

Fabrication of HTGR Fuel Compact Matrix Powder Using Jet Milling

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1. Introduction

Block-type High Temperature Gas-cooled Reactor (HTGR) employ cylindrical graphite fuel compacts in which TRISO-coated fuel particles are uniformly dispersed. To achieve homogeneous distribution of TRISO particles within the compact, a process known as *overcoating* is applied. In this process, matrix graphite powder is coated onto the surface of each TRISO particle, enabling even packing during subsequent compaction. The overcoated TRISO particles are then directly pressed without additional mixing with other matrix powders, followed by thermal treatments including carbonization and purification, to produce the final fuel compact.

For overcoating powder preparation, earlier developments by NUKEM and the AGR-1/2 and AGR-3/4 programs utilized the A3-3 process. [1,2] In this approach, resol-type resin containing an embedded curing agent was mixed with graphite powder through kneading and ball milling. However, several limitations were identified: metallic contamination introduced during ball milling and the short shelf life of resol resin due to the pre-mixed curing agent. To address these issues, the AGR-5/6/7 program adopted the A3-27 process. In this method, novolac resin, free of curing agents, was used in combination with a small additive of hexamethylenetetramine (HMTA) as an external curing agent, thereby extending resin shelf life. Furthermore, jet milling was introduced to replace ball milling, significantly reducing the risk of metallic contamination, since the grinding occurs via particle-particle collisions rather than direct contact with milling media.

In the present study, matrix graphite powder was fabricated using the A3-27 process, and particle size distributions of the final powders were analyzed under different jet milling conditions.

2. Method

Natural graphite, artificial graphite, novolac resin, and hexamethylenetetramine (HMTA) powder were blended according to the weight ratios summarized in Table 1. The mixture was homogenized using a 3D-

mixer for 5 hours to ensure uniform dispersion of the resin and curing agent within the graphite powders.

Subsequent pulverization was conducted using a 2-inch jet milling system (Jet Pulverizer Co.), as illustrated in Figure 1. Jet milling was selected to minimize contamination and to obtain fine powders suitable for overcoating applications. Among the various process variables of jet milling, the most influential parameters are the nozzle pressure and the powder feed rate. In this study, two nozzle pressure conditions, 3 bar and 5 bar, were applied to examine their effect on powder refinement. Additionally, the mixed powders were introduced into the milling chamber at controlled feed rates of 1 g/min and 3 g/min. These parameter combinations enabled a systematic evaluation of the relationship between jet milling conditions and the resulting particle size distribution.

Table 1. Compositions and mixing ratios of raw materials for matrix graphite powder

Natural graphite	Artificial graphite	Novolac resin	HMTA
64 wt%	16 wt%	19 wt%	1 wt%



Figure 1. 2-inch jet-milling equipment

3. Results

Figures 2–5 present SEM images of the powders

milled under different jet milling conditions: Figure 2 shows the case of nozzle pressure at 5 bar with a powder feed rate of 1 g/min, Figure 3 corresponds to 5 bar with 3 g/min, Figure 4 to 3 bar with 1 g/min, and Figure 5 to 3 bar with 3 g/min. The results indicate that higher nozzle pressure and lower feed rate lead to finer particle sizes.

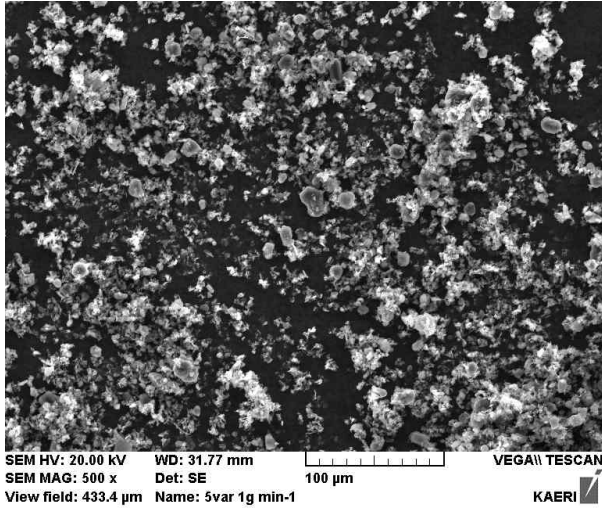


Figure 2. Jet-milled powder in 5 bar and 1 g/min conditions

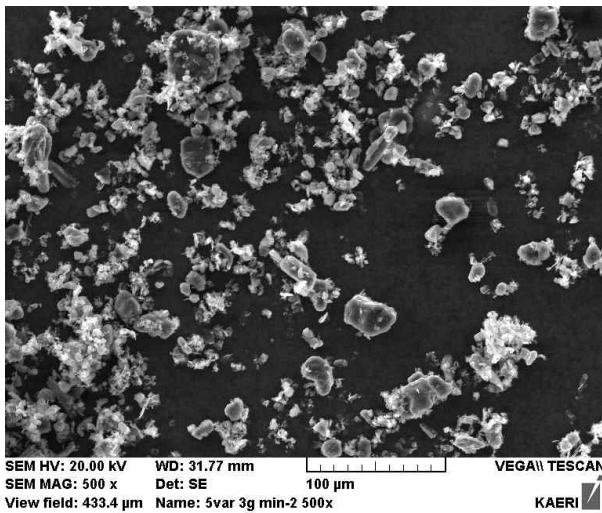


Figure 3. Jet-milled powder in 5 bar and 3 g/min conditions

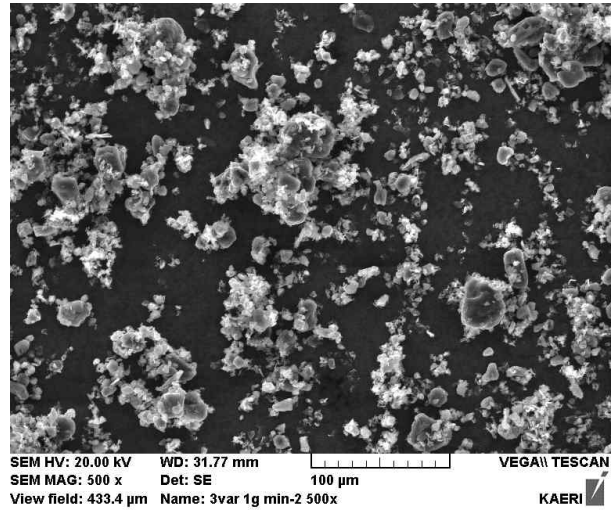


Figure 4. Jet-milled powder in 3 bar and 1 g/min conditions

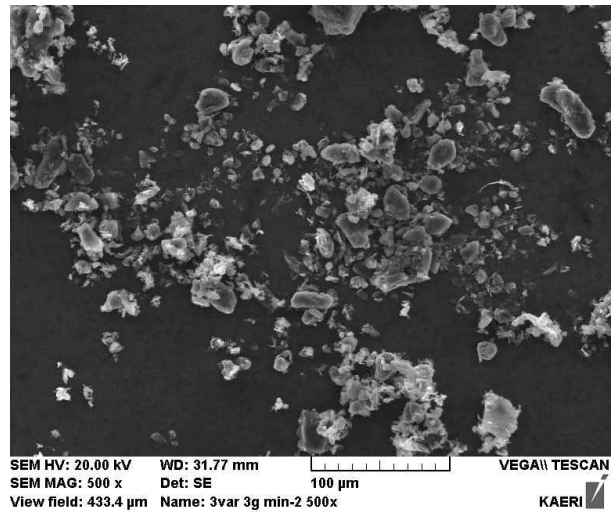


Figure 5. Jet-milled powder in 3 bar and 3 g/min conditions

Table 2 presents the particle size distribution of the milled powder measured using a wet particle size analyzer, which determines particle size by analyzing laser light scattering from particles dispersed in a liquid medium. Here, “D” followed by a number denotes the particle diameter at which the corresponding cumulative percentage of particles is below that value.

Table 2. Results of Particle Size Analysis of the Milled Powder

	5 bar 1 g/min	5 bar 3 g/min	3 bar 1 g/min	3 bar 3 g/min
D10 [μm]	1.17	3.59	3.14	3.42
D50 [μm]	3.11	10.5	8.82	13.3
D90 [μm]	20.8	47.4	52.6	47.8

3. Conclusion

The specification for fabricated matrix graphite powder presented in the AGR-5/6/7 program requires an average particle size (D50) of less than 15 μm . The powders produced under all milling conditions in this study were found to satisfy this requirement, demonstrating their suitability for TRISO fuel compact fabrication. Furthermore, the results clearly indicate that increasing the nozzle pressure and decreasing the powder feed rate lead to finer average particle sizes and narrower particle size distributions, highlighting the strong influence of these parameters on the milling efficiency and powder quality.

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