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An Investigation of Cooling Characteristics in Air-Mist Cooling by Eulerian-Lagrangian Method with V2F Model

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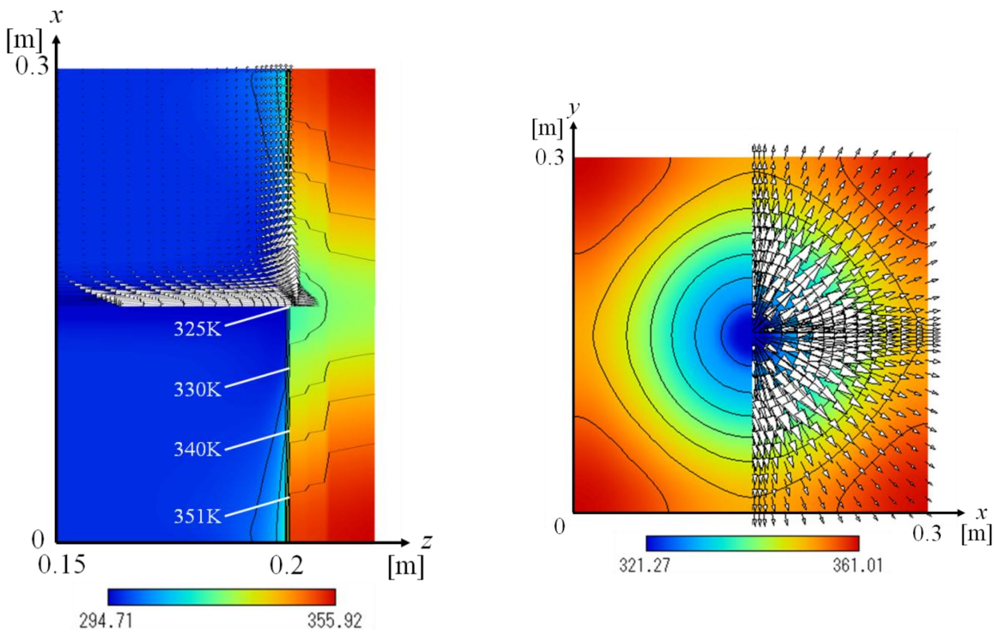
Many industrial devices require the abilities to remove high heat quickly with the development of industry in the region of high speed electrical components [1] or high power leasers [2] and so on. These requests will not be met by the limited capacity of convectional cooling technologies such as forced convection. An air-mist cooling [3, 4] is a very efficient technique for dissipating high heat fluxed with low coolant mass fluxes at low wall superheats. It is used in a wide range of applications from metal quenching over cooling of high power electronics to medical treatments. Recently, since water droplets of mist become smaller and vaporize more easily with the advance of atomization technologies, the cooling capability of the air-mist cooling is enhanced. In order to apply air-mist cooling to industrial devices and develop to a higher level, it is necessary to understand the heat and mass transfer of air-mist cooling in detail. However, it is difficult to understand the transport phenomena of air-mist cooling only using experiments, because air-mist cooling is a complex two phase fluid flow with droplet evaporation, latent heat and convection heat. A numerical simulation is a powerful tool for better understanding of the transport phenomena of air-mist cooling. There have been little studies that investigated the heat and mass transfer of air-mist cooling in detail using the numerical simulation.

In this study, we pay the attention to evaporative latent heat of fine mist, which has very small particles of several ten micrometers in diameter and easily evaporates. The objective of present work is to apply the air-mist cooling as a high heat removal technology to the cooling of high temperature industrial devices. The comprehensive simulation model has been constructed in order to analyze the air-mist cooling intended for high temperature iron laminated wall. A three dimensional numerical simulation has been carried out to investigate the behavior of fine mist particles, flow of gas phase and temperature distribution of laminated wall.

Figure 1 shows the predicted temperature distribution and velocity vector of gas phase at x-z cross section of central axis and x-y cross section near the laminated wall after steady state condition. After the air jetted from nozzle impinges on the laminated wall with a little spread, it uniformly spreads out from the center of laminated wall and flows outside the analytical region. Water droplets move near the laminated wall with gas phase under the influence of drag force and turbulence fluctuation. And then there are observed three cases that they directly collide with the laminated wall by inertial force, they impinge on the laminated wall with spreading along the flow of gas phase, and they flow outside the analytical region. Water droplets impinge on the stagnation region with high frequency and collision frequency decreases with distance from the stagnation region. The behaviors of water droplets in the numerical simulation are classified four categories, which are evaporation in gas phase, flowing out of analytical region, evaporation on the laminated wall after impingement and staying on the laminated wall after impingement. Simulation results indicate that 21.5 % of water droplets flow out of analytical region and 78.5 % of water droplets collide on the laminated wall for air-mist cooling. In particular, 70.2 % of water droplets impinge on the stagnation region, 26.9 % of water droplets evaporate on stagnation region and 43.3 % of water droplets stay on stagnation region. As a consequence, air-mist cooling has a highly effective in cooling at the stagnation region.



(a) x-z cross section (b) x-y cross section

Figure 1 Predicted temperature distribution and velocity vector of gas phase after steady state.

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