301a Simulations of Spouted Beds for Coating Triso Fuel Particles

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Spouted beds have been long used for various applications including coating particles (Mathur and Epstein, 1974). Spouted beds have been applied to coat nuclear fuel particles starting in 1970s, when there was renewed interest in the nuclear power due to the world-wide energy crisis and various countries including US have started looking at alternate safer nuclear power plants. It was proposed to coat the nuclear particles (around 500 microns) with amorphous carbon, pyrolytic carbon and Silicon Carbide (SiC) called the TRISO particle. The coated particles are then compacted using resin to form pebbles which go into a reactor like pebble bed reactor. The coatings need to have extremely high quality with failures less than 1 in 10000 or less to ensure in-reactor retention of fission products (fuel performance). Germans produced some of the best fuel through several decades of trial-and-error experimental process (Heit, 1986). The US had an active fuel coating program but the coating quality never met the required quality (Noren and Devalasco, 1992). The nuclear fuel coating has been revived recently and controlled experiments along with developed multiphase flow modeling tools are targeted to produce high quality coated particles (Lowden et al, 2004; Pannala et al, 2004). Spouted beds represent excellent examples where all the regimes of particulate flows can be found in a single device.

Spouted beds are similar to a water fountain in appearance and dynamics. In the core region, the loading of particles is small (a few volume percent); the particles (from the annular region) are picked up by the gas entering at the bottom and carried up. At the top of the bed, a fountain of particles transfers them from the core to the annular region. In the annular region, a dense assembly of particles descends slowly, and at the boundary separating the core and annular regions, complex interaction occurs between the particles.

This paper will report on the process-modeling activities carried out in support of the small coater process development and how the model can help the transition from laboratory scale coaters to production scale coating equipment. A major challenge is to account for the effects of the turbulent gas-solids contacting in the fluidized bed reactor on the rate controlling factors and the final product quality of the chemical vapor deposition process. A detailed multiphase Computational Fluid Dynamics (CFD) model (MFIX – http://www/mfix.org) is used to simulate the hydrodynamics, heat and mass transfer, and chemical reaction kinetics on the particle surfaces. Experimental validation is performed at each stage of development to ensure that the model predictions are consistent with the actual physics and chemistry. The latter is critical to the implementation of successful scale-up from the laboratory to production prototype.

It is anticipated that the modeling process will ultimately lead to both highly detailed and low-order descriptions of the coating process that will have more than one use. At one end of the spectrum (e.g., with CFD implementation), it should be possible to predict the effects of design and operating changes on the detailed physical properties of the particle coatings as well as the effects of scale. The potential power of CFD is balanced by the fact that it requires very large computational resources (e.g., parallel computing) and considerable simulation times. At the other end of the spectrum (e.g., with low-order agent-based implementation), spatial detail is sacrificed for much greater computational speed and the possibility of on-line diagnostics and control. Both of these avenues are pursued in the overall program at Oak Ridge National Laboratory (ORNL). Ultimately, it is expected that modeling will not only help to replicate the previous production-scale quality of the German fuel, but it should provide approaches for improvements beyond that previously achieved.

References:

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