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Evolution strategy for gas-turbine fault-diagnoses

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Abstract

The aim of this investigation is to be able to diagnose gas-path faults in gas turbines by minimising the differences between the observed and simulated data for the engine's behaviour. The simulated data are generated using a known set of faults as the input to the engine-behaviour aero-thermo model and an appropriate objective function is minimised to yield the best solution to the problem. The application of evolution strategy (ES) in the search for this minimum is an effective, flexible, robust and reliable way of solving engine-diagnostics problems. Adopting this approach leads to a considerable reduction in the overall time taken to obtain a convergent solution when compared with that required using a simple genetic-based algorithm.

Keywords: Performance; Diagnostics; Evolution strategy; Genetic algorithm

Abbreviations: ANN, Artificial neural-network; BBN, Bayesian belief network; ES, Evolution strategy; GA, Genetic algorithm; GPA, Gas-path analysis; HP, High pressure; MOPA, Multiple operating-point analysis; MSA, Mutative step-size adaptation; NG, Number of generations; NM, Number of measurements; NS, Number of strings; PC, Probability of crossover; PDF, Probability density function; PM, Probability of mutation; PS, Population size; SOPA, Single operating-point analysis; TPM, Total productive management; TQM, Total quality management

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Nomenclature

b	vector of sensor bias
B	constant
g	magnitude of chromosomes
$J(x,w)$	objective function
p	objective parameter
t	current generation
T	flow capacity
v	vector of sensor noise
x	environment and power-setting parameter
y	vector of engine measurement
α	heuristic factor
η	component efficiency
σ	standard deviation

Suffixes

1,2,3,4,5	gas-turbine station numbers
mut	mutation
odj	jth off-design undeteriorated condition

1. The problem

During the last two decades, new strategies (such as just-in-time, kanban and lean manufacturing) have been developed and introduced into industry and commerce. Simultaneously, the need for the implementation of more cost-effective maintenance procedures has been increasingly recognised, and so concepts such as total quality management (TQM), which includes total productive management (TPM), have been devised. Thus, lifetime costs for many manufactured artefacts (e.g., gas-turbines) have been reduced. It has also been realised that the main barriers to the more widespread successful application of TPM are the out-of-date perceptions (in the minds of those involved in the operation process) of the benefits of optimising maintenance schedules. The goal, even though unattainable, but which can be approached asymptotically, in any planned maintenance programme should be zero breakdowns during the operation of the artefact. A realisation should also occur of the energy wastages and costs that would ensue if a breakdown occurs. One of the means of reducing such disruptions and ensuant cost is to implement an optimal maintenance schedule for diagnosing the causes from the symptoms and the magnitudes of the faults arising because of say the engine being operated and the consequences for the engine's performance.

Gas-turbine engines, that are operated continually, suffer component deteriorations of performance. Traditionally, the use of gas-path analysis (GPA) [1] has been