Diesel Engine Piston Shape Design Using Multi-Objective Efficient Global Optimization

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Key Words: Multi-objective optimization, Efficient Global optimization (EGO)

INTRODUCTION

Recently, the reduction of nitrogen oxide (NOx) and soot is one of the main interests in the development of a diesel engine. In this study, a diesel engine piston shape was optimized to reduce the NOx and soot emission. NOx and soot emission were evaluated using a combustion analysis code, called GTT (Generalized Tank and Tube) [1] which takes into accounts the fluid flow, fuel injection and combustion at the same time. Multi-Objective Genetic Algorithm (MOGA) was used as an exploration engine. However, MOGA coupled with GTT evaluation takes a tremendous computational time to explore the optimum solution. Adoption of an approximation model will be one alternative for this problem. However, it is said that there is probability of missing the global optimum when using an approximation model in optimization because approximation model contains uncertainty in its estimation value. For the robust search of the global optimum with approximation model, Jone suggested the efficient global optimization (EGO) algorithm [2] which makes use of the Kriging model. The Kriging model predicts not the function value itself but the distribution of function value at the unknown point. From the distribution of the function value, one can predict not only the function value but also its uncertainty. The uncertainty information plays a key role in EGO. In EGO, the exploration is based on the potential of being the optimum instead of the objective function value itself. According to the concept of EGO, the solution that has a high predicted function value with a large error may be a more promising solution than the solution that has a low predicted function value with a small error in the minimization problem. By using EGO, the balanced exploitation and exploration is possible. EGO is successfully applied to the single objective problems [3]. In this study, EGO is extended for multi-objective problems and applied to the diesel engine piston shape design.

DEFINITION OF OPTIMIZATION PROBLEM

In this investigation, the geometry of diesel engine piston is defined by seven parameters and injection angle (θ) is also used as the design parameter as shown in Fig. 1. As the objective functions, CO emission and thermal efficiency as well as NOx and soot emissions were defined.

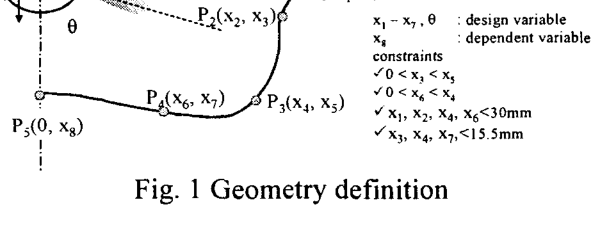

Fig. 1 Geometry definition

OPTIMIZATION PROCEDURE

The overall procedure of the design is shown in Fig. 2.

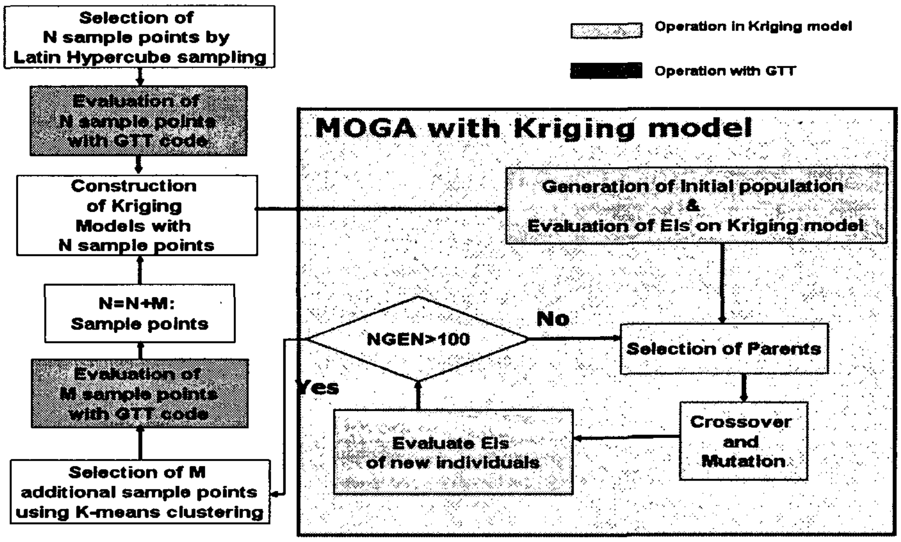

Fig. 2 Overall procedure of optimization

1) Initial sample points for construction of Kriging models are selected by Latin Hypercube sampling [4] and these points are evaluated with GTT code.

2) Kriging models are constructed based on values obtained from GTT code.

3) MOGA operations are performed to find the non-dominated solutions about EIs of objective functions.

4) M additional sample points are selected by using K-means clustering method.

5) These points are evaluated with GTT code.

Routines 2)-5) are iterated until determination criterion is reached.

DESIGN RESULTS

The objective function values of additional sample points are compared with that of baseline geometry in Fig. 3. The results show that the NOx, soot and CO emission of additional sample are reduced while maintaining thermal efficiency. This means that the present method selects promising design points properly.

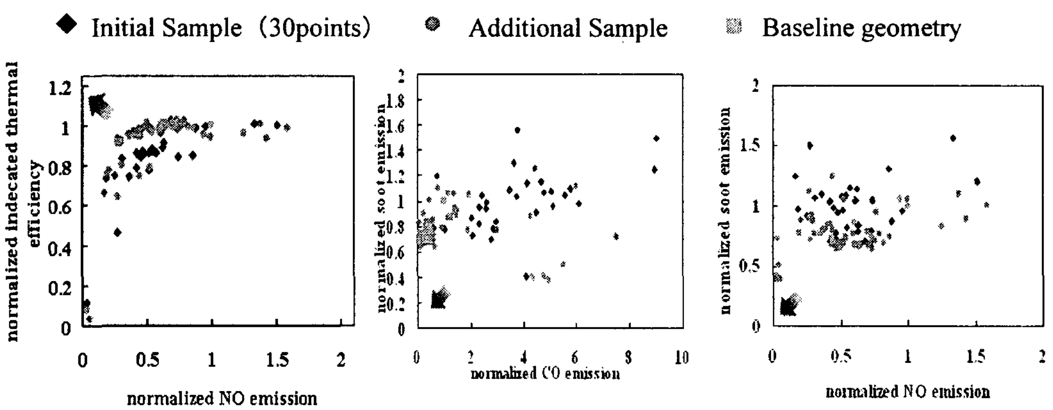

Fig. 3. Comparsion of objective functions between designed and baselin geometry

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