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Author: Dr. Andrew Murphy
University College Dublin (UCD), Ireland

Dr. David Browne
University College Dublin (UCD), Ireland
Dr. Wajira Mirihanage
Norwegian University of Science and Technology, Norway
Prof. Ragnvald Mathiesen
Norwegian University of Science and Technology, Norway

THE INFLUENCE OF BUOYANCY ON EQUIAXED GRAIN NUCLEATION AND GROWTH CHARACTERISTICS AS OBSERVED VIA IN SITU X-RADIOGRAPHY OF AL-CU ALLOYS

Abstract

During metal casting, gravity induced thermosolutal convection pays a significant role in the formation and distribution of defects and inhomogeneities throughout the solidified component, e.g. hot tearing, porosity, and micro/macro-segregation. Further, the resultant fluid flow causes a significant increase in the required complexity of analytical models and numerical simulations used to predict the as-cast micro/macro-structure. The main simplifying assumption traditionally used for analytical and numerical models of solidification has been to neglect the effect of gravity, i.e. diffusion controlled solidification. To provide essential verification/validation for these mathematical models, sophisticated and carefully controlled solidification experiments are required. *In situ* X-radiography of solidification has been used extensively in recent years to provide insight into both micro and macro-scale solidification dynamics from solid nucleation to total freezing. In this work laboratory-based near-isothermal *in situ* X-ray solidification experiments were performed on a number of Al-Cu alloys, in preparation for an upcoming sub-orbital microgravity solidification experiment on board the European Space Agency MASER 13 sounding rocket mission, with a view to quantifying the buoyancy effects on solidification dynamics within the sample cell. A number of thin (200 μm) Al-Cu samples, of varying copper concentrations and Al-5Ti-1B (wt%) grain refiner addition levels, were solidified near-isothermally at constant cooling rates in the range 0.025 - 0.5 K/s, thereby promoting equiaxed solidification within the X-ray field-of-view (FOV). To isolate the effect of gravity-induced equiaxed grain buoyancy, the X-ray FOV was oriented both perpendicular and parallel to the gravity vector, with the latter case exhibiting solidification dynamics similar to those observed under normal casting conditions. In the former case, however, with gravity acting through the thin dimension of the sample, macro-scale equiaxed grain buoyancy was largely eliminated from the FOV thereby providing somewhat microgravity-like solidification conditions. Critically, it was observed that equiaxed grain buoyancy caused a significant reduction in the final grain size, at lower cooling rates and lower inoculant addition levels, due to early grain coherency, which results in a cessation of primary growth. Higher inoculant addition levels caused an increase in the grain density, resulting in a lower sensitivity to cooling rate, along with a morphological change from dendritic to cellular-equiaxed. Finally, the results of this analysis allowed for appropriate sample composition selection and time-line definition for the forthcoming MASER 13 sounding rocket flight.