INFLUENCE OF PHASE COMPOSITION AND PARTICLE SIZE DISTRIBUTION OF ALUMINA ON ITS DISSOLUTION RATE

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It is well known that reduction of α-Al_2O_3 in alumina leads to the increased rate of its dissolution. The studies of the microstructure of dissolving particles demonstrated that α-Al_2O_3 has a rounded shape without considerable roughness, and particles of γ-Al_2O_3 have an irregular shape with fissured and a well-developed surface. The specific weight of γ- Al_2O_3 (3.20-3.77 g/cm^3) and density of crystal lattice packing (72%) is lower than that of α-Al_2O_3 (3.95-4.1 g/cm^3 and 76%, respectively); γ-Al_2O_3 contains small amounts of water, which is retained in its structure even during prolonged heating at 1000°C. All these factors promote faster dissolution of γ-Al_2O_3 particles compared to α-Al_2O_3 particles. At the same time, valid data on the influence of phase composition was obtained during dissolution of sintered alumina disks. For dissolution of powdered alumina, the results were not so unambiguous. For example, according to Maeda et al., only at close to 100% α-Al_2O_3 content, can a reducing dissolution rate during loading of powdered alumina into bath be noted (Fig. 1).

Analysis of other studies provides similar outcomes. In the range of α-Al_2O_3 values up to 30%, the data spread is large, which does not allow a certain relationship to be formed. This is chiefly related to the fact that soluble types of alumina were distinguished not only by their phase composition, but also by other properties, for instance, their particle size distribution, LOI, and BET surface.

At present, the content of α-Al_2O_3 in alumina from almost all suppliers does not exceed 20%, and it can differ significantly from 2 to 20%. Does the alumina dissolution rate really change if the content of α-Al_2O_3 changes in this range?

In order to answer this question, we should consider the phenomena that occur during loading of a batch of powdered alumina into bath.

During loading, alumina is usually spread across the bath surface in the shape of a disk. The temperature of loaded alumina is a lot lower than the bath temperature, therefore the alumina batch is covered with a frozen bath crust a few millimetres thick. Some time after loading (2-20 sec), an agglomerate is formed in the shape of a disk (or a lens) which represents alumina powder covered with a bath crust. Since the apparent density of alumina is 0.95-1.2 g/cm^3, the agglomerate is lighter than bath, so it floats on its surface. When bath is mixed, the agglomerate can be broken into smaller pieces. As the agglomerate warms up, the bath crust dissolves. Liquid bath penetrates into the alumina powder.

Under high temperature and bath vapour, phase re-crystallisation occurs in alumina powder: transformation of γ-Al_2O_3 into α-Al_2O_3, the start of which is presented in a diagram in Fig. 2.

As a result of phase transition, α-Al_2O_3 crystals are formed out of γ-Al_2O_3 crystals, in the shape of fine flakes, which penetrate into each other to form a unique matrix (lattice) becoming saturated with bath (Fig. 3). The transformed agglomerate represents a cryolite-alumina crust, which has a higher density than bath, therefore sinks in bath. Being on the bottom of the reservoir, the crust dissolves. Visually, dissolution can be observed as crust 'melting' until complete disappearance. The crust can

Fig. 1

Relationship of alumina dissolution rate from the content of α-Al_2O_3 (according to R. Maeda, S. Matsui, A. Era)

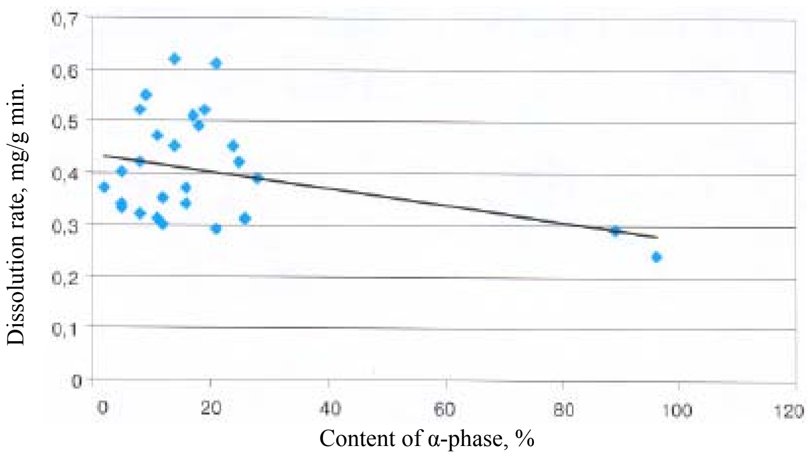


Fig. 2

Alumina re-crystallisation diagram (N.P. Ostbo):
a – alumina particles packed in agglomerate at the start of bath penetration;
b – starting re-crystallisation of alumina particles in agglomerate, generation of a matrix of bound crystals, bath penetration

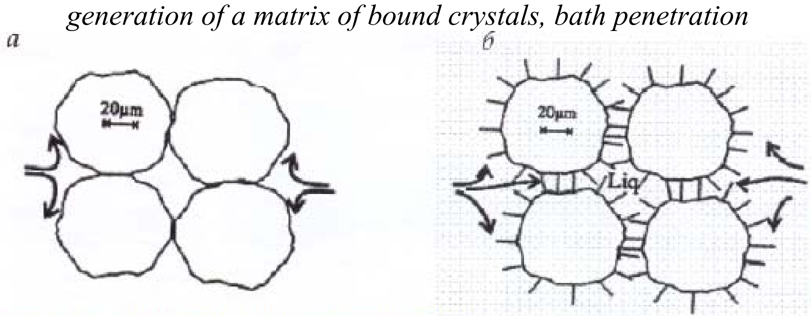


Fig. 3

Photographs of cryolite-alumina crust (alumina with a low content of α-Al_2O_3, less than 5%) taken with an electronic microscope (Townsend, Boxall).
The photographs clearly show lattices of bound α-Al_2O_3 flakes:
a – crust formed by alumina with a low content of fines;
b – crust formed by alumina with a high content of fines.

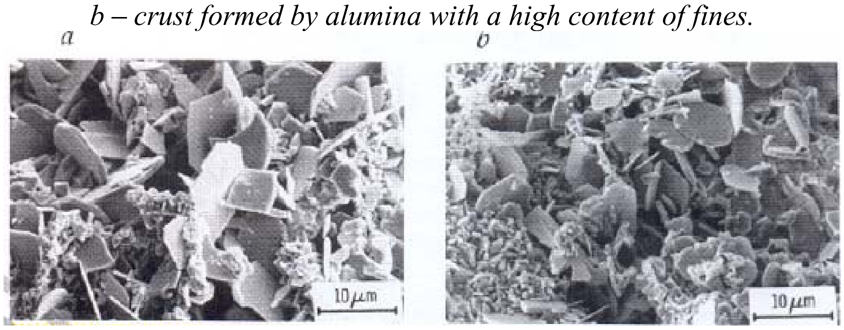


Fig. 4

Relationship of alumina dissolution rate from the content of α-Al_2O_3 therein

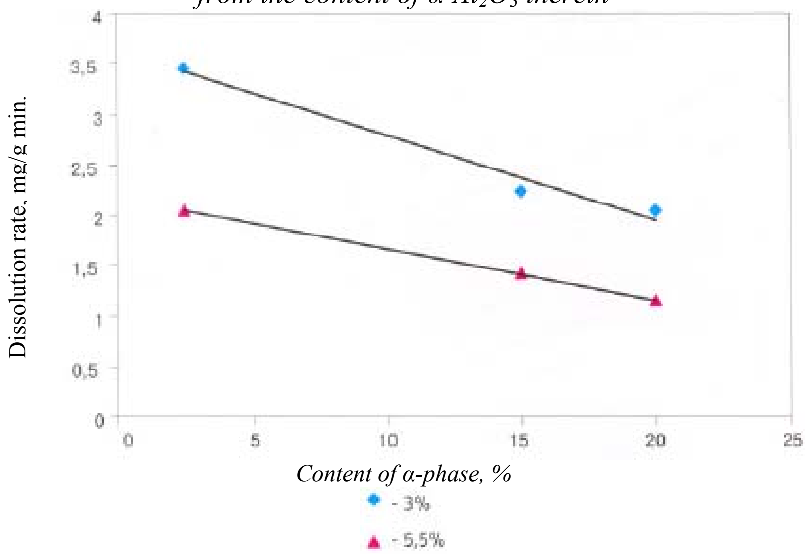
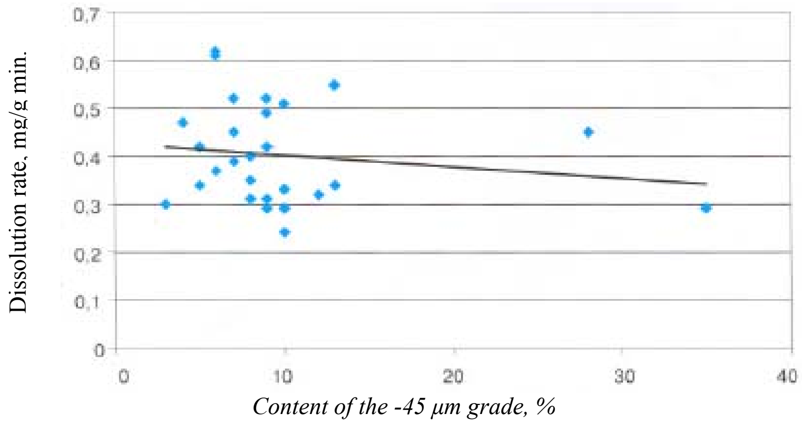


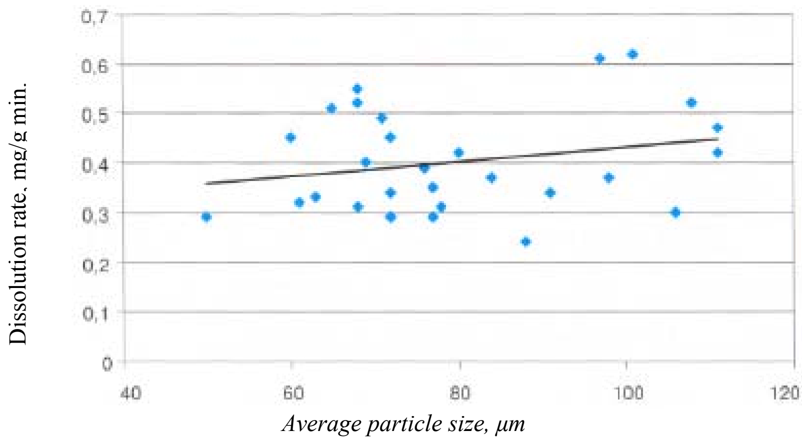
Fig. 5

Relationship of alumina dissolution rate:
a – from the content of the -45 µm grade;
b – from the average particle size
(according to R.Maeda, S.Matsui, A.Era)

a



b



Under high temperature and bath vapour, phase re-crystallization occurs in alumina powder: transformation of γ-Al_2O_3 into α-Al_2O_3.

break into several pieces; then pieces of crust dissolve. This crust has a very large surface area, therefore its dissolution rate should be very high.

α-Al_2O_3 particles in initial alumina do not undergo any transformation after loading into bath. Apparently, they incorporate into the crust matrix and will dissolve slower than the matrix itself. With a high content of α-Al_2O_3 in alumina, the crust formed is fragile, and it easily breaks into pieces in bath. After dissolution of the matrix, α-Al_2O_3 particles are left, which form a pile on the bottom of the reservoir, whose dissolution rate is lower than the dissolution rate of separate particles. We could observe these dissolution patterns in the laboratory.

The above-mentioned mechanism allows the reduced dissolution rate to be explained if α-Al_2O_3 content increases (Fig. 4). The data presented was obtained during the laboratory study of the dissolution rates for alumina from Nikolaev alumina refinery, Kazakhstan Alumina, and Achinsk alumina refinery, whose content of α-Al_2O_3 is 2.5, 15, and 20%, respectively.

As for the impact of particle size distribution on the alumina dissolution rate, there are contradictory opinions. However, most of the researchers believe that when the content of fines is increased or the average particle size is reduced, there is a tendency for reduction of the alumina dissolution rate. These trends can be observed in the experimental data presented on Fig. 5-6.

Our experiments on dissolving the alumina from Nikolaev alumina refinery with the content of the -45 µm grade of 17.9% (coarse) and 33.2% (standard) demonstrated the reduction of the dissolution rate if the content of fines is increased (Fig. 7).

The reduction of the dissolution rate could be related to two major reasons:

- firstly, when alumina with a high content of fines is loaded, crust is formed whose matrix has very small cells (Fig. 3b). Their wetting in the bath is lower therefore the dissolution surface area reduces, as well as the dissolution rate. At the same time, crust formed by fine alumina is very weak, that's why they easily break into pieces in bath, which increases the dissolution surface. It is hard to say which of these factors impacts the dissolution rate more;
- secondly, it is well known that fine grades contain a larger amount α-Al_2O_3. The studied alumina from Nikolaev alumina refinery was not an exception. The average content of α-Al_2O_3 was 2.6%, and in the -45 µm grade – 8.7%.

Thus, increased content of α-Al_2O_3 and the -45 µm grade, results in the reduction of the alumina dissolution rate. The dissolution mechanism considered allows these trends to be explained.

Fig. 6

Relationship of alumina dissolution time from the average particle size (according to G.I. Kushel, B.J. Welch)

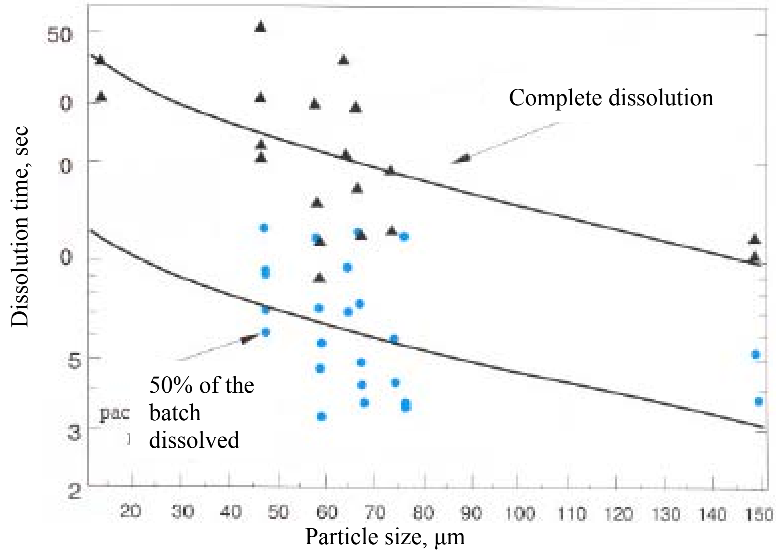
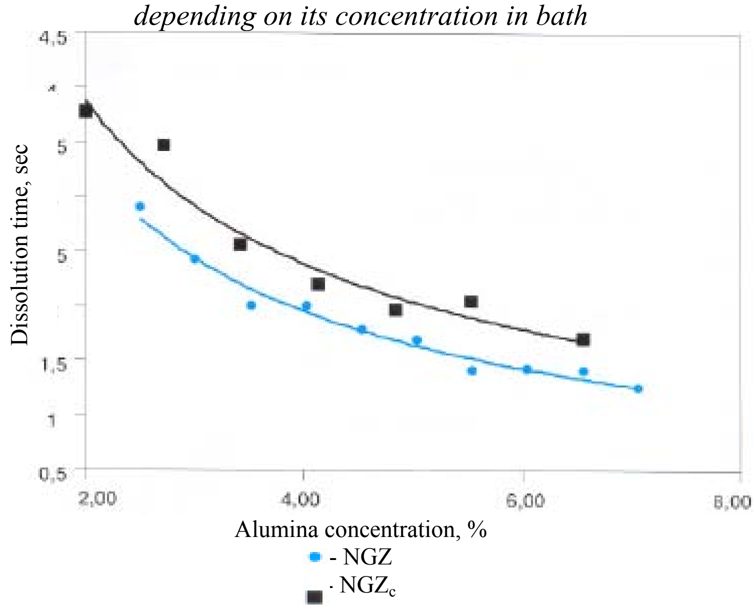


Fig. 7

Dissolution rates of standard (NGZ) and coarse (NGZ_c) alumina, depending on its concentration in bath



Increased content of α-Al_2O_3 and the -45 µm grade results in a reduced alumina dissolution rate.

This material has been prepared in co-authorship with A.B. Braslavsky, Assistant of Light Metals and Alumina Production Chair, ITsMiZ SFU.