Development of Powder Mill Remotely Operated in Hot-cell

Jung Won Lee*, Jae Won Lee, Young Hwan Kim, Geun Il Park
Korea Atomic Energy Research Institute,1045 Daedeokdaero, Yuseong, Daejeon, Korea, 305-353,
*Corresponding author: *jwlee3@kaeri.re.kr*

1. Introduction

The Korean government has maintained the "*wait and see*" policy for spent fuel management, while several alternative options have been studied at KAERI as a part of the national long-term nuclear R&D program. The DUPIC is one of the prominent approaches among R&D activities in this area. Recently, based on the national long-term R&D plan, finalized at the 255th Atomic Energy Commission in the end of 2008, the R&D activities to develop the SFR-pyroprocessing mechanism for a future nuclear energy system are in progress [1]. Since 1992, KAERI has developed pyro-processing technologies which are composed of head-end process, electro-reduction, electro-refining, electro-winning, and waste treatment. The aim of head-end process is to produce a feed material suitable for electro-reduction. The type of feed material can be granule or pellet depending on the electro-reduction efficiency, but its composition should be homogeneous from the viewpoint of material accounting. In order to make a feed material in homogeneous composition, the powder produced from a voloxidation process should be treated by using mixing process. In this paper, based on the lessons learned from DUPIC technology, the powder mill system to be used in a remote manner for the head-end process of pyroprocessing was investigated.

2. Experiments

Considering the remote operation in hot-cell, a horizontal rotary ball milling has been chosen for the dual purpose, mixing and milling, as a result of milling performance test in comparison with a planetary ball milling. And operating conditions, such as milling media, media wear and rotor speed were investigated with Al_2O_3 powder.

2.1 Mixing in a Remote Manner

There are many kinds of mixer [2]. To accomplish a homogeneous mixture, it is more effective to combine milling and mixing. It is also considered that mixing work should be conducted in a remote manner in hot-cell. Based on these requirements, milling test was carried out by using a horizontal rotary ball mill (Zoz, Model; CM01) and a planetary ball mill (Model; Fritsch Pulverisset-5) with a rock-like ore (Serpentine, $Mg_3Si_2O_5(OH)_4$). Milling test is conducted in a dry atmosphere by using the crushed ore powders having average particle size of 20.6 ㎛ after screening with a sieve 200 mesh. After milling, the particle sizes were measured by a laser light scattering instrument (U.K. Malven Co. Model; Mastersize/E).

(a) (b)

Fig. 1. Ball mill; (a) a horizontal rotary ball mill, (b) a planetary ball mill

2.2 Milling Performance Test

Chemical grade Al_2O_3 powders (Aldrich Chemical Co. Ltd) with 99% of purity were used for the performance test and the establishment of the milling conditions. 100g of the powder was charged into the milling chamber. The weight ratio of powder to ball was 1:10. Two kinds of milling media, steel (100Cr6) ball and zirconia (ZrO_2) ball, were used. The average diameter of the milling ball is 5mm. Several rotational speeds were chosen to investigate the optimum conditions.

3. Results and Discussions

Fig. 1 shows the variation in particle size of a rock-like ore with the milling time in a different milling method. As shown in this figure, the minimum particle of 7 ㎛ is reached in 120 minutes at the rotation speed of 300 rpm for a planetary ball mill, but reached in a few minutes for a horizontal rotary ball mill. It means that a horizontal rotary ball milling system is much more effective for milling. The basic function of this mill is the same as that of an attritor, which is a mill containing internally agitated media [3]. The operation of the mill is very simple. Conclusively this mill system is evaluated better for using in hot-cell.

Fig. 2 shows the variation in the particle size of Al_2O_3 powder in terms of two kinds of milling media, steel and zirconia balls, with the milling time. As shown in the figure, almost the same particle size reduction was observed regardless the ball materials, steel ball and zirconia ball.

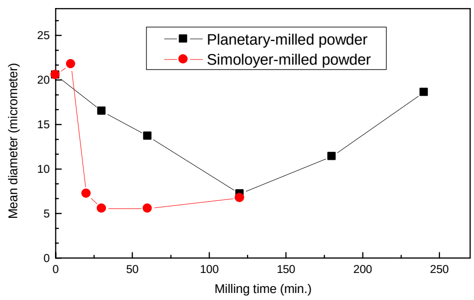

Fig. 1. The variation in particle size of a rock-like ore with the milling method.

This means that both balls can be used. The particle size quickly reduces and reaches to about 3.7 ㎛ after 10 minutes of milling at 1200 rpm in the early stage of milling. Subsequently it still tends to decrease slightly by milling up to 30 minutes, but the variation is very small and almost independent of the milling time. Further milling beyond this range, however, resulted in an increase in the particle size up to 6.8 ㎛. Thus, most of the particle size reduction of the powder seems to be completed in the early stage of milling, the fine particles agglomerate upon prolonged milling. This may be due to the mechanical activation caused by prolonged dry milling [4].

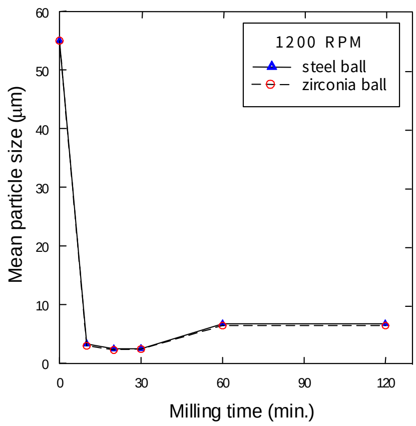

Fig. 2. The variation in particle size of Al_2O_3 powder with the milling time by suing different ball materials.

According to the analysis results of impurity contents, Cr, Fe, and Zr, are generated during milling at 1200 rpm. Fe and Cr contents increase with the milling time, but Zr content remains as the same as that of early stage. In the case of steel balls, Fe content increases rapidly by 0.2 wt% and Cr content increases gradually by 0.1 wt% after 120 min of milling. The increase of Fe and Cr contents, while little change in Zr contents, is considered to be closely related to the materials of the milling media and chamber, which are chrome steel (100Cr6) and stainless steel, respectively. The increase of Fe and Cr contents, as major impurities, during milling is attributed to the breakage and the wear of the milling media and chamber, while zirconia balls are very hard and high wear resistant. From these results, the zirconia ball is better than the steel ball from the viewpoint of particle size reduction and contamination control.

3. Conclusions

Considering the mixing efficiency with grinding and the remote operation in hot-cell, a horizontal rotary ball mill is recommended for making homogeneous powder which is used to produce feed material such as granule or pellet. To evaluate the milling performance, the milling conditions with this mill were investigated. The results show that (1) A horizontal rotary ball mill is preferable to a planetary ball mill and suitable for operation in a remote manner. (2) From the viewpoint of contamination and size reduction of the milled powders, lower rotational speed, shorter milling time and zirconia ball media are optimal conditions.

ACKNOWLEDGEMENTS

This work has been carried out under the Nuclear Research and Development Program supported by the Ministry of Education, Science and Technology in the Republic of Korea.

REFERENCES

[1] NRF, The 1st Workshop on The Future Nuclear Energy System, June 11-12, 2009, Heongsung, Korea.
[2] R. M. German, Powder Metallurgy Science, Metal Powder Industries federations, New Jersey, pp.171-177, 1994.
[3] D. A. Stanley, L. Y. SadlerIII, D. R. Brooks and M. A. Schwartz, Ceramic Bulletin, Vol.53, p. 813, 1974.
[4] Q. Zhang, E. Kasai, H. Mimura and F. Saito, Advanced Powder Technol., Vol.5, p.289, 1994.