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Effect of Manufacturing Procedures on the Properties of Gd Pellet

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Abstract

Gd pellets supplied by three vendors have been investigated to evaluate the impact of their manufacturing procedures on physical properties. The data were collected from each vendor's test report for three kinds of Gd pellets. Five physical properties considered to be important for fuel performance were compared. Manufacturing conditions including additives played a decisive role in determining pellet physical properties. Especially, grain size and thermal stability of pellets were greatly affected by the manufacturing conditions. The grain size of pellets is found to increase with addition of Al and Si compounds. As expected, the pellets with large grains are more stable after resintering than the pellets with small grains. There are no significant differences in sintered density and uranium content among three Gd pellets. However, the surface roughness of one Gd pellet is lower than that of the others.

1. Introduction

Gd pellets have been used as a burnable absorber both in PWR and BWR type reactors for more than 20 years. Most of the manufacturing procedures for Gd pellets are not quite different from those of UO_2 pellets except the powder preparation step. Because the characteristics of Gd_2O_3 powders differ from those of UO_2 powders, additional processes are needed for Gd pellets to acquire properties of a burnable absorber. [1] Powder preparation processes such as master mixing and milling are commonly used to meet that purpose. These two steps are used independently or simultaneously depending on manufacturers. In addition to the powder preparation steps, sintering conditions and additives have also an impact on the properties of Gd pellets. Each vendor has developed its own manufacturing conditions, which may generate different Gd pellets. Because there exists no facility for Gd pellet manufacturing in our country, all Gd pellets needed for domestic nuclear power plant should be imported from foreign countries. Four suppliers have supplied Gd pellets to our country. The suppliers have different

manufacturing facilities and conditions for Gd pellets. Therefore, the test results provided by each supplier are quite different though it meets the requirements given in our specification. Therefore, this study has been performed to find the effect of the manufacturing conditions on the physical properties of Gd pellets which will be very helpful in localizing manufacturing technology of Gd pellets in our country.

2. Data acquisition and analysis

Physical properties of Gd pellets were obtained three suppliers which have different manufacturing procedures and experiences. The quality assurance reports [2] which were provided by those suppliers were reviewed and key physical properties were taken from them. The key properties were compared with regard to fuel performance and integrity. They include sintered density, density changes after resintering, grain size, surface roughness and uranium content. In order to find the effect of manufacturing conditions on the properties of Gd pellets, manufacturing procedures of each vendor such as powder preparation, sintering conditions and additive types and contents were classified and analyzed in detail.

3. Comparison of manufacturing procedures

The manufacturing procedures of three suppliers are quite different, as can be seen in Fig.1. They all have their own reconversion facility such as AUC and DC. The difference of manufacturing process between UO_2 and UO_2-Gd_2O_3 is a mixed powder preparation step. In case of UO_2-Gd_2O_3 pellet, some additional processes are needed because Gd_2O_3 powders whose characteristics are much different from those of UO_2 powders are added. The conventional methods that are currently used are mastering blending and milling. These two processes are used separately or simultaneously with the consideration of productivity and manufacturing cost. Among our suppliers, only supplier B does not milled UO_2-Gd_2O_3 powders, while the other two suppliers (A and C) prepare mixed powders using two processes. There are big differences in the utilization of additives among three suppliers. The supplier A does not add poreformers but it uses Al compounds as additives to improve sinterability. The supplier B uses only poreformers. The supplier C adds poreformers and use SiO_2 and Al compounds as additives. The sintering conditions of three suppliers are similar. The sintering temperatures are in the range of 1760 to 1780^{o}C and the sintering atmospheres are wet hydrogen gas even though its dew points are different among three suppliers.

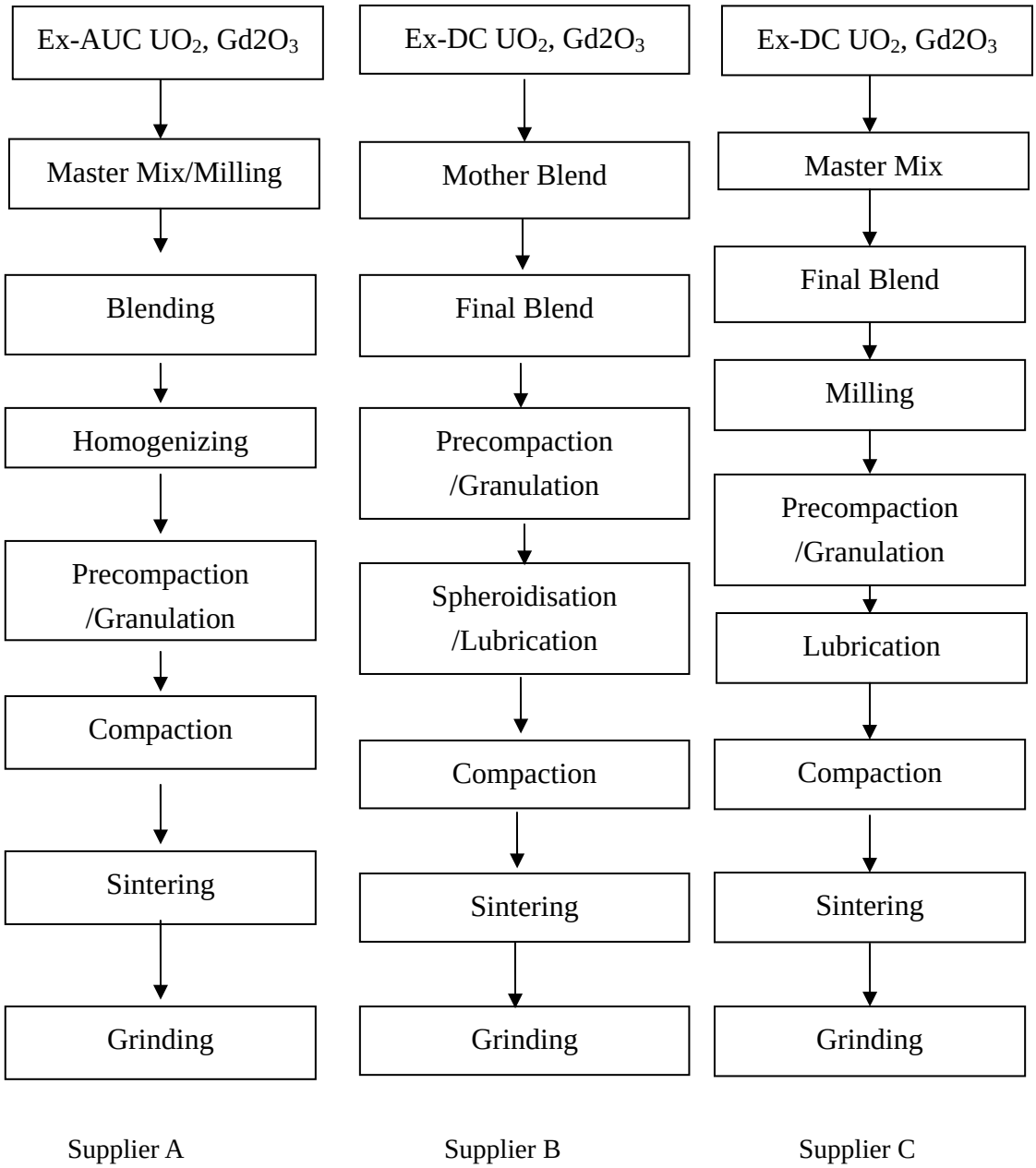

Fig. 1. Manufacturing procedures

4. Results and discussion

According to our specification, the density of Gd pellets should be in the range of 94 ~ 96.5%T.D.. It should be noted that theoretical density of Gd pellets can be written as 10.96 g/cc-0.033×Gd_2O_3 contents(w/o). In general, manufacturers set target value of density and meet them

by controlling the amount of additives, $(U,Gd)_3O_8$ and/or poreformers. All three suppliers' Gd pellet densities are found to be in a range of 95 to 95.7%, as can be seen in Fig. 2.

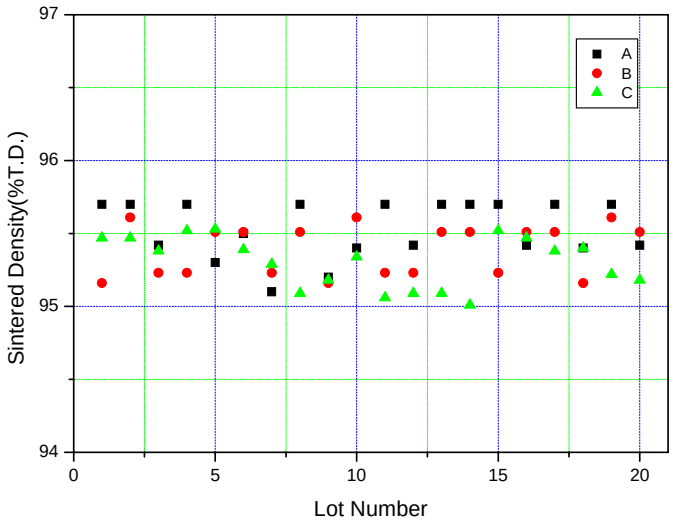

Fig. 2. Comparison of density variation

Grain sizes of Gd pellets can be different depending on manufacturing conditions such as sintering atmospheres and additive contents and types. Three supplier's sintering conditions are nearly the same while their additives are different. It can be clearly seen that grain sizes changes according to manufacturing conditions. From Fig. 3, grain sizes of Gd pellets supplied by the supplier C is greater than that by the supplier A and B. This is because the supplier C uses additive such as Al compounds and SiO_2 which cause grain growth. It is generally known that Al compounds act as a grain growth promoter and if SiO_2 is added simultaneously, its effect becomes greater due to the formation of liquid phase along the grain boundary. Table 1 shows the impurity contents of each supplier's pellet. This table shows that quite a large amount of Al and Si is included in Gd pellet of the supplier C. It is also generally known that the amount of densification after resintering is determined by initial sintered density, and microstructure of pellet. As there is no substantial difference in sintered density among the three suppliers, Gd pellet's pore size distribution and grain sizes may play a decisive role in determining thermal stability. Fig. 4 shows the density changes of the pellets after resintering. As expected, the pellet of the supplier B with the smallest grain shows the largest density change after resintering.

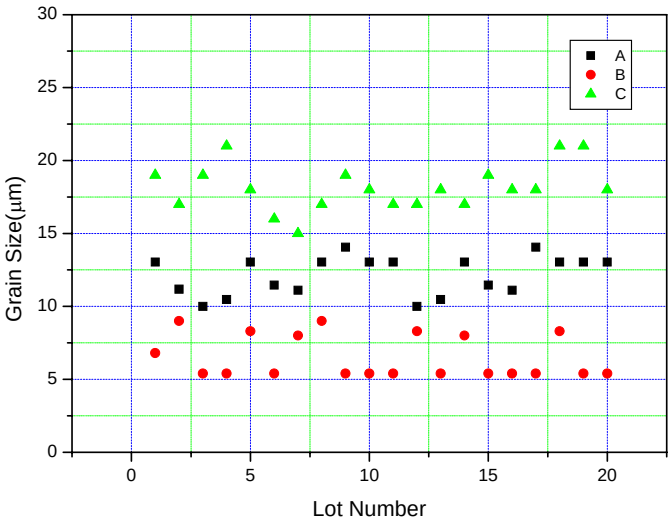

Fig. 3. Comparison of Grain size variation

	A	B	C
Al	95	21	112
Si	11	10	28
Ca	5	10	30
Mg	2	1	5
Cr	2	10	10
Fe	16	10	38
Ni	1	5	5
Th	0.2	1	1
Cl	3.2	3	2
F	3.6	3	1
C	9.2	5	5
Ni	5	10	5

Table 1. Comparison of impurity level in the pellet

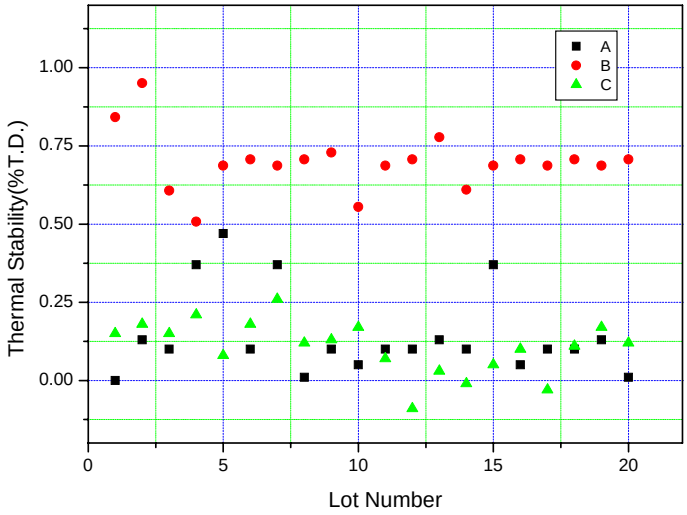

Fig. 4. Comparison of density change after resintering

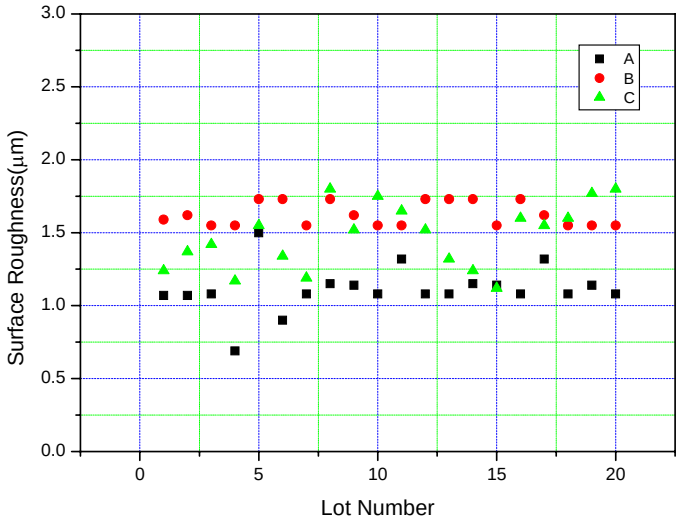

Fig. 5. Comparison of surface roughness

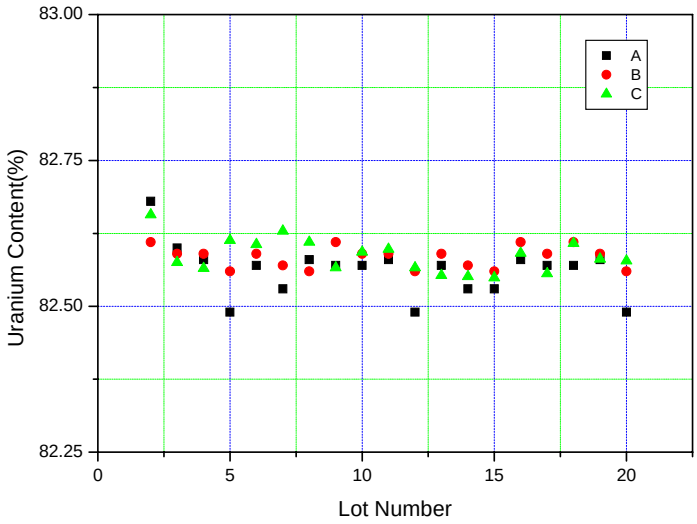

Fig. 6. Comparison of uranium content

On the other hand, there is no difference in uranium content among three supplier's Gd pellets but surface roughness of the supplier A is lower than that of the other suppliers.(Fig. 5,6) It is thought that this is due to the differences of UO_2 powder and additive the supplier used.

5. Conclusions

The properties of Gd pellets which have been imported from three different suppliers are compared and the effects of manufacturing conditions on them are investigated. Three suppliers which were inspected have different manufacturing procedures. All of them have a master mixing process and two of them have a milling process simultaneously. For the purpose of increasing homogeneity and thermal stability of Gd pellet, wet hydrogen gas is used and Al compounds and SiO_2 are added independently or simultaneously depending on manufacturer. Due to these manufacturing differences, Gd pellets properties of the three suppliers are quite different. In case of grain size, Gd pellets of the supplier C which are fabricated through master mixing and milling and Al_2O_3 and SiO_2 are added have the largest grain, which lead to the smallest density changes after resintering. There is no significant difference in density and uranium content among these three Gd pellets but surface roughness are slightly different depending on the supplier.

Acknowledgement

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References

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2. Inspection Report for Gadolinium Uranium Dioxide Fuel Pellets.