Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

CFD modeling of an air-argon binary gas mixture for optimizing argon distribution in a semi-closed enclosure under non-vacuum conditions

Nourhen Jouini[1], Maha Bhouri[1], Jean Brousseau[1], Véronique Dassylva-Raymond[1], Jean-Sébastien Deschênes[1]

[1]Department of Mathematics, Computer Science, and Engineering, University of Quebec at Rimouski, Rimouski, Canada

ABSTRACT

Many industrial processes use gas purging techniques to create inert atmospheres. For example, in additive manufacturing of metal parts, the printing chamber is filled with inert gases such as nitrogen or argon to prevent oxidation of the molten metal. This ensures the integrity of printed components by maintaining a controlled, protective environment during manufacture. In aluminum recycling, the injection of inert gases under non-vacuum conditions into the furnace serves to protect the molten aluminum from atmospheric oxygen, this mitigating oxidation and minimizing scum formation. This work involved a computational fluid dynamics (CFD) analysis to improve argon injection in a semi-closed enclosure initially filled with heated air. The objective was to achieve optimal argon saturation at a designated surface through the analysis of diverse injection settings. The binary air-argon mixture was simulated using a methodology that integrates the k-ε turbulence model, fluid heat transfer, and the transport of concentrated species. The mathematical model was then solved with COMSOL Multiphysics. The research examined how injector position, number of injectors, injection flow rate, and the distance from the gas input to the target surface affect argon distribution within a semi-closed enclosure. Understanding these factors is crucial for optimizing injection configurations and achieving desired gas distribution outcomes. The simulations were conducted on a semi-closed enclosure with a volume exceeding 3 m³ over a 1-hour injection interval. The simulation results indicate that the injector's position does not significantly influence the argon mass fraction at the target surface or throughout the enclosure's volume, as similar outcomes were observed across three distinct injector positions. The simulation results also demonstrate that the argon concentration is significantly influenced by the injection flow rate. For example, after one hour of injection, the mass fractions were 83%, 68%, and 60% for flow rates of 40, 30, and 20 L/min respectively. Furthermore, the distance between the gas inlet and the target surface significantly influences inertization efficiency. Reducing this distance enhances inertization by promoting more uniform and rapid argon coverage. The results show that industrial processes can be optimized through real-time flow rate adjustments based on this parameter. Industrial applications involving semi-closed enclosures with minimal gas evacuation, where inert gas injection is performed in non-vacuum environments, are particularly relevant to these results. The findings of this investigation provide recommendations for optimizing inertization techniques and enhancing gas injection strategies, leading to improve process efficiency in industrial environments.

Keywords: COMSOL, binary gas mixture, CFD, transport of concentrated species, semi-closed enclosure, non-vacuum injection, industrial gas inertization.