Numerical study on g-jitter induced melt convection in a three-dimensional cylindrical container and its control

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G-jitter is induced by acceleration varying in the shuttle, rocket and space station, and might affect the flow and concentration fields in microgravity field. The effect of g-jitter on transport phenomena in 2D and 3D rectangular has already been reported. Therefore, this study aims at the understanding and controlling of melt convection induced by g-jitter in 3D cylindrical container. As the understanding of melt convection, the effects of the direction and frequency of g-jitter on the flow were investigated. The effects of steady crucible rotation and applying magnetic fields on the flow were investigated for controlling the melt convection.

Fig.1 shows the schematic diagram for the analysis. An incompressible, Newtonian melt is filled in a crucible. The governing equations were namely the continuity, Navier-Stokes, energy, diffusion and electric scalar potential equations. They were discretized by the finite differential method (FDM), and were solved by the HSMAC method.

Fig.2 shows the effects of g-jitter and residual gravity directions on the flow fields in the 3D VGF (cylindrical) crucible filled with CdZnTe melt. Results when the convection and temperature gradient became stable under the residual gravity, was used for initial condition.

Fig.3 shows the time dependence on the z-directional velocity of Fig.2 in the point $(R,Z,\theta)=(0.6,0.4,1.5\pi)$. G-jitter in the vertical direction to the temperature gradient was more enhanced than the parallel direction.

Fig.4 shows the effects of vertical(a) and horizontal (b,c) magnetic field (Ha=50, frequency=0.01[Hz]) on the flow fields.

Fig.5 shows the time dependence on the z-directional velocity of Fig.4 in the point $(R,Z,\theta)=(0.6,0.4,1.5\pi)$. When the magnetic field was applied, the Lorentz forces suppressed natural convection. Especially, the horizontal magnetic field with the direction equal to g-jitter was more effective to suppress natural convection.

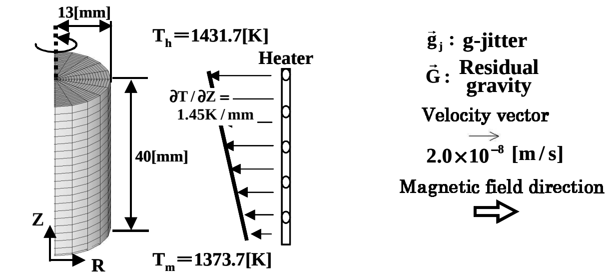

Fig.1 Configuration of 3D VGF model

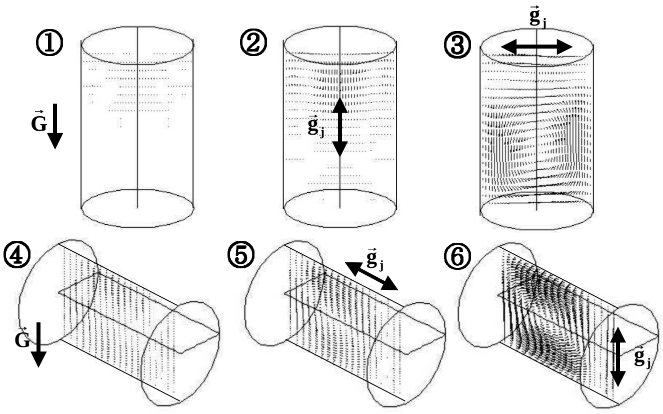

Fig.2 Effect of g-jitter direction on the flow at t=150[sec] (①,④ without g-jitter; color is temperature, vector is velocity)

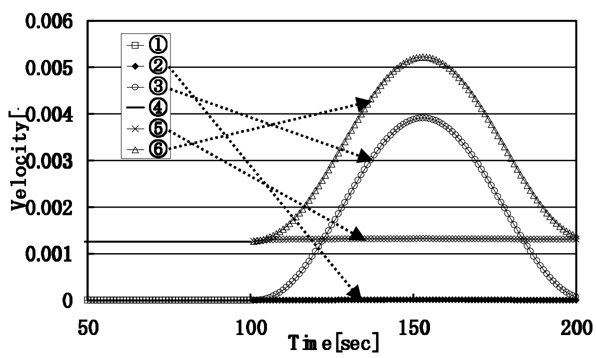

Fig.3 The time dependency of z-directional velocity of Fig.2(point; $(R,Z,\theta)=(0.6,0.4,1.5\pi)$).

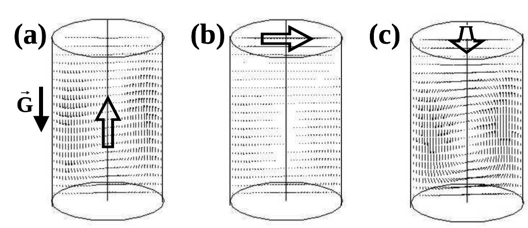

Fig.4 Effect of magnetic field on the flow at t=350[sec] (Ha=50, frequency=0.01[Hz])

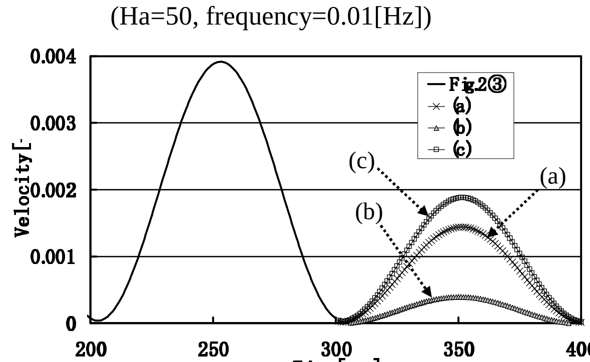

Fig.5 The time dependency of z-directional velocity of Fig.4(point; $(R,Z,\theta)=(0.6,0.4,1.5\pi)$).