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Application of 3D Tomography Method for Analysis of Iron-Ore Sinter Porosity. Part 2: Open and Closed Porosity Characteristics

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Data about concentrate ratio and sinter basicity influence on parameters of open and closed porosity are presented. Reducibility of sinter samples, the porosity of which had been previously identified by tomography, has been investigated for the first time. The fact that samples with pre-measured porosity could be analyzed further opens new possibilities to investigate mechanical and physic-chemical properties of sinter.

Keywords: IRON ORE SINTER, POROSITY, REDUCIBILITY

Introduction

The innovative X-ray tomography method for investigation of iron ore sinter porosity and experimental data about effect of sinter basicity and concentrate ratio in the charge mixture on the total porosity of sinter are observed in the first part of the paper [1]. More details about effect of specified factors on characteristics of open and closed porosity, compared results of X-ray tomography and mercury method and also results of investigation of reducibility for samples with pre-measured porosity are presented in the paper.

Methodology

Experimental procedure is explained in works [1, 2]. Certain sinter samples after tomography are investigated on the mercury porometer Micromeritics Autopore at pressure from 0.036 to 400 MPa for comparison of 3D tomography results to traditional porometry ones.

Besides, some of scanned sinter samples after 3D tomography estimation of porosity are tested for reducibility at Department of Physical Chemistry and Theory of Metallurgical Processes of National Metallurgical Academy of Ukraine. We used a vertical reactor with quartz tube, in which sinter samples are put in a platinum wire basket connected to weight change self-recording device. The reactor is isolated prior to experiment, and inert atmosphere is created in it using purified Ar. Further, the sample is heated to 900 °C and inert gas is replaced with hydrogen with the rate 36 l/h. Experiment lasted for 1 hour. Fractional loss in weight is computed using equation (1) for estimation of reducibility

$$\Delta m_{frac} = \Delta m_{cur} / \Delta m_{fin} \text{ x}100, \%, \qquad \text{(Eq. 1)}$$

where Δm_{cur} and Δm_{fin} - current and final absolute loss in weight, respectively.

Results and Discussion

Comparison of open porosity data obtained via 3D tomography and mercury method for sinter at concentrate - ore ratio 1:1 is shown in **Figure 1**. Higher values of porosity obtained using 3D tomography can be explained by the fact that the mercury porometer measures the entrance holes of pores in the narrow range - from 329 to 0.01 microns. Thus, rather considerable part of sinter pores (**Figure 2**) could not be measured by mercury method.

Figures 2, 3 enable to compare porosity and fraction of volumes corresponding to certain diameter pores obtained by mercury and tomography methods (here we considered only pores to 300 microns which are identified by both methods). The reason of incomparability of obtained results is that fact that tomography allows characterizing pores by their equivalent diameter, while mercury porometry - by entrance hole diameter: the large pores can have small entrance hole diameter. Frequency distribution of open pores by equivalent diameter is illustrated in **Figure 4**. It is seen that 85-90 % of pore volume are pores larger than 500 microns. Distribution is shifted towards pore diameter 200 microns for almost all types of sinters which is close enough to average pore diameter obtained by Hosotani, et al. [3] (within 148-159 microns), though open and closed pores are not differentiated in present research. Scanning resolution enabled to receive information about material or pores not larger than 20 microns. However when using region growing procedure, the pores with equivalent diameter 40-60 microns have not been actually processed and considered. Hence, it is possible to state that open pores in diameter less than 60 microns are not considered in present investigation. According to Higuchi, et al. [4], summed volume of pores less than 15 microns is approximately 13 %. Bhagat, et al. [4] inform about fraction of microporosity less than 10 microns in the volume 5.23-10.38 % from the total porosity. It is necessary to note that quantity of pores with diameter exceeding free length of regenerative gas molecules (approximately 0.0004 microns on the average at 1000 °C and pressure 10^5 Pa [6]) should affect reducibility [5]. In the future application of tomography with higher resolution will enable to investigate morphological parameters of microporosity in details.

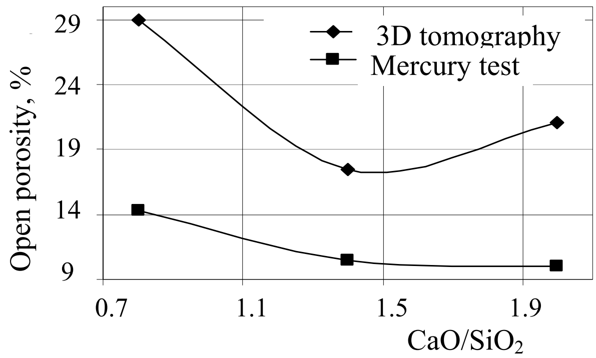

Figure 1. Comparison of open porosity using 3D tomography and mercury method (sinter with concentrate/ore ratio 50/50)

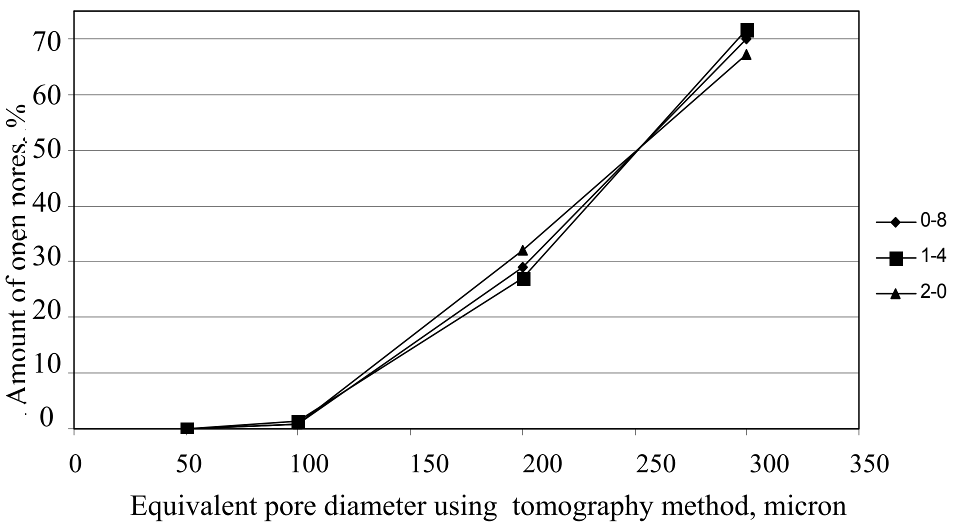

Figure 2. Fraction of porosity volume occupied by open pores with equivalent diameter less than 300 microns, (tomography method: sinter with ore/concentrate ratio 50/50): ◆ - basicity 0.8, ■ - basicity 1.4, ▲ - basicity 2.0

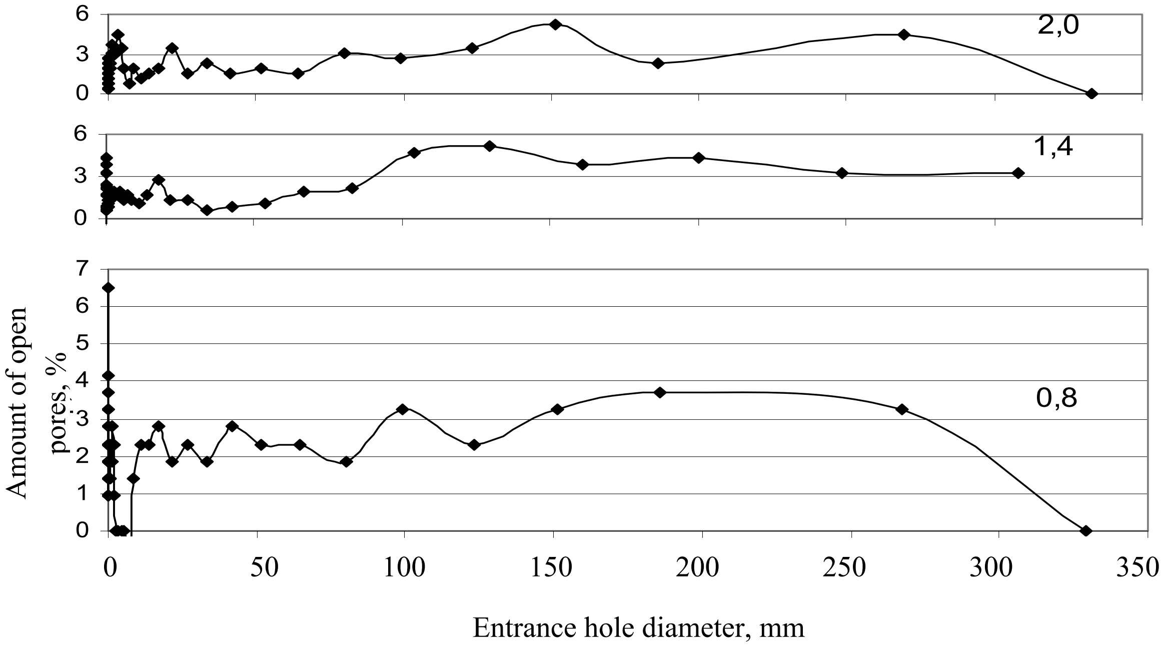

Figure 3. Fraction of porosity volume occupied by open pores with various entrance hole diameter, (mercury method: sinter with ore/concentrate ratio 50/50 and basicity 0.8; 1.4; 2.0)

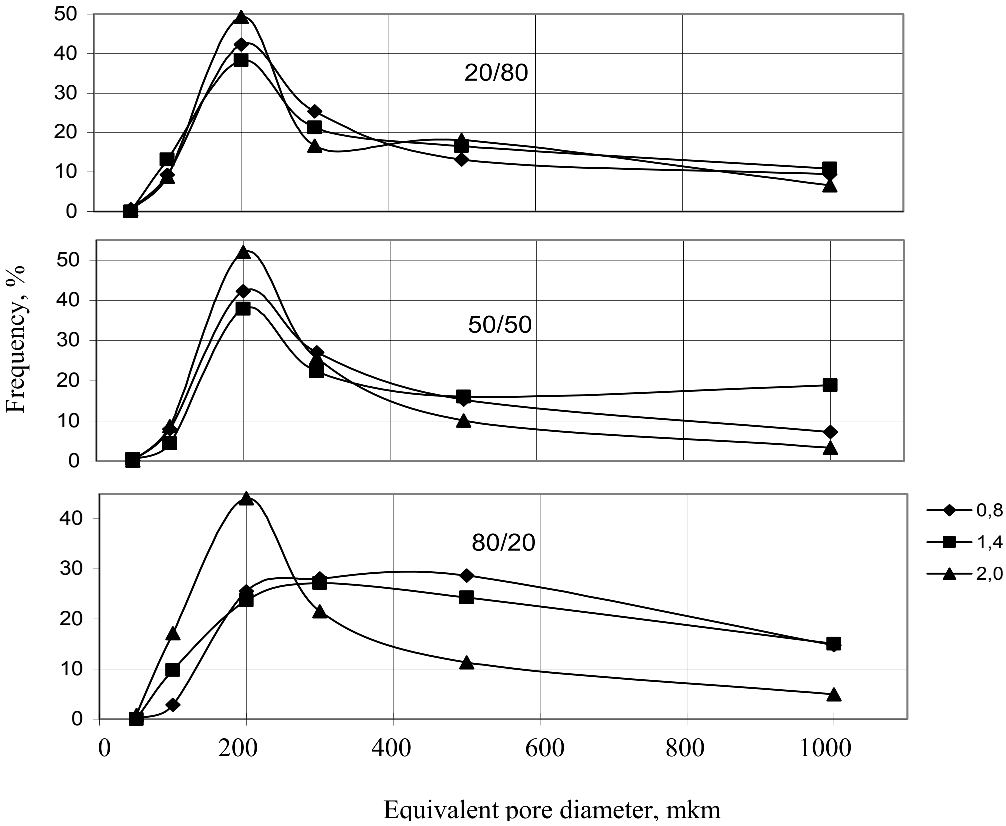

Figure 4. Frequency distribution of open pores by equivalent diameter for sinters produced from charge materials with ore/concentrate ratio 20/80, 50/50 and 80/20, basicities: □ - 0.8, ■-1.4, ▲ - 2.0

The most significant peaks on frequency diagrams are observed for sinters with basicity 2.0 in all cases. Data for sinters with basicity 0.8 and 1.4 are similar enough. Distribution of open pores by size for sinters produced from mixes with ore/concentrate ratio 20/80 and 50/50 is almost equal. Growth of concentrate content to 80 % is accompanied by flattening of the peak for sinters with basicity 2.0 and its shift to the area of large pore diameters. Effect of basicity on the value of open pore fraction with equivalent diameter more than 200 microns is shown in **Figure 5**. The formation of larger pores accompanied by drop of total porosity (**Figure 4**), observed with growth of porosity and - at equal basicity - with growth of concentrate fraction, can be explained by effect of amount and properties of melt observed in first part of present research. Debrinkat, et al. [7] found out that growth of melt flowability promoted merge of gas bubbles.

Results of closed pores measurement are presented in **Figure 6**.

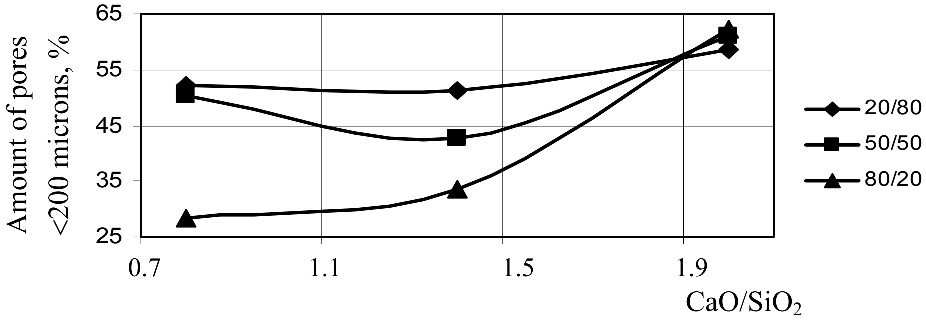

Figure 5. Effect of basicity on pore fraction with equivalent diameter less than 200 microns at ore/concentrate ratio: ◆ - 20 % of concentrate in the mix, ■- 50 % of concentrate in the mix, ▲- 80 % of concentrate in the mix

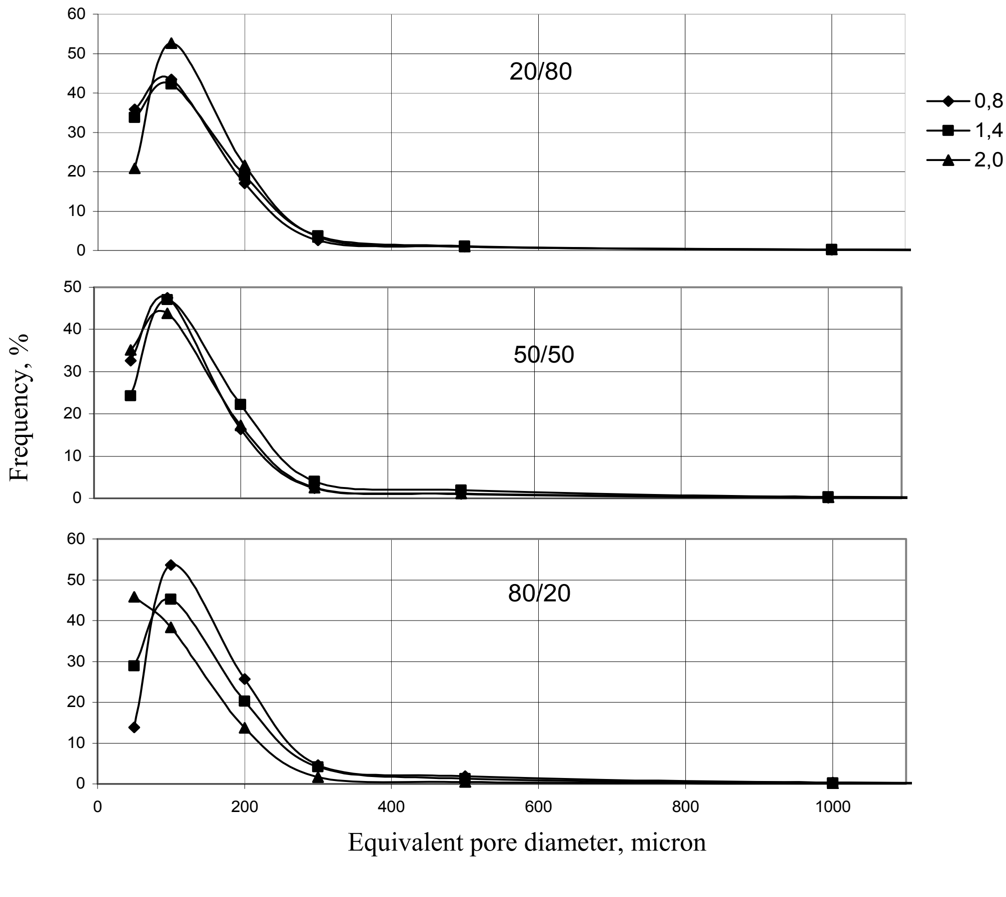

Figure 6. Frequency distribution of closed pores by equivalent diameter for sinter basicity: ◆ - 0.8, ■- 1.4, ▲- 2.0 with ore/concentrate ratio 20/80, 50/50 80/20

Curve pattern is similar to that obtained for open pores, however the median is shifted to the left to maximum approximately 100 microns. We tested three sinter samples with various basicities from mix materials with 50 % content of concentrate and ore, porosity of which is pre-measured, for reducibility. The most intensive loss in weight is observed for basicity 2.0, (**Figure 7**) which correlates well with the current concepts and can be explained by the formation of easily-reducable calcium ferrites. However, more intensive reduction of sinter with basicity 0.8 as compared to basicity 1.4 is less expected as growth of reducibility with increase of basicity [8] is usually observed in this interval of basicities. It can be explained by higher porosity of sinter sample with basicity 0.8 as the positive effect of porosity on reducibility is proved by many authors [3-5].

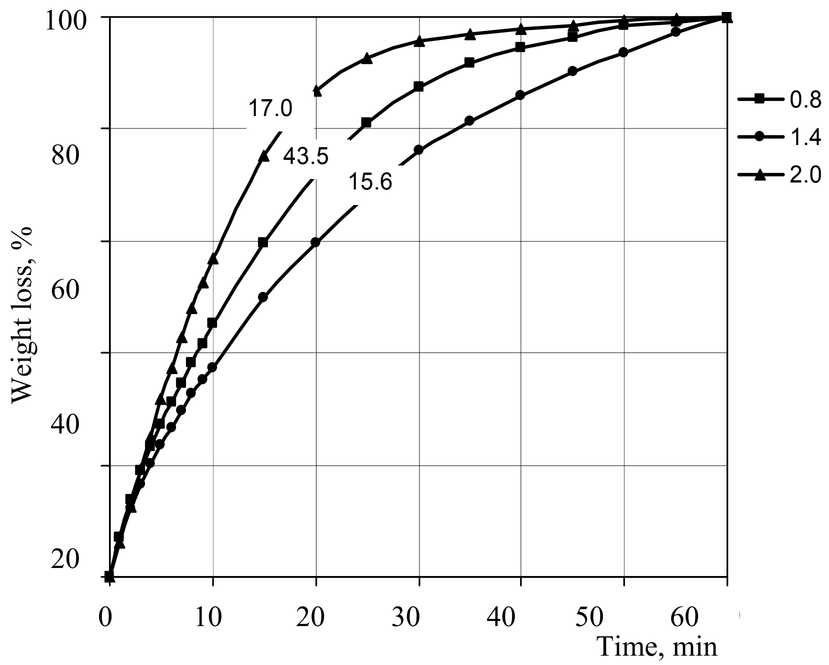

Figure 7. Fractional loss in weight during test for reducibility for sinters with various basicity: □ - 0.8, ■- 1.4, ▲ - 2.0 (figures at lines - open porosity, %)

Conclusions

After tomography scanning sinter can be used for various investigations which opens new possibilities for analysis of porosity effect on mechanical and physic-chemical properties of sinter.

When investigating porosity, the mercury method and 3D tomography give non-comparable results as the first method characterizes pores by entrance hole diameter and the second - by equivalent diameter.

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Применение метода 3D томографии для анализа пористости железорудного агломерата. Часть 2: Характеристики открытой и закрытой пористости

Шатоха В.И., Коробейников Ю.Ю., Камкина Л.В., Колбин Н.А.

Приведены данные о влиянии доли концентрата в агломерационной шихте, а также основности на параметры открытой и закрытой пористости. Впервые исследована восстановимость образцов агломерата, пористость которых была заранее определена на томографе. Возможность дальнейшего использования образцов с предварительно определенной пористостью для исследований открывает новые перспективы для изучения механических и физико-химических свойств агломерата.