GENETIC ALGORITHMS IN MATERIALS PROCESSING: FEW SELECT CASE STUDIES

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ABSTRACT

A number of evolutionary algorithms, both single and multi-objective in nature, are being applied to various problems of materials interest. This paper deals with three specific studies related to (i) ground state geometry optimization of silver clusters, (ii) designing of magneto-rheological fluids and (iii) compaction and sintering of nano-sized Aluminum Oxinitride (ALON) powders.

Continued advancement of technology calls for newer materials and increasingly complex processing techniques associated with them. Acceptable performance of many such materials requires rigorous optimization studies, both in terms of their design and processing parameters, where, in recent times Genetic Algorithms have been contributing in a very significant way. In this paper we have briefly documented the applicability of a Genetic Algorithms based analyses on the three materials related problems mentioned above. A wide variety of Genetic Algorithms, involving both single and multiple objectives, have been used in our studies.

Among the problems presented here, for the computations on the silver clusters we have essentially utilized the Genetic Algorithms for energy optimization. Such studies have got immense practical consequences, particularly in connection with processes like catalysis and adsorption. A certain number of silver atoms can virtually adopt an infinite number of configurations, out of which only one perhaps correspond to the ground state, and the task of the Genetic Algorithms here is to locate that structure through an exhaustive search, where in many instances, the evolutionary methods actually outperform the gradient based techniques and also the algorithms like simulated annealing.

In the second problem we have taken up the design aspects of Magneto-Rheological fluids. The basic concept behind such fluids is to impregnate a fluid of known viscosity with small particles of magnetic materials. When a magnetic field is applied to such fluids, the magnetic particles tend to align themselves, and the system instantaneously demonstrates a solid like behavior with measurable values of yield stress and other properties, which again can be varied significantly by adjusting the intensity of the magnetic field and the other parameters, and also can be effectively reversed by turning off the magnetic field. Thus, using these fluids, one can, in principle, instantly create a material of required strength as and when needed. Widespread engineering applications of such fluids are on the anvil. In this study we have looked into the various design possibilities of them using a multi-objective formulation and the computations were performed using two different multi-objective evolutionary algorithms.

Our third problem deals with compaction and sintering of nano-sized Aluminum Oxinitride (ALON) powders. This material is a ceramic spinel. If properly processed, it provides an unusual combination of excellent optical transparency and very high strength and is a promising candidate for many civilian applications like supermarket scanner windows, scratchproof lenses and watch crystals, in addition to be used as protective transparent armor systems for military personnel and vehicles. Processing of ALON, however, is a formidable task and its cost is still quite a prohibitive factor for many real-world applications. The efficacy of a Genetic Algorithms based optimized processing strategy could be quite overwhelming for this system.

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Each problem discussed in this article has got its own special need and a number of Evolutionary Algorithms were utilized to study them. For single objective formulations we have used: Simple Genetic Algorithms, Gray Coded Genetic Algorithms, and Differential Evolution. We have used Pareto-converging Genetic Algorithms and also a Distance Based Multi-Objective Genetic Algorithms for our multi-objective studies. Effects of various parameters like crossover and mutation probabilities, population size etc. on the performance of the algorithms has also been studied and discussed.