Powder Compaction: consolidation and bonding in soft granular solids

Powder compaction is a widely utilized manufacturing operation in many industries, including the pharmaceutical one where it is used to produce medicines in the form of tablets. During compaction, the particles deform significantly and usually develop bonding at contact surfaces. The amount of deformation of each particle and the bond strength created between contacting particles depends on the properties of the particles and the applied compaction pressure. Thus, the evolution of the microstructure during powder compaction process imparts the critical response of the compacted solid. To investigate such a response, we have developed a particle mechanics formulation, which incorporates non-local contact, attendant to particle physical and material properties including plasticity, elasticity, and inter-particle bonding. In addition, we have conducted a series of experiments on common pharmaceutical powders such as lactose and microcrystalline cellulose to contrast the model predictions to the experimental record in terms of the consolidation history and tensile strength. The numerical studies allow us to extract the probability distribution function and the orientation of contact forces as a key element to describe the evolution of the microstructure during the application of compaction pressure, unloading, and ejection of the compact from the die. The probability distribution function reveals that the compression contact forces increase as the compaction force increases (or the relative density increases), while the maximum value of the tensile contact forces remains the same. During unloading of the compaction pressure, the distribution approaches a normal distribution with a mean value of zero. As the contact forces evolve, the anisotropy of the powder bed also changes. Particularly, during loading, the compression contact forces are aligned along the direction of the compaction pressure, whereas the tensile contact forces are oriented perpendicular to the direction of the compaction pressure. After ejection, the contact forces become isotropic. This numerical platform enables tracing the evolution of the microstructure in the high-density regime, towards an in-silico design of compacted solids.

Dr. Alberto Cuitino is a Professor in the Mechanical and Aerospace Engineering at Rutgers University and currently serving as Department Chair. He has served as a Site Leader of the NSF Engineering Research Center for Structured Organic Particulate Systems. He received a Civil Engineering Diploma from the University of Buenos Aires, Argentina, in 1986, and an MS degree in Applied Mathematics, and a Ph.D. degree in Solid Mechanics from Brown University in 1992 and 1994, respectively. His research interests include material modeling and simulations, dislocation mechanics, deformation and fracture in metal single crystals, granular materials, mechanical behavior of solid foams and folding patterns in thin films.