The development of a cyclone-filter for the removal of hot particulate from the inside surface of the hot cell

Gye-Nam Kim, Cheol-Jin Jeong, Hui-Jun Won, Wang-kyu Choi, Chong-Hun Jung, Won-Zin Oh , Jin-Ho Park

Researcher, Korea Atomic Energy Research Institute, kimsum@kaeri.re.kr
Korea Atomic Energy Research Institute, 150 Duckjin-dong, Yuseong-gu, Daejeon, Korea

1. Introduction

Generally, each nuclear hot cell at KAERI executes several different kinds of reaction processes, for example, oxidation and reduction reactions for DUPIC(Direct Use of spent PWR Fuel In CANDU reactors), spent fuel treatment such as an extension, destruction, pulverization and cutting, group separation, chemical convention processes etc., with high radioactive materials such as uranium and zirconium alloy. Due to the generation of hot particulate during these processes, the level of radioactivity becomes very high inside each hot cell. Therefore, a periodical removal of the hot particulate in a hot cell is necessary to reduce the radioactivity level. A cyclone could be considered, as one of the most advantageous decontamination tools for a hot particulate removal from a hot cell at KAERI, South Korea. Cyclones are devices that employ a centrifugal force generated by a spinning air stream to separate the particles from the carrier air [1-3].

2. Experimental

The actual size of the cyclone filter train made of steelness steel is shown in Figure 1. It's highly stable under high radioactive environments and the durability of this cyclone filter train is longer inside a hot cell.

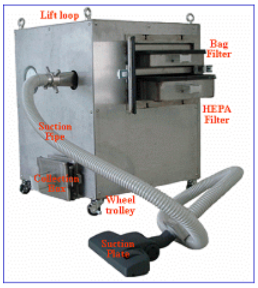

Figure 1. An actual view of fabricated cyclone

Figure 2 compares the collection efficiencies of the cyclones with different vortex finder lengths, at different inlet flow rates. The collection efficiencies of the cyclone changed with the vortex finder lengths. Many researchers [4-5]have observed that the effect of the vortex finder length on the particle collection efficiency may be important due to its role in controlling the inner area of a cyclone, which means that, in a cyclone with a short vortex finder length, the inner area of a cyclone is larger than a long vortex finder length. Meanwhile, a long vortex finder length would influence the particle movement to the lower part of the cyclone, which collects the particles on the cyclone wall or bottom. This would force an increase of the pressure drops inside the cyclone. On the increase of the vortex finder length to the selected limit, the collection efficiency of the cyclone increases and the cut size diameter decreases. But over the limit of the vortex finder length, the collection efficiency begins to decrease. A higher collection efficiency was measured with a vortex finder length of 65 mm, S/D_c=0.65. Therefore, the vortex finder length is very important to achieve a higher particle collection efficiency for a cyclone. These figures also illustrate the effect of the inlet flow rates on the collection efficiency. The collection efficiency of the cyclone increased with an increase of the particle size and the inlet flow rate. For the inlet flow rate range from 8m/sec to 20m/sec, the increased rate of the collection efficiency was not so much for the inlet flow rates faster than 15 m/sec. It was found that the inlet flow rate of 15 m/s was the best condition for this cyclone efficiency.

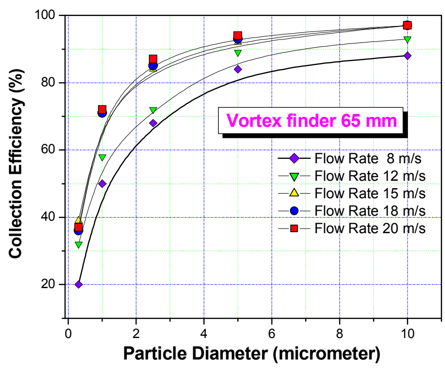

Figure 2. Collection efficiency versus particle diameter (vortex finder 65 mm)

To evaluate the feasibility of operating cyclones at high inlet flow rates, the pressure drops of the cyclone filter trains for different inlet flow rates were measured. As expected, the pressure drop is seen to become higher with an inlet flow rate increase. Additionally, the pressure drop increases substantially as the vortex finder length becomes longer or as the cylinder height becomes shorter. Pressure drops which decrease in longer cyclones may be due to an additional space. As a result, the greatest pressure drop occurs at 20 m/s for the longest vortex finder length. It should be noted that the highest pressure drop we obtained, was 26 cm of water (2.548 kPa), which almost equals 2.5 kPa which is the maximum pressure drop generally allowed in cyclone pre-cleaners. Since the pressure drop is, in general, a measure of the energy which the cyclone consumes, care must be exercised to balance the effects of the vortex finder length of a cyclone for both the collection efficiency and the pressure drops. However, it is not advisable to operate a cyclone at an excessively high inlet flow rate.

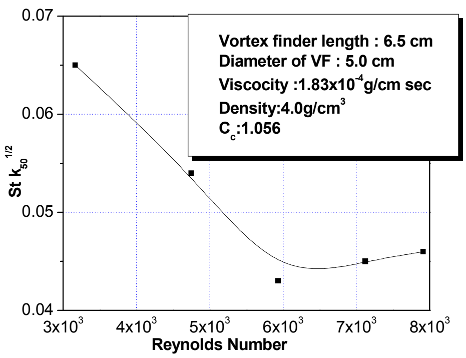

Figure 3. Correlation between the Storkes number and the Reynolds number

Figure 3 shows the correlation between the Stokes number and the Reynolds number. Values of $Stk_{50}^{1/2}$ decreased with increasing values of the Re and they gradually approached a constant value at higher values of the Re as Moore and McFarland predicted. Namely, $Stk_{50}^{1/2}$ approached approximately 0.045 between 6,000 and 8,000 of the Re..

The temperature effect on the air laden with particles was investigated for a cyclone with a vortex finder length of 65 mm. The collection efficiency of 20˚C is higher than the collection efficiency of 80˚C, which indicates that the collection efficiency decreases as the temperature of the inlet air laden with particles increases. The collection efficiency of the fine particles was affected less than that of the bigger particles and the variation of the 1.0 µm size particles was the highest. It is well known that an air flow is established by an curved flow in an cyclone. When the temperature of the air laden with inlet particles increased, the collection efficiency slightly decreased. It may be due to the change of the air flow from a turbulent flow to a laminar one in the cyclone. **B**oth flows are similar in the angular velocity of the air streams in which the mean acceleration forces on the particle. But the particle deposition rate is higher in the turbulent flow than in the laminar flow, because the particle concentration gradient is decreased by a turbulent mixing.

3. Conclusion

The cyclone was designed and manufactured to be suitable for contamination characteristics and the structural characteristics of a KAERI hot cell, which was made from stainless steel with the dimensions of 0.7x0.55x0.55m and a weight of 60kg, and can be operated by a manipulator. Collection efficiency of the cyclone was considerably affected by the vortex finder length and the corresponding inlet flow rates. A vortex finder length of 65 mm (S/D_c=0.65) and an inlet flow rate of 15 m/s were the best condition for the efficiency of the cyclone. Values of $Stk_{50}^{1/2}$ decreased with increasing values of the Re and they gradually approached a constant value at higher values of the Re. The collection efficiency gradually decreased with the temperature of the inlet air

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