Effect of crystal and crucible rotation on the thermal and oxygen instabilities in a Czochralski process for solar silicon growth

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In a Cz process, time-fluctuations in temperature and in the concentration of impurities are mainly due to the melt convection with its two components: the natural convection and the forced convection generated by the rotation of the crystal and the crucible.

In this study, we will concentrate on the influence of crystal and crucible rotation on the oscillatory properties of temperature and oxygen concentration. Four values for crucible rotation have been considered: ω_{cru} = 2, 4, 6 and 8 rpm and three values for the crystal rotation ω_{cry} = 5, 10 and 20 rpm. In order to understand the sole influence of the crystal and crucible rotation on the melt convection, numerical simulations have been performed with the same temperature boundary conditions. The numerical results show that first, the temperature fluctuations are higher near the crystal edge than at the center of the melt, mainly because the centrifugal forces are weaker in the central part of the melt and the effect of buoyancy is higher. The frequency histograms for the time fluctuations of temperature (Fig.1, a-d) show that the increase of crucible rotation has an effect of "pushing to the left". For ω_{cru} = 2 rpm the histogram shows a skewed right distribution, which means that the lower amplitude temperature fluctuations are more probable. For the higher crucible rotations, the histograms are more like a normal distribution, which denotes an equal probability for both lower and higher amplitude of temperature fluctuations.

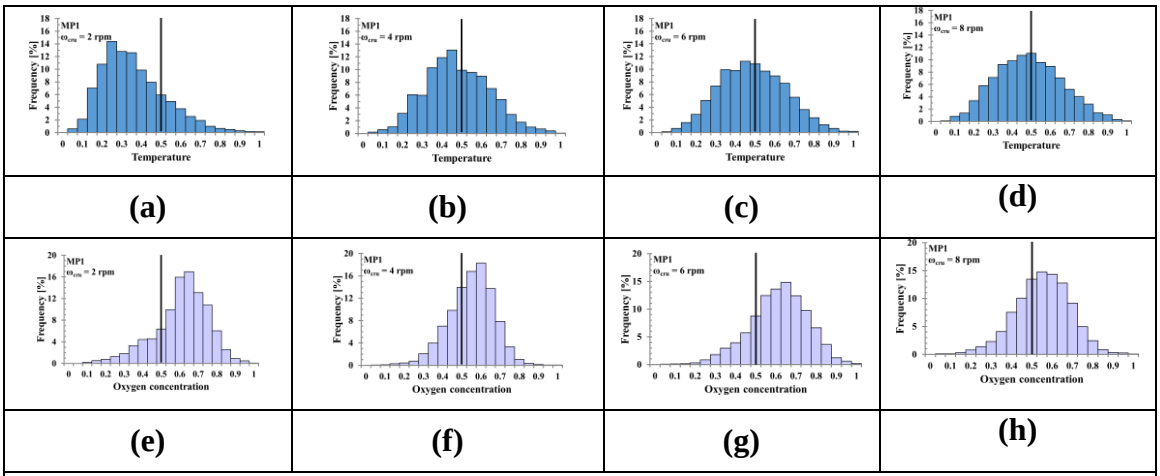

Figure 1. Histograms for temperature (a,b,c,d) and oxygen (e,f,g,h) in MP1 for different values of the crucible rotation rate

The frequency histograms for the time fluctuations of oxygen concentration (Fig. 1, e-h) show the characteristics of a skewed left distribution, which means that the higher amplitude of oxygen concentration oscillation are more probable. With the increase of crucible rotation, the distribution tend to be closer to a normal one for 8rpm, but in general remain a skewed left one. As a general conclusion, we observed that the temperature oscillations are closer to a normal distribution than the oxygen concentration, which is closer to a skewed left distribution.