8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

Multi-Objective Design Optimization for Stator Blade Configuration of Steam Turbine

***Shu Yoshimizu[1], Koji Shimoyama[1], Shinkyu Jeong[1], Shigeru Obayashi[1] and Yasuyuki Yokono[2]**

[1] Institute of Fluid Science, Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai, 980-8577, Japan
{yoshimizu, shimoyama, jeong, obayashi}@edge.ifs.tohoku.ac.jp

[2] Toshiba Corporation
1 Komukai-Toshiba-cho Saiwai-ku,
Kawasaki, 212-8582, Japan
yasuyuki.yokono@toshiba.co.jp

Key Words: *Multi-Objective Optimization, Genetic Algorithm, Kriging Model, CFD.*

ABSTRACT

To design a high-efficient steam turbine, it is essential to simultaneously consider various design objectives. Actually, however, it is almost impossible to do that by relying only on designers' knowledge or experience because there is limitation in designers' knowledge. In these days, a multi-objective optimization technique has attracted a large attention in the field of an engineering design.

In addition, computaional fluid dynamics (CFD) analysis techniques have greatly matured to be able to predict a flow field around even a complicated configuration and precisely evaluate its aerodynamic performance.

Thus, a combination of the multi-objective optimization technique with the CFD analysis enables us to design fluid machineries more systematically; a number of experiments and development period can be reduced. This allows us to develop a fluid machineries with the lower cost.

In this study, a new design system based on the multi-objective optimization approach coupled with the CFD analysis has been developed and applied to the design of airfoil for a steam turbine stator blade. Through the design optimization, design candidates with good performance regarding all design objectives have been searched, and the design information has been investigated.

In the design system, the genetic algorithm (GA)[1)] was adopted as the multi-objective optimization approach. In addition, to reduce the time for objective function evaluation, the response surface approximation using the Kriging model[2)] was used.

Using the developed design system, the multi-objective design optimization of airfoil for a steam turbine stator blade was performed. The stator blade configuration was defined as a combination of the camber line and the thickness distribution. They were represented by the Bézier curves, which have one control point for the camber line and two for the thickness distribution. X and Y coordinates of the three control points were considered as the design variables, so the number of design variables was six. The objective functions were profile loss (η), inverse of outflow velocity (V) and outflow angle disagreement (A, difference between target outflow angle and outflow angle of a design candidate). All the objective function values were minimized through the

optimization.

As a result of the present optimization, a lot of design candidates which outperform the baseline design in terms of each objective have been obtained. Figure 1 depicts the distributions of the obtained candidates (shown in percentages of the baseline values) and Fig. 2 illustrates the airfoil configurations which have the best performance concerning each objective function. Figure 1 indicates that there were trade-offs between η and *A*, *V* and *A*, while no trade-off could be seen between η and *V*. In addition, Figs. 2(a) and 2(b) indicate that a configuration with narrower throat width (minimum clearance between the trailing edge and the neighboring airfoil) improves η and *V*. This is because small *V* can be realized by the throat-converging effect, and small η is involved by the non-conflicting relation between η and *V*. However, the aft-part of this configuration is not parallel to the target direction, and thus it results in large *A*. On the other hand, the configuration shown in Fig. 2(c) can realize small *A* by matching the aft-part with the target direction, while this has large η and *V* due to large throat width. Therefore, it is shown that the throat width and the aft-part configuration have great influences on *V* and *A*, respectively.

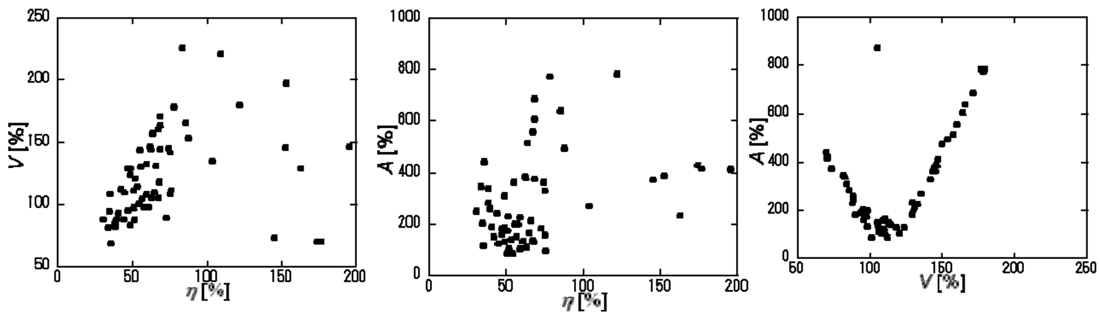

Fig. 1 Distributions of obtained design candidates

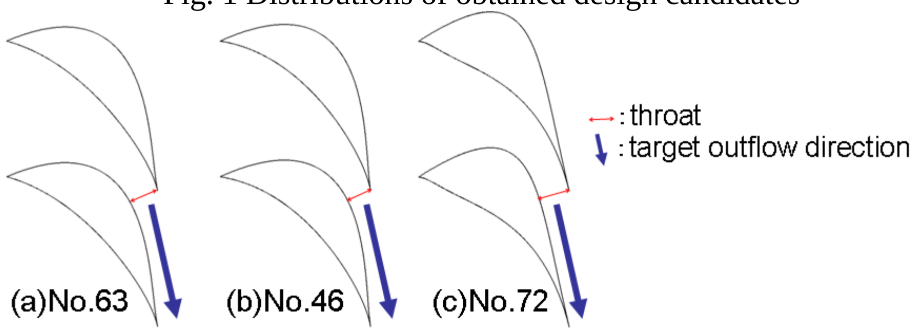

Fig.2 The best performance airfoil configurations concerning (a) η , (b)*V* and (c)*A* .

As a conclusion, this study has proved that the developed design optimization system has a capability of finding airfoil design candidates dominating the baseline design regarding several design objectives. Some design information of steam turbine stator blade has also been discussed.

REFERENCES

[1] Deb, K., *Multi-Objective Optimization using Evolutionary Algorithms*, John Wiley & Sons, 2001

[2] Jeong, S., Murayama, M. and Yamamoto, K., "Efficient Optimization Design Method Using Kriging Model," *Journal of Aircraft*, Vol. 42, No. 2, 2005, pp.413-420.