Multidisciplinary Wing Design Optimization Using Multiobjective Evolutionary Algorithm

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1 Introduction

The design of a wing for commercial aircrafts today, such as B747, B777, and A340 cruise at transonic speeds, i.e., just below the speed of sound, is a typical example of multidisciplinary and multiobjective design optimization problems. Although the principal objective of a wing design is minimization of aerodynamic drag, there are a lot of tradeoffs. One of the tradeoffs lies between minimizations of drag and structural weight of wing. An increase in wing thickness allows the same bending moment to be carried with reduced skin thickness, resulting in reduction of weight. On the other hand, it will lead to an increase in wave drag. In addition, an elliptical spanwise load distribution that minimizes induced drag results in a large bending moment at the inboard of the wing with an accompanying increase in weight.

Furthermore, wing designs are difficult due to the followings. First, aerodynamic performance of a wing is very sensitive to its shape. Very precise shape definition is needed and thus it usually requires more than 100 design variables. Second, function evaluations are very expensive. An aerodynamic evaluation using a Navier-Stokes flow solver usually requires 60-90 minutes of CPU time on a vector computer.

In this paper, a MOEA will be applied to a multiobjective multidisciplinary optimization of a transonic wing design.

2 Results

The objectives of the present design problem are minimizations of drag and weight at Mach number of 0.8 at the lift coefficient C_L of 0.5. A typical planform for civil aircrafts is selected. Wing profiles of designs are parameterized by the PARSEC airfoils [1]. In total, 43 parameters determine a wing shape.

Aerodynamic performances of the designs are evaluated by using a Navier-Stokes flow solver [1] to guarantee an accurate model of the flow field. The wing structure is modeled on a box-beam to estimate the wing thickness and weight.

The present real-coded MOEA uses the Pareto ranking, fitness sharing, and best-*N* selection [1]. Population size and maximum number of generations are set to 32 and 30, respectively. The computation is parallelized using the *Master-Slave* concept on NEC SX-4 computers at Computer Center of Tohoku University in Japan. The total turn around time was roughly 60 hours.

Pareto solutions are shown in Fig. 1. The present MOEA successfully displayed the tradeoff information between minimizations of drag and weight. B747 is also plotted according to the data in [2]. In spite that the planform shape is different to some extent, it is close to the tradeoff surface.

Figure 2 compares spanwise thickness distributions of the minimum drag design, the minimum weight design and a compromised design of same C_D as B747. The minimum drag design minimizes its drag by reducing its thickness but on the contrary, requires large weight. The minimum weight design has a very thick wing to reduce its weight but it leads to large drag. The compromised design has a reasonable spanwise wing thickness distribution.

Figure 3 compares spanwise load distributions. As expected in the aerodynamic theory, the minimum drag design achieves the elliptical spanwise load distribution, which requires a heavy structure due to the large lift at the outboard of the wing. The minimum weight design, on the other hand, decreases lift at the outboard of the wing to reduce its moment, which, on the contrary, results in a substantial increase in induced drag. The compromised design has straight spanwise load distribution.

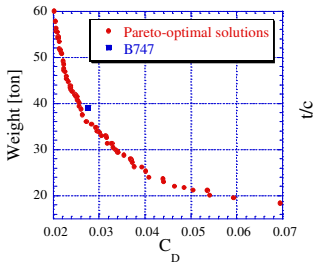

Fig. 1. Pareto solutions

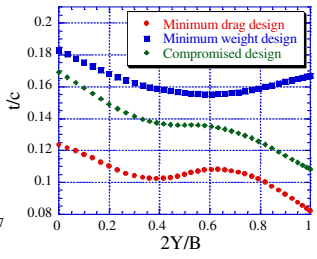

Fig. 2. Spanwise thickness distributions

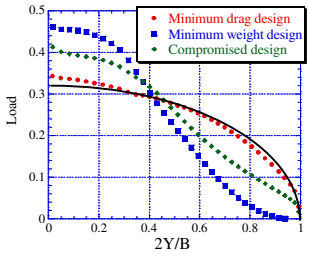

Fig. 3. Spanwise load distributions

References

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