Ceramics International 31 (2005) 647–653

CERAMICS INTERNATIONAL

www.elsevier.com/locate/ceramint

The effect of deflocculants on the self-flow characteristics of ultra low-cement castables in Al_2O_3–SiC–C system

Sasan Otroj [a], Mohammad Ali Bahrevar [a,*], Fatollah Mostarzadeh [a], Mohammad Reza Nilforoshan [b]

[a] *Materials and Energy Research Center, P.O. Box 14155-4777, Tehran, Iran*
[b] *Shahrekord University, Iran*

Received 12 January 2004; received in revised form 2 February 2004; accepted 29 June 2004
Available online 7 March 2005

Abstract

The influence of several deflocculants on the self-flow characteristics of an ultra low-cement high-alumina castable in the Al_2O_3–SiC–C system has been studied. The behavior of various deflocculants in high-alumina castables was evaluated in terms of apparent viscosity and pH of the matrix and self-flow value of the castable.

Our study shows that the best self-flow characteristics in the Al_2O_3–SiC–C system is obtained using sodium polyacrylate and the optimum content is considered to be 0.06 wt.%.

Keywords: Castable; Self-flow; Ultra low-cement; Deflocculants; Al_2O_3–SiC–C; Rheology

1. Introduction

The development of low and ultra low-cement castables (LCC & ULCC) started in the late 1970s by replacing part of the cement with fine (1–100 μm) and ultra fine (<1 μm) particles such as fume silica and reactive alumina [1,2]. Successful performance of these castables during the installation and their high-temperature properties have been attributed to the ability of fine and ultra fine particles to fill in the voids between aggregates (>100 μm), resulting in the higher packing density [3,4].

Due to reduced cement content and higher packing density, the water demand in high-alumina castables is decreased remarkably. Therefore, both LCC and ULCC exhibit better physical properties than the traditional medium-cement castables [1–5]. Furthermore, it is easily recognized that the particle size distribution (PSD) of the castables is an important factor in improving the flowability of the mix. The fine and ultra fine particles can increase the separation distance between aggregates and improve flowability. The idea of self-flow and pumpable castables has, indeed, been developed from this improved flowability [1–3].

Self-flow castables are characterized by their consistency after mixing, which allows them to flow and de-air without the application of external energy (i.e., vibration) [6,7]. In addition to the PSD of the castable and nature of the raw materials, the choice of a proper deflocculant is the key factor in modern self-flowing refractory castables [5,8].

The refractory castables used in blast furnace (BF) trough linings have to withstand high temperatures and exhibit high thermal shock resistance. They should also have good corrosion and erosion resistance. Castables in the Al_2O_3–SiC–C system have been developed by different workers for such applications [9–11].

The main raw materials are fumed silica, reactive alumina, calcium aluminate cement (CAC), silicon carbide and carbon (graphite or pitch).

Silicon carbide is commonly used to increase the thermal conductivity and decrease the thermal expansion coefficient of high-alumina castables so as to enhance their resistance to

* Corresponding author.
E-mail address: ma-bahrevar@merc.ac.ir (M.A. Bahrevar).

0272-8842/$30.00
doi:10.1016/j.ceramint.2004.06.023

Table 1
Raw materials and composition of the Al_2O_3–SiC–C ultra low-cement castable studied

Raw materials		wt.%
Tabular alumina	Alcoa Chemicals, T-60	63.5
Silicon carbide	Chinese Origin	15
Pitch	Palayesh Gatran-Iran	3
Fume silica	Elkem, 971U	4.5
Reactive alumina	Alcoa Chemicals, CTC 20	12.5
Calcium aluminate cement	Lafarge, Secar 71	1.5

thermal shock. Carbon has a similar effect on these properties and inhibits metal and slag corrosion because of its non-wetting nature. Incorporation of these raw materials into the refractory composition is expected to increase the complexity of the matrix particles. This is mainly caused by the non-oxide nature of silicon carbide and the decreased wetting ability of carbon [11].

The dispersion of high-alumina zero-cement castables containing silicon carbide and graphite has been investigated in many articles [11]. However, less attention has been paid to the ultra low-cement castables in the same systems.

In this paper, the effects of deflocculants on the properties of ultra low-cement self-flowing Al_2O_3–SiC–C castable is studied. The effect of four industrial deflocculants; namely, sodium polyacrylate acid (Na-PAA), citric acid (CA), sodium tripolyphosphate (TPP) and sodium hexametaphosphate (HMP) on the apparent viscosity and pH of the matrix and the self-flow value of the castable is evaluated.

2. Experimental procedure

2.1. Raw materials and composition

The raw materials and composition used for the ultra low-cement self-flowing castable in Al_2O_3–SiC–C system are listed in Table 1 [10].

Particles, with a small mean diameter (<100 μm) and a large specific surface area (>1 m^2/g) play a major role in the dispersion of the castable. These particles constitute the castable matrix [5,11]. The purity and physical characteristics of the raw materials in the matrix are shown in Table 2. The four deflocculants used in our study and their sources are listed in Table 3. It was necessary to add small amounts of a wetting agent to the refractory composition to compensate for the low wetting ability of pitch. The wetting agent employed is the non-ionic polymer polyoxyethylene cetyl ether [$C_{16}H_{33}(OCH_2CH_2)\cdot 20OH$, 1120 g/mol, Sigma–Aldrich]. Separate tests were done to determine the exact amount of the wetting agent needed and an optimum content of 0.02 wt.% was obtained.

2.2. Particle size distribution

The PSD of the castable was adjusted to a theoretical self-flow continuous curve based on the Andreasen model as follows:

$$\mathrm{CPFT} = 100\left(\frac{d}{D}\right)^q$$

where CPFT, d, D, and q indicate the cumulative percentage finer than, particle size, the largest particle size (5000 μm) and the distribution modulus, respectively. In order to achieve self-flow, the q values should be in the range 0.21–0.26 [4]. For the present study, q is chosen to be 0.24, and the particle size distribution of the castable with this value of q is represented in Fig. 1.

2.3. Viscosity measurements

Due to the presence of coarse particles up to 5000 μm, it is very difficult to measure the viscosity of the castables directly. It is the rheology of matrix (the finer fraction of the raw materials (<100 μm), additives, and water form the matrix of refractory castable), which determines the flow behavior of the castable. In the absence of coarse particles, the viscosity of the matrix can be measured using a coaxial cylinder viscometer, which offers a wider range and a higher precision in measurements [12]. Therefore, a Brookfield digital rheometer (model LVD-III) was used for viscosity measurements. Steady-shear rheological tests have been carried out on the suspensions by applying a shear rate from 2.5 to 50 s^{-1}. Apparent viscosity at a shear rate of 50 s^{-1} was used in the matrix rheological analysis because of its good correlation with castable flowability [5,13]. The contents of raw materials and solids loading used to prepare the matrix representative suspensions are shown in Table 4. Because of the viscosity variation with time in the castables containing calcium aluminate cement, apparent viscosity was measured

Table 2
Purity and physical characteristics of matrix particles

Raw materials	Characteristics			
	Purity (wt.%)	Specific surface area (m^2/g)	Density (g/cm^3)	Particle size D_{50} (μm)
Tabular alumina	>99	0.83	3.83	7.70
Silicon carbide	>94	0.54	3.22	36.73
Pitch	>67	0.52	1.46	53.43
Fumed silica	>97.1	17.12	2.27	0.25
Reactive alumina	>99.7	2.10	3.91	1.90
Cement	(Al_2O_3)>70	1.00	2.93	3.03