ratios of two reductant fractions, has been measured.

As it can be seen from figure 6, the relationship between resistance and 10-20 mm fraction concentration of coke has an extremum trend. Mixture resistance increases if coke 10-20 mm larges will be added to coke 5-10 large; mixture 70% of 5-10 mm and 30% of 10-20 mm fractions has maximum resistance. Positive influence of 10-20 mm fraction starts with 50% and more concentration this fraction in coke mix. This means that coke 5-20 mm large should be divided into two fractions and used separately.



Numbers under the lines – gas velocity, m/sec

Figure 6: The relationship between the HCFeCr mixture resistance, gas velocity and reductant size

CONCLUSION

Based upon the above investigations the following conclusions have been reached: the most important properties which affect on gas permeability are gas velocity, sample size and different classes coarseness ratio. The method provides a possibility for direct measuring of raw materials and charge gas throughout resistance. It is a best tool for effective charge preparation from different type's materials. Resistance of raw materials and charges for HCFC has been measured. The investigations show big differences (in 300-400 times) between gas permeability of the materials. Fines (0-5 mm) presence has an adverse affect on gas permeability.

Pallets using instead of chromite fines allows improving gas permeability of HCFeCr charges for a minimum of 4 times. Therefore, there is a possibility to use a less large reductant. This leads to interaction surface increasing and thus process capacity, also the electric resistance of burden would be improved. Finally, all metallurgical parameters could be enhanced. This is particularly significant for a reductant with low reactivity, like Shabarcol special coke. This reductant application in practice is constrained due to its low reactivity.

Coke 5-20 mm large used in practice should be divided into two fractions and used separately.

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