Plant-Scale Model Development for Fuel Recycling

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The overall goal of this plant-scale model development is to produce a computational model of a used fuel reprocessing plant. Since there is interest in modeling various reprocessing technologies, a computational model needs to be flexible to account for corresponding variations of a plant layout and flowsheet. This can be accomplished by building the model by composition of modules, i.e., a computer software realization of models representing significant processes. To that end, an integrated reprocessing plant is envisioned as a collection of all physicochemical processes needed to transform spent nuclear fuel into new fuel and waste forms. The long-term vision for this work is the development of a fully integrated, dynamic, plant-level simulator able to design and optimize, a reprocessing plant based on a toolkit concept. This requires the development of modules following a given architecture and the integration of these modules into an environment.

The work in FY13 entailed three tasks – module development for common architecture; module integration into a plant-level environment; and roadmapping future development of modules for separations.

The first task continued the development of plant-level modules for an integrated recycling plant simulator. The modules are realizations of mathematical models into computer software for three processes, namely, voloxidation, dissolution, and solvent extraction. These are in development following a commonality approach to enable the design of future integrated process modules with a common architecture; as such, they are prototypes for development of modules for other processes. During FY13, progress was made in modeling and development of computational modules for two unit operations – dissolver (fig. 1) [2] and voloxidizer [3] (fig. 2) and. Time integration coupling between a module and an external host code or environment has been described/proposed previously [1]. Recently, the dissolver module has been fully integrated into an application [4]. Time coupling was achieved by making the whole history of the state variables available to the application; this worked well for the testing intended. Additional development is needed in this topic for future larger integration.

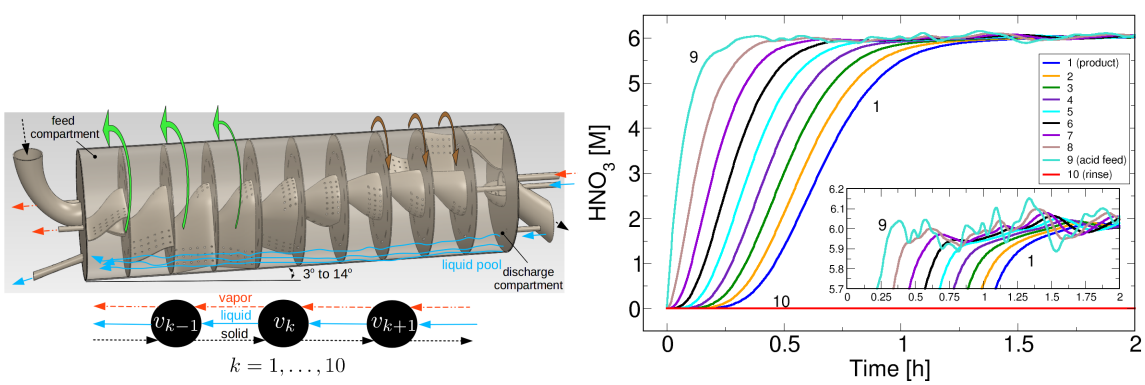

Fig. 1. Rotary dissolver module Nitron [2].

[1] Oak Ridge National Laboratory is managed by UT-Battelle, LLC for the U.S. Department of Energy under contract DE-AC05-00OR22725

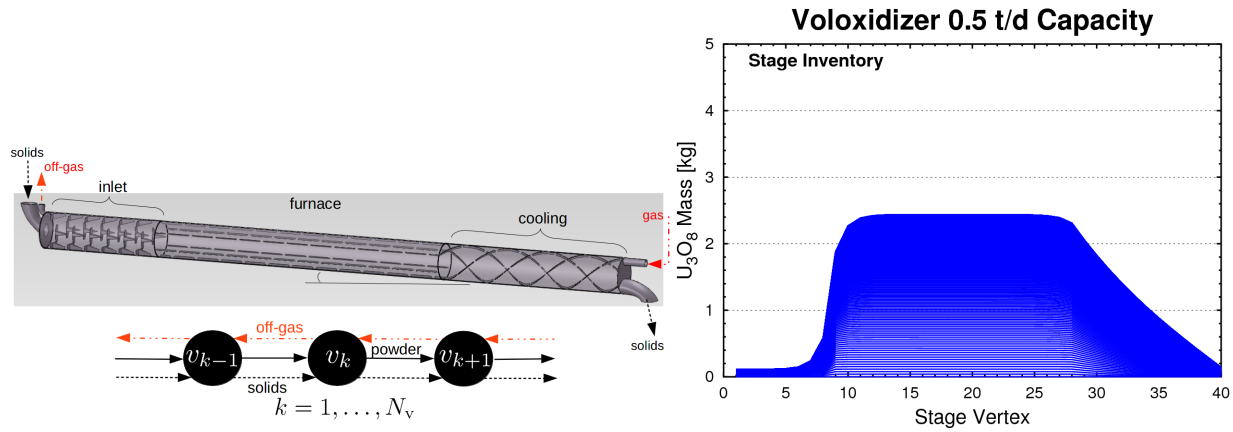

Fig. 2. Rotary voloxidizer module Pulvox [3].

The second task continues the integration of one of these modules, dissolution, into the Separations and Safeguards Performance Model (SSPM) developed at Sandia National Laboratories (fig. 3) [4]. This effort, conducted by collaboration of ORNL with SNL, is aimed at providing improved rigor to the modeling and simulation capabilities of SSPM and to test and analyze the integration of modules into a third-party environment. This experience helps refine the architecture of the modules developed in the first task. In FY13, the dissolver module, Nitron, was integrated into the SSPM successfully. A MATLAB open source version of Nitron was used for this purpose.

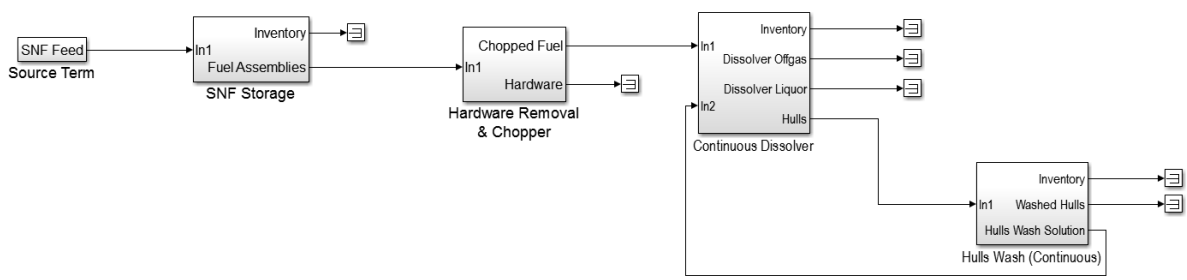

Figure 3 – Simplified SSPM (Sandia) front end for Nitron integration testing.

The third task involves roadmapping the development of additional separation process modules related to the work performed by the Separations and Waste Forms campaign. Topics involving solvent extraction (e.g., integration of SXFIT with SSPM to enable evaluation of candidate processes for minor actinide separations), off-gas management (development of adsorption bed modules for integration with SSPM), and continued development of additional plant-level modules are candidates.

[1] de Almeida, V. F., Progress on Plant-Level Components for Nuclear Fuel Recycling: Commonality. Letter Report ORNL/LTR-2011-176, Oak Ridge National Laboratory, September 2012. Also available by request to dealmeidav@ornl.gov.

[2] de Almeida, V. F., Progress on Plant-Level Modeling and Simulation of Used Nuclear Fuel Dissolution: Startup Condition with Quasi-Developed Flow and Varying Acid Concentration, ORNL/LTR-2013/437, Oak Ridge National Laboratory, September 2013. Also available by request to dealmeidav@ornl.gov.

[3] de Almeida, V. F., Progress on Plant-Level Components for Nuclear Fuel Recycling: Voloxidizer. Letter Report ORNL/LTR-2012-26, Oak Ridge National Laboratory, September 2012. Also available by request to dealmeidav@ornl.gov.

[4] de Almeida, V. F., Cipiti, B. B., McDaniel, M. D., DePaoli, D. W., Milestone Letter Report – Plant-Scale Model Development, ORNL/LTR-2013-438, September 2013.