Modeling Convection Coefficients with Genetic Algorithms

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1 INTRODUCTION

Natural convection is an important mode of heat transfer in many fields. Convection coefficient, Nusselt number *Nu*, is usually modeled as a function of Rayleigh number *Ra*, which describes the conditions that affect convection. Inclination and spacing are important parameters of stacked cylinders. Of the latest models for two-cylinder array includes both inclination θ and spacing *d* as parameters (Ji, et al 1998). The coefficients were obtained from experimental data by an empirical combination of linear regression and exponential function fitting. This paper uses GA to seek for better coefficients.

2 APPLICATION OF GENETIC ALGORITHM

We assume the three coefficients *A*, *B*, and *n* in $Nu = (A + B \cdot Ra\cos\theta)D^n$ are within the value ranges of [0, 10], [0,1], and [0,1], respectively. A chromosome is encoded as a set of three coefficients {*A*, *B*, *n*}.

The objective function (f) is the mean-square-root of the deviations between the model and the experimental data at all the experimental points. Then individual's ranking of *F* is used to decide the selection probability.

Binary representation with ranking selection scheme is used. The initial population is generated randomly. Single point crossover is used. Crossover rate is chosen to be 60%. Mutation is applied to each of the three coefficients separately in the chromosomal representation. Elitism is used where the best individual is always passed to the next generation unchanged.

3 EXPERIMENTAL RESULTS ALGORITHM

The GA program was developed in Visual C++ with *chrom, popul, convecDoc* and *convecView* as major functional components.

An improved model for Nusselt number is obtained.

Top cylinder:
$Nu = (2.2032 + 0.307\times10^{-3}\, Ra\cos\theta)\, d^{\,0.2295}$.

Bottom cylinder:
$Nu = (2.5891 + 0.507\times10^{-3}\, Ra\cos\theta)\, d^{\,0.0444}$.

The mean-square-root deviations of them from the experimental data are 0.1218 and 0.1065 for the top and bottom cylinders, respectively. Those of the original model are 0.2854 and 0.3970. They are cut by 57% and 73% using GA.

To analyze GA performance, tests with some variations of parameters were compared. Average of 20 runs is taken for each choice.

Populations size 25, 50, 100 are compared with selection pressure 1.5 and mutation rate 0.1. Some tests with population 25 did not converge. Selection pressures 1, 1.25, 1.5, 1.75, and 2 are compared. Higher selection rate did not improve the performance significantly. Results from different mutation rate from 0 through 1are compared. For mutation rate 0.01, only 1 out of the 20 runs converged. On the other hand, large mutation rate up to close to 1 all resulted to the optimum. This result suggests that either the fitness landscape of this problem is very rugged, or the crossover operation does not capture the good schema effectively.

4 CONCLUSIONS

Modeling of Nusselt numbers of two vertically stacked inclined cylinders is improved significantly over the original method. On the other hand, it also confirmed that the relative dependence of *Nu* on the three coefficients *Ra*, θ and *d*. The method looks promising to obtain better model while there is much to improve in the implementation.

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