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Global optimization as an alternative in the solution of the inverse problem of hydraulic tests in fractured media

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The understanding of groundwater flow in fractured media is a very complex problem due to the natural all scale-heterogeneity of the massif rocks. These types of rocks have a gigantic number of fractures with unknown properties, reason why these media are modeled in a stochastic framework. One of the methods for the modeling of fracture massif is the Discrete Fracture Network (DFN) approach where fractures are modeled by means of probability density functions (e.g., Donado, 2009) of their properties (length, orientation, location, density and size).

With the objective of having a feasible problem in parametric terms, we use the proposed methodology in Donado (2009) that join the all the fractures in five families. These families are defined in term of geological criteria. In this sense, is possible to define the hydrodynamic parameters as the product of two terms. One is the specific for each fracture, defined a priori based on the their characteristics and the other is the value of the parameter of the family. The latter is the estimated parameter, reducing the number of parameters to compute and avoiding the over-parameterization.

For achieving a good fit among the defined and computed values is necessary to define an appropriated objective function to minimize the distance between this two values. In this work we use the Nash correlation factor, R^2. This factor is the ratio between the variance of the residues and the data. We use hydraulic tests, which were realized, in *El Berrocal* Site (center Spain). Five families of fractures were defined in this massif. The number of fractures, their location, the spatial location and size of the fractures defined each family. The size of the selected size is 600 $\times$ 600 $\times$ 300 m, and a total number of 100 simulations of the media were analyzed.

Four algorithms of optimization were used to represent the tests (Yeh, 1986): (i) Monte Carlo simulations, which are funded in the generation of a cloud of points over an uniform distribution in the parametric space of the possible solutions. This method also permits us to analyze the parametric uncertainty, identifying the more influential flow parameters. (ii) Maximum likelihood that consists on the maximization of the observation probability of the measured data against the parameters probability. (iii) SCE-EA, which combines the strength of the evolutionary algorithms of controlled random search (CRS) with the concept of competitive evolution (Holland, 1975). This method is demanding in computer time whit a high number of fractures. And (iv) PSO, that is a population technique based on stochastic optimization inspired in the behavior of birds and fishes. PSO have a lot of similarities with the computational evolutionary techniques as the genetic algorithms (GA), however, GA have evolutionary operations as crossing and mutations. In PSO, the potential solution (called particle), each particle executes a fly in the space of the problem following the actual optimal particle. Each particle covers the space coordinates in the space of the problem that are associated with the best-achieved solution. This is called *pbest*. Another obtained value from PSO is the best value that is the value obtained by any particle in the neighborhood of the particle. This is the *ibest* value. When a particle has in all the population as topological neighbors, the best value is in global level and is called GBETS.

Some preliminary results show us that SCE-UA and PASO methods give us R^2 near to 0.9, representing in a best way the hydraulic behavior of the media. Fractured media have the problem called parametric uncertainty, where multiple combinations of parameters fit satisfactorily the hydraulic tests, reason why, it is not observable a unique tendency to a unique global value. Hydraulic conductivity of the family 2 is the only identifiable value between the ten analyzed parameters.

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