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QA program which meets the requirements of
☒ - DOE Order 414.1 ☐ NQA-1-2000 ☐ Other

This Deliverable was subjected to:

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Technical Review (TR)	**Peer Review (PR)**
Review Documentation Provided	**Review Documentation Provided**
☐ Signed TR Report or,	☐ Signed PR Report or,
☐ Signed TR Concurrence Sheet or,	☐ Signed PR Concurrence Sheet or,
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Report on results of current and future metal casting

by

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Abstract

New modeling capabilities needed to simulate the casting of metallic fuels are added to Truchas code. In this report we summarize improvements we made in FY2015 in three areas; (1)Analysis of new casting experiments conducted with BCS and EFL designs, (2) the simulation of INL's U-Zr casting experiments with Flow3D computer program, (3) the implementation of surface tension model into Truchas for unstructured mesh required to run U-Zr casting.

Caster design with a straight cup mold did not cast. Potential reasons are speculated. Truchas heat transfer models are constructed for BCS and EFL designs and steady state temperatures are calculated. Results indicated that EFL design lost 18% more heat to mold resulting in U-Zr liquid temperatures at the bottom of crucible that are close the liquidus temperature of U-Zr mixture. Mitigation options are explored. It is concluded that the skirt must be redesigned.

Computational simulations of gravity casting for metallic U-Zr nuclear fuel rods were performed with the flow solver Flow3d. Numerical simulations were validated with experimental data obtained by Idaho National Laboratory (INL). The experimentally measured transient temperature profiles inside the casting apparatus were matched by adjusting primarily the heat transfer coefficients between melt and mold at different locations. The volume of the rods cast, length of rods were predicted through the transient casting process and were found to be in a reasonable agreement with experimental data. A sensitivity analysis with vent locations, pressure, mesh refinement and effects of the surface tension at the interface was explored. This work provides specific guidelines on

using numerical experiments for better understanding of the gravity casting process. This work also serves as a validation benchmark for the casting problem and provides guidelines when performing simulation exercises for modeling casting. The validated modeling parameters will be used in the simulation of larger size caster with larger outputs in the coming fiscal year.

A new method for curvature calculation in Truchas is investigated. The new method computes curvature as an L2L2 projection (L1L2 refers to minimization with respect to L1 with an L2 smoothing term (L2 norm of the derivatives), and L2L2 refers to minimization with respect to L2 with an L2 smoothing term), rather than a convolution (existing method in Truchas). The major drawback of the convolution method is that the method is local to the interface, and requires a search for neighboring elements. The search limits its implementation to serial only. The projection approach requires a global linear solve, that is easily parallelized. In addition the projection is elliptic in nature, thus applicable to scalable multigrid methods.

Preliminary results of implementing a curvature algorithm into Truchas shows agreement with the legacy method and published results. We examined a method to compute the curvature in a Volume of Fluid (VOF) method based on weighted L1L2 and L2L2 projections and compare the projection method against the legacy method in the Truchas code.

Problem studied was a static drop problem. A square 2D domain was [0, 8]x[0, 8] with an interface of radius R = 2 centered at (4,4). The exact curvature is given by $1=((x - 4)^2 + (y-4)^2)1=2$. Surface tension coefficient of 73 dyne/cm, a density ratio of 10^3, and x = .4, .2, .1, .05 were used in this test problem. We compared results with results from a previous LANL publication. L1L2 method showed good qualitative agreement with the results obtained by the convolution method.

Below we present the details of improvements and achievements in each area in separate sections. The primary author who did the work is listed in each section.