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Numerical Thermal Model of Liquid-to-Solid Phase Change of Free Falling CuCl and AgCl Droplets

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ABSTRACT

Extracting hydrogen from nature is an arduous and energy intensive process and the challenge is aggravated as most of the current H_2 production methods are not eco-friendly. A promising alternative is the copper-chlorine (Cu-Cl) cycle in which the constituents are recycled internally on continuous basis without emitting pollutants into the atmosphere. The Cu-Cl cycle is one of the hydrogen (H_2) production methods, in which cuprous chloride (CuCl) salt is cooled down from 500 °C to 80 °C and reacted with hydrochloric acid (HCl) in stoichiometric proportions to produce the anolyte for the H_2 production step of the cycle. This paper focuses on enhancing the overall thermal efficiency of the Cu-Cl cycle by recovering heat from molten CuCl salt, the output of one of the cycle's three reactors. It has been determined that approximately 350 kJ of waste heat energy can be recovered during the production of 1kg of hydrogen. A novel numerical method is adopted to analyze the quenching process to estimate the heat that could be recovered and the temperature distribution of the CuCl droplet with its surroundings at different timesteps. The interactions between droplets with the nitrogen (N_2) are modeled numerically in COMSOL Multiphysics for various droplet sizes of CuCl and silver chloride (AgCl), as the droplets are cooling, and the salts are changing phase from molten to solid. The heat recovery analysis shows that the average internal temperature of the droplet does not change significantly with droplet diameter and quenching height. To validate the results the heat distribution around a droplet of AgCl has been modelled since the thermophysical properties of AgCl are widely available. As a result of this study it has been determined that the heat transfer rates are significantly higher for AgCl compared to CuCl for identical droplet diameters since AgCl has higher thermal diffusivity.

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