ISSN: 1999-6691, e-ISSN: 2782-3709 DOI: http://doi.org/10.7242/1999-6691/2024.17.4.36

Research article

Mathematical model of solder flow in a vertical tube at different gravity levels taking into account the wetting and melting processes

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The motion of a solder inside a ceramic tube with an aluminum insert is considered using the phase-field model of multiphase flows. The problem is solved in the non-isothermal formulation, which allows analyzing the two-phase flow dynamics and the kinetics of the contact line driven by wetting. The total time required for the solder to heat up, melt and then move inside the tube is calculated accounting for its position in the insert and action of wetting forces. The melting heat of the solder is taken into account in the system through the introduction of effective heat capacity as a function of temperature. The values of the dimensionless Bond, Rayleigh, Grasgoff and Marangoni numbers are calculated, which made it possible to analyze the contribution of various physical phenomena to the behavior of the system. It was found that the effect of gravity forces on the shape of the upper and lower free surfaces of the melt is not significant because of the small weight of the solder and the small diameter of the tube. The graphs showing the variation in the center of mass of the solder are obtained. The model predicts the solder leakage from the insert in the presence of gravity, while under microgravity this does not happen. The velocity fields, which develop in a liquid solder at the gravity levels of 1g and μg, are analyzed. Under microgravity conditions, the maximum velocities are caused by the movement of the melt due to wetting forces, while in Earth gravity the average velocities are two orders of magnitude higher since convection currents are present near the walls of the tube. A small thermocapillary effect on the average flow velocity was noted as a result of low temperature gradients.

Keywords: two-phase flow, surface tension, solder melting, wetting contact angle, gravity, mathematical model

Received: 30.05.2024 / *Published online*: 30.12.2024

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