CONVECTIVE PATTERNS ON COLUMNAR OR EQUIAXED DENDRITIC STRUCTURES DURING DIRECTIONAL SOLIDIFICATION OF AL BASED ALLOYS – RELEVANCE OF MICROGRAVITY EXPERIMENTS.

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Topics : 1). Experimental investigations of the dendritic solidification of metallic alloys 2). Effects of microgravity 3) Effects of natural convection and forced convection through external fields.

The dendritic microstructure is the most common microstructure found during the elaboration of metals and their alloys. Depending on the morphology of the dendrites, whether columnar or equiaxed, resulting materials properties will be different. A better understanding of the formation of the dendritic structure and when or how it changes from the columnar to equiaxed grains, is thus crucial to tailor materials in a reproducible fashion during casting processes. The selection of these solidification patterns is controlled by the complex interplay of thermal, solutal, capillary and kinetic length or time scales. Comparatively, our knowledge about the influence of natural or forced convection on microstructure development is more limited. Convection results in interfacial morphologies that are potentially very different from those generated in purely diffusive transport conditions. Inversely, the evolving microstructure can also trigger unexpected and complicated flow phenomena in the melt. Convection plays an even more important role upon equiaxed solidification and columnar to equiaxed transition (CET), since not only the liquid moves, but both nuclei (resulting from fragmentation of dendrites arms or refining particles added to the melt) and growing crystals may be driven by the flow. Moreover, they can also settle by gravity.

Our experimental approach is devised to deepen the quantitative understanding of the basic physical principles that, from the microscopic to the macroscopic scales, govern structure formation and segregation patterns of dendritic solidification under diffusive conditions and with fluid flow in the melt. Our strategy is based on a joint attack of pending questions by performing and analysing dedicated and well-defined directional solidification experiments on Al-based alloys, refined or not. We perform systematic series of:

- Critical experiments under diffusive conditions in microgravity, (CEA Grenoble and then EPM, CETSOL team project)
- Critical experiments under convective conditions, with fluid flow in the melt due to:
  - Natural buoyancy-driven convection
  - Forced convection imposed by applying a travelling magnetic field (EPM).

In this review article, I will illustrate by some examples our team contribution to deepen the understanding of the dendritic solidification of metallic alloys. One application of these benchmark experiments is to give criteria predicting parameters ranges where convection will have an influence, and extract laws describing the influence of convection on microstructure transitions. This enables us to incorporate convective effects in a simple way into the microstructures map as a function of the experimental parameters.
Other key insights and open questions will be enlightened in this paper: primary spacing adjustment in columnar dendritic growth, grain selection mechanism through the crystallography, columnar to equiaxed transition in presence of forced or natural convection.