

Green body density analysis using tomographic reconstruction

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Progress in the manufacturing of ceramics, but also of sintered metals, strongly relies on the evaluation of the density distribution in green bodies. With a homogeneous density field in the green body, the sintered strength and density are more uniform across the body and suffer from less variance from ceramic to ceramic. The push to increase uniformity is driven by the factors of reducing waste, increasing performance, and expediting the development process. Accurate numerical modeling of the mechanical densification process can directly improve each of these cases through optimizing mold geometry and pressure distribution. The density evaluation process is crucial from many points of view, specifically for the calibration of constitutive models for the *in-silico* simulation of mechanical densification processes.

To this end, X-ray tomography and other techniques are possible but their costs are prohibitively and the equipment can be unmanageable for smaller institutions. Other more cost-effective techniques are present in the literature[1], but most presume a certain set of experimental equipment that, while certainly more available, is not universally available at all institutions. Therefore, a destructive method is introduced to measure the density field of a green body sample using a CNC mill, an analytical balance, and analysis techniques from the field of computational tomography. This method supplements the class of density measurement techniques because it uses more common and different equipment than most other methods.

The basis of tomography is that any 2D field can be exactly reconstructed from an infinite number of unique projections. The reconstruction step is, essentially, solving an ill-constrained system of equations and is often referred to as the inverse radon transform. The system of ill-constrained equations can be solved in many different ways, with each method being a different tomographic reconstruction technique. A simple, ubiquitous method is the algebraic reconstruction (ART) method [2] and has been found to produce acceptable results with minimal implementation complexity.

The projections are obtained by using an analytical balance to measure the mass difference of the green body before and after using a CNC mill to remove a strip of material. This process is repeated until the entire section has been removed, one strip at a time. The method requires at least two unique projections to create a reconstruction while each additional projection increases the accuracy of the reconstruction. When using only two projections, it is best to align one or both projections with a natural orientation of the green body (such as along symmetry planes, if any). If symmetry planes exist, each representative section can be analyzed independently to produce a valid projection thus yielding multiple projections from a single green body.

A virtual experiment is presented (Figure 1) where the method is used to reconstruct a simulated green body density field and is found to satisfactorily correspond to the simulated solution. However, the two-projection method is best suited as a means to compare experimental density fields with simulated density fields in the same reconstruction space, not as a means to accurately reconstruct the actual density field. This method aims to be particularly useful for small laboratories with limited equipment that are performing research or prototyping.

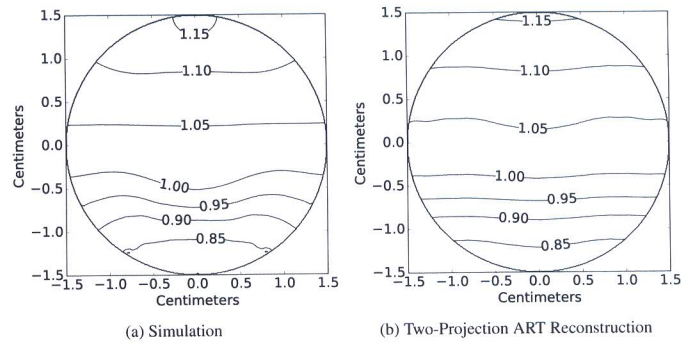


Figure 1: A virtual experiment where a representative density field is extracted from a ceramic powder compaction simulation of a truncated cylinder and reconstructed from two orthogonal projections using ART. The reconstruction adequately represents the simulated density field, even though it smooths along the projection directions.

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