Milling Behavior of Matrix Graphite Powders with Different Binder Materials in HTGR Fuel Element Fabrication: II. Variation of Pour and Tap Densities

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1. Introduction

The fuel element for HTGR is manufactured by mixing coated fuel particles with a matrix graphite powder properly prepared and pressed into a spherical shape or a cylindrical compact finally heat-treated at about 1900°C to form either pebble type or cylindrical type compacts depending on their use in different HTGR cores

The basic steps for manufacturing a fuel element include preparation of graphite matrix powder, over-coating the fuel particles, mixing the fuel particles with a matrix powder, carbonizing green compact, and the final high-temperature heat treatment of the carbonized fuel compact. In order to develop a fuel compact fabrication technology, it is important to develop a technology to prepare the matrix graphite powder (MGP) with proper characteristics, which has a strong influence on further steps and the material properties of fuel element. In this work, the milling behavior of matrix graphite powder mixture with different binder materials and their contents was investigated by analyzing the pour and tap densities and powder morphology.

2. Experimental

2.1 Materials used and methods of analysis in the experiment

A natural graphite powder and an electro-graphite powder, supplied by Graphit Kropfmühl AG, Germany and SGL, Germany, respectively, were used. Two binder materials, a phenolic resin (PR) and a PVB (poly vinyl butyral), were used to observe the difference in behaviors of binder during matrix graphite cake preparation and milling. For the analysis of MGP milling behavior, pour and tap density were measured. The pour density of the MGP samples was defined as measured density (weght/volume) by pouring a weight of 5 grams of the milled MGP samples into a volumetrically graded mass cylinder and measuring poured volume of the powder sample. The tap density of the milled MGP samples was defined as measured density (weight/volume) by measuring tapped volume after dropping 50 times from a height of 5 cm the volumetrically graded mass cylinder with 5 grams of poured MGP sample. For the observation of the morphology of the milled powder samples, scanning electron microscope was used to take micro-photographs with different magnifications.

2.2 Preparation of binder solutions with different contents

In order to examine any change in the quality of MGP depending on binders, PVB (Poly Vinyl Butyral) and phenolic resin (PR) with 3 different contents which give viscosities of binder solution of 3.63, 6.47 and 10.60 centipoise (Cp) were selected and prepared as shown in Table 1.

Table 1. Preparation of samples with different contents of binder

binder type	material	content 1	content 2	content 3
Phenol resin	N. graphite wt., g	128	128	128
	E. graphite wt., g	32	32	32
	binder wt., g	31.5	40	47.1
	solvent (wt., g)	MeOH (73.6)	MeOH (73.6)	MeOH (73.6)
	Wt. %	30.0	35.2	39.0
PVB	N. graphite wt., g	128	128	128
	E. graphite wt., g	32	32	32
	binder wt., g	2.9	4.24	5.62
	solvent (wt,.g)	EtOH (113.5)	EtOH (109.3)	EtOH (107.89)
	Wt. %	2.54	3.74	4.95
binder solution viscosity, Cp		3.63	6,45	10.6

2.3 Experimental conditions

Sample preparation and other detailed experimental procedure are described in the presentation of the parallel work by Lee and Cho. [1] Milling of the prepared matrix graphite cake for each sample was carried out using an attrition mill at 280 rpm for 2, 4, 6 and 8 hrs to observe the variation of pour and tap density as well as the morphology of the milled samples.

3. Results

Pour and tap densities are important characteristics in a R&D work on powdered materials. In this work, in order to study the milling behavior of the MGP samples, variations of the pour density for the different milled MGP samples (Table 1) and their tapping behavior as a function of number of tapping.

Fig. 1 shows the variation of pour density of MGP samples with different PR binder contents milled for 2 hrs. and variation of their tap densities as a function of number of tapping, Fig. 2., for MGP samples milled for 8 hrs, Fig. 3, for MGP samples with different PVB binder contents milled for 2 hrs and Fig. 4, for MGP samples milled for 8 hrs. They are also compared with variations of pour and tap densities for raw graphite powders.

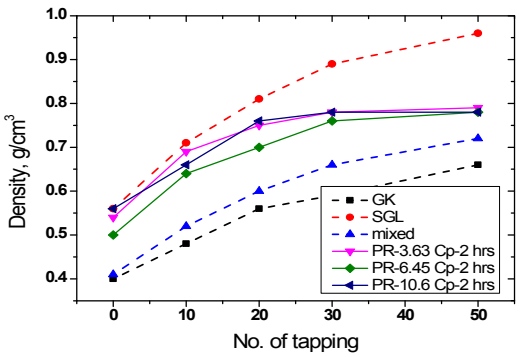


Fig. 1. Variation of pour density of MGP samples with different PR binder contents milled for 2 hrs and variation of their tap densities as a function of number of tapping

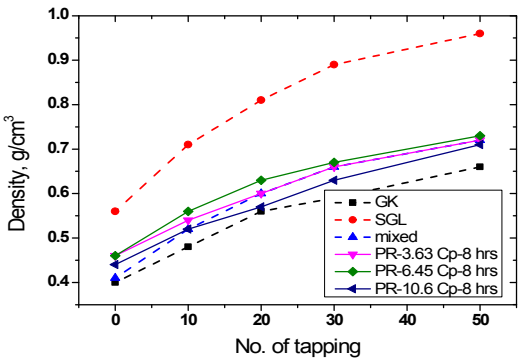


Fig. 2. Variation of pour density of MGP samples with different PR binder contents milled for 8 hrs and variation of their tap densities as a function of number of tapping

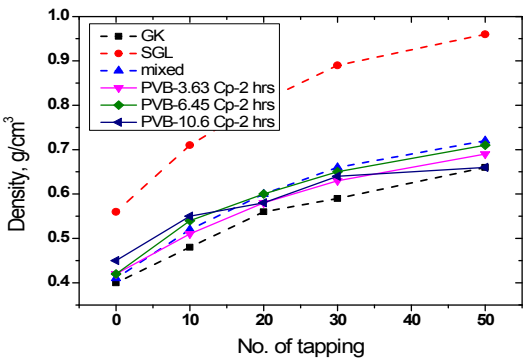


Fig. 3. Variation of pour density of MGP samples with different PVB binder contents milled for 2 hrs and variation of their tap densities as a function of number of tapping

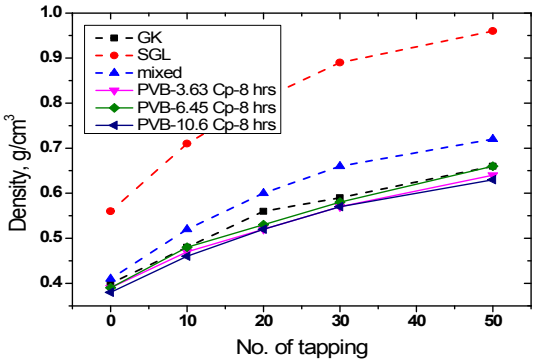
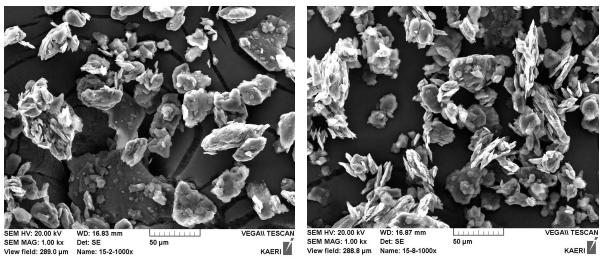


Fig. 4. Variation of pour density of MGP samples with different PR binder contents milled for 8 hrs and variation of their tap densities as a function of number of tapping

By comparison between Fig. 1 and 2, it can be elucidated that pour and tap densities are higher for the MGP samples with PR binder milled for 2 hrs than those for the MGP samples with PR binder milled for 8 hrs., the densities for both samples being between the densities for raw natural and electro- graphite powders. Also, for the MGP samples with PVB binder the tendency is similar, but showing much lower density ranges than for the MGP samples with PR binder. This is certainly due to the change of powder morphology depending on the milling time, as revealed by Fig. 5 (a) and (b), which show the SEM micro-photographs of the MGP samples with PR binder milled for 2 hrs and 8 hrs, respectively.



(a) (b)

Fig. 5. SEM micro-photographs of the MGP samples with PR binder milled for 2 hrs (a) and 8 hrs (b)

4. Conclusions

1) Both MGP samples with PR and PVB binders show similar tendensy of variation in pour density and tapping behavior that the pour and tap densities are higher for the MGP milled for 2 hrs than those for the MGP milled for 8 hrs.
2) This is due to the change of powder morphology depending on the milling time, i.e., irregularity and increase of pores etc.

REFERENCES

[1] Y.-W. Lee and M. S. Cho, present transactions, 2011