Optimum Aerodynamic Design of Centrifugal Compressor using a Genetic Algorithm and an Inverse Method based on Meridional Viscous Flow Analysis

Sasuga Itou, Department of Mechanical Engineering, Kyushu University, Fukuoka, Japan
Nobuhito Oka, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd., Kanagawa, Japan
Masato Furukawa, Department of Mechanical Engineering, Kyushu University, Fukuoka, Japan
Kazutoyo Yamada, Department of Mechanical Engineering, Kyushu University, Fukuoka, Japan
Seiichi Ibaraki, Mitsubishi Heavy Industries, Ltd., Nagasaki, Japan
Kenichiro Iwakiri, Mitsubishi Heavy Industries, Ltd., Nagasaki, Japan
Yoshihiro Hayashi, Mitsubishi Heavy Industries, Ltd., Nagasaki, Japan

Long Abstract

Introduction

Centrifugal compressors are used as turbochargers in engines of passenger cars. There is a strong demand for miniaturization and high performance of centrifugal compressors used as turbochargers because of miniaturization of engines and increasing its performance. Performance of centrifugal compressors is influenced by its meridional flow passage shape and its impeller blade loading. Therefore, it is important to investigate optimum the meridional shape and the impeller blade loading due to increase performance of centrifugal compressors.

The objective of the present study is to investigate optimum the meridional shape and the impeller blade loading of centrifugal compressors in an optimum design method using a genetic algorithm (GA) and an inverse method based on meridional viscous flow analysis. Centrifugal compressors designed by the present optimum design method are verified by three-dimensional Reynolds averaged Navier-Stokes (RANS) analyses.

1. Optimum Design Method

An optimum aerodynamic design method for centrifugal compressor impeller has been developed. The present optimum design method is using a genetic algorithm (GA) and an inverse method based on a meridional viscous flow analysis. In the GA procedure, the Non-dominated Sorting Genetic Algorithm II (NSGA-II) is used as evaluation and selection models. The Real-coded Ensemble Crossover (REX) is used as crossover model.

The inverse method consists of two parts: meridional viscous flow analysis and one-dimensional inverse blade design [1]. In the meridional viscous flow analysis, an axisymmetric viscous flow is numerically analyzed on a meridional plane to determine the flow distribution around the impeller. A blade force modeling is successfully introduced in the analysis to take into account for the blade effect. In the one-dimensional inverse blade design, the compressor impeller is designed with blade loading distributions. In the present optimum aerodynamic design procedure, the spanwise and chordwise blade loading distributions of impeller are given as the design variables, and the aerodynamic performances of designed centrifugal compressors are evaluated by the aerodynamic performances. These aerodynamic performances are obtained from the meridional viscous flow analysis results at the design operating condition. Pareto-optimum design cases which have better aerodynamic performances have been obtained by the present optimum aerodynamic design method.

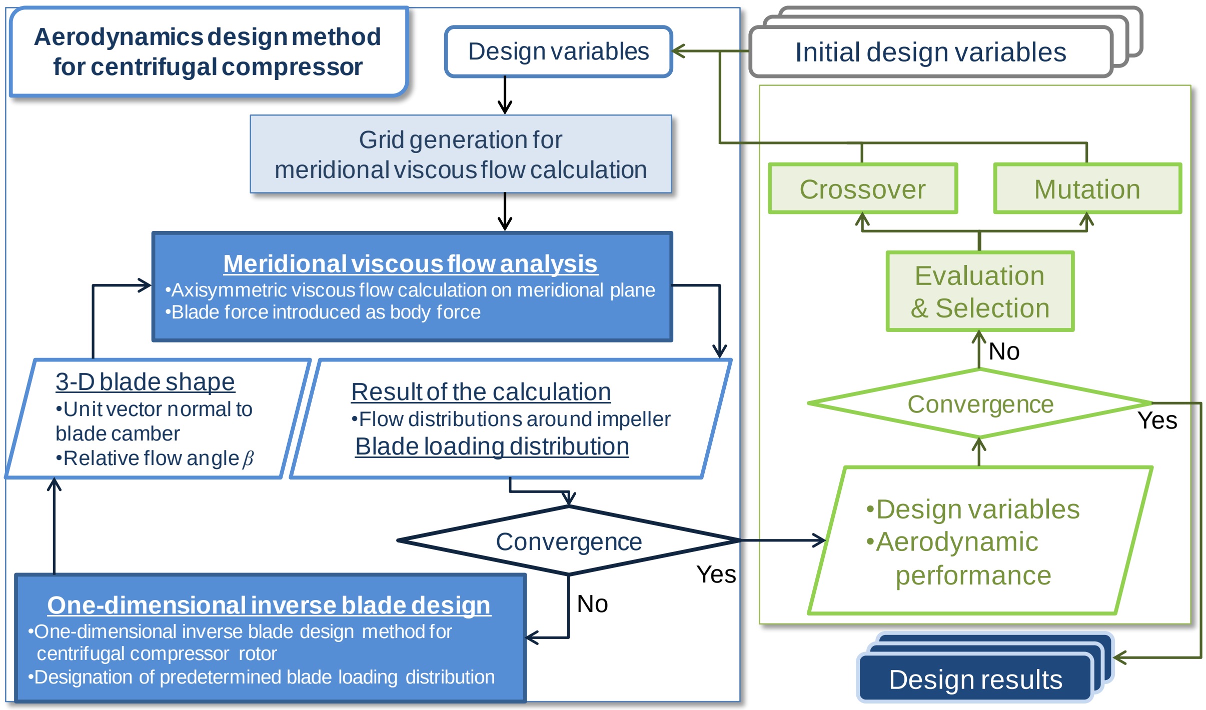

Figure 1. Flow chart of optimum aerodynamics design method

2. Verifying Method

In order to verify the present design method, total performances in the Pareto-optimum design and conventional design cases have been investigated by three-dimensional Reynolds averaged Navier-Stokes (RANS) analyses and experimental analyses. The Reynolds averaged Navier-Stokes equations were solved by an unfactored implicit upwind relaxation scheme with the k-omega two-equation turbulence model of Wilcox. The flow visualization techniques [2] have been applied to the RANS simulation results in the Pareto-optimum design and conventional design cases, in order to elucidate the relation between their aerodynamic performances and the flow fields.

References

[1] Eckardt, D., "Detail Flow Investigations within a High-Speed Centrifugal Compressor Impeller", Trans. ASME, Journal of Fluids Engineering, Vol. 98 Ser , No. 3, pp. 390-402, 1976.

[2] Sawada, K., "A Convenient Visualization Method for Identifying Vortex Centers", Transactions of the Japan Society for Aeronautical and Space Sciences, Vol. 38, No. 120, pp. 102-116, 1995.