Gravity Induced Settling in Interconnected Liquid-Solid Systems

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Abstract

The goal of this recently initiated program is to unravel the causes of the phase separation that occurs in interconnected solid-liquid microstructures in a gravity (e.g., 1g) environment. In brief, the lighter of the two phases is displaced upward and the heavier of the phases downward in such a mixture. As noted, the phenomenon is observed even when both phases are contiguous, as they are in liquid-phase sintered materials.

In our program we are studying the mechanisms by which this separation occurs. Previous work has suggested some possibilities. Previous work in our laboratory suggests that settling takes place by "extrication" of individual particles from the solid network, such extrication possibly being linked to particle coarsening. Once extricated, a particle sinks a distance on the order of the solid interparticle spacing where, via sintering, it reattaches itself to the solid network. Repetition of the process results in the slow "slumping" of powder compacts that is ubiquitous to LPS structures sintered in a gravity environment. Another view of the phenomenon relates settling to creep of the solid skeleton. When the solid phase is not contiguous – that is, when a thin film of liquid is present between solid "particles" – this mechanism appears viable for explaining settling. In effect, "grain boundary sliding" by the viscous liquid interboundary phase can lead to creep. However, when the solid phase is contiguous, the gravity stress seems insufficient to cause creep of a rate sufficient to account for observed compact slumping.

We will conduct experimental and modeling studies that attempt to unambiguously determine (as best one can hope to accomplish such a thing) the mechanism(s) of settling. In particular, extrication times required for particles situated at the interface between solid and solid-liquid regions will be measured over a broad range of solid volume fractions. These times will be correlated characteristic compact slumping times. Systems to be investigated are W-Ni-Fe heavy metals, and Pb-rich, Pb-Sn alloys. The Pb-Sn system has the additional attraction of being a low temperature system and the composition of the liquid phase can also be substantially varied by alterations in the sintering temperature. We further characterize settling phenomenon by thorough microstructural evaluation of "slumped" compacts. Solid volume fractions and solid particle "sizes" are determined as a function of vertical location within the compact and for different settling times and overall solid volume fractions in the compact. A continuity equation allows us to numerically mimic the settling in terms of a characteristic "settling" time. This time can be compared to independently measured particle extrication times and/or to characteristic creep times.

The program clearly has relevance to microgravity. Settling is gravity instigated, albeit the kinetics of settling might not directly relate to the gravity force. (For example, particle extrication times are thought to controlled by diffusion and surface energy effects. Or to put it another way, while gravity is the driving force for settling, this force does not control the rate of it except in the limiting case of microgravity conditions.) Although this program focuses on liquid-phase sintered materials, settling of the type we are studying is found in other systems. Phase separation of this nature takes place in gravity environments in processing of polymer blends and colloidal ceramics, for example. Further, creep in solid-liquid mixtures has relevance to certain geological phenomena.

A "succinct statement" describing the significant results of our investigation to date are requested for this abstract. Alas, that is all to easy to do. The program was funded in March 1998. However, there were no "available" graduate students in our department at that late date in the academic year. Our first graduate student will become involved in this program in July, and a second one will join it in September. In the meantime, the preliminaries necessary to enable these students to "jump start" this program have been attended to. For example, materials are on hand, an undergraduate student will be employed in June to conduct "enabling" experiments and, as is discussed in the paper tied to this abstract, some computational modeling programs are being developed. Further, while no experimental studies are "simple" to execute, some are – as are the ones we propose in this study – fairly straightforward. So we are looking forward to the next Microgravity Materials Science Conference at which we hope to "succinctly" present far more extensive and significant results.