A high-pressure ratio and a wide operating range are highly required for a turbocharger in diesel engines. The technical issue of the design concept is achievement of suppression of the flow separation at small flow rate without deteriorating the efficiency at design flow rate. A numerical simulation is very effective approach for design procedure of the impeller, the diffuser and the outer shroud casing. However, the cost of the numerical simulation is generally high during the practical design process, and it is difficult to confirm the design which is combined with many parameters. A multi-objective optimization technique is the idea that has been proposed for solving the problem in the practical design process. The main theme of this thesis is passive control method which focuses on stationary components of radial compressors such as casing treatment or diffuser rather than main component, impeller. This idea allows us to conduct researches without facing much difficulties in manufacturing the prototype. Improve manufacturing technology such as 3D printing technology makes possible to produce prototypes and test materials under academic research facilities.

The objective of this thesis is to study the performance improvement and the flow rate range enhancement of radial compressors. This is done in three radial compressors with seven research works. These are (1) Flow Rang Enhancement by Secondary Flow Effect in Low Solidity Circular Cascade Diffusers, (2) Optimization and Validation of Secondary Flow Effect for Flow Range Enhancement in a Low Solidity Circular Cascade Diffuser, (3) Study on the Performance Improvement of Centrifugal Compressors for Small Turbocharger, (4) Study on Flow Range Enhancement of Centrifugal Compressors for Small Turbocharger, (5) Study on Guide Vane in Recirculation Flow Type Casing Treatment by Applying Global Optimization Technique, (6) Study on Performance Improvement in Centrifugal Compressors by a Global Optimization Approach and (7) Off-design Performance Improvement in Centrifugal Compressors with Recirculation Flow Type Casing Treatment by Optimized Guide Vane. In this research work, a LSD blade is successfully optimized and validated the flow range enhancement experimentally. The detailed flow structure in the LSD diffuser has been presented by PIV measurement technique. Increase in pressure ratio at small flow rate and enhancement of operating range to surge margin by applying casing treatment in centrifugal compressors has been confirmed experimentally. Several optimized designs of recirculation flow type casing treatment have been proposed under different objectives. Improvement in efficiency, increase in pressure ratio and enhancement in operating range are presented numerically.

In Chapter 1, background, scope and objectives of the thesis is discussed and outline is described.
In Chapter 2, overview of research methodology used in this thesis is presented. The idea of optimization system, various optimization technique, meta-modeling, overview of artificial neural network, overview of genetic algorithm and optimization system used throughout in this thesis are discussed.

In Chapter 3, a Low Solidity circular cascade Diffuser (LSD) in a centrifugal blower is successfully designed. The optimized LSD blade has an extended operating range of 114% towards smaller flow rate as compared to the baseline design without deteriorating the diffuser pressure recovery at design point. The diffuser pressure rise and operating flow range of the optimized LSD blade are experimentally verified by overall performance test. The detailed flow in the diffuser is also confirmed by means of a Particle Image Velocimeter. Secondary flow is clearly captured by PIV and it spreads to the whole area of LSD blade pitch. It is found that the optimized LSD blade shows good improvement of the blade loading in the whole operating range, while at small flow rate the flow separation on the LSD blade has been successfully suppressed by the secondary flow effect.

In Chapter 4, three research work studying on performance improvement and flow range enhancement for a centrifugal compressor of a small turbocharger are presented. The shape of baseline recirculation flow type casing is modified and optimized by using a multi-point optimization code. Objective functions in the first research are to improve adiabatic efficiency of the compressor at two different operating points, the design mass flow rate and near surge mass flow rates. Objective functions in the second research are to improve adiabatic efficiency of the compressor at the design mass flow rate and to enhance the surge margin. Sensitivity analysis of design parameters as a function of efficiency has been performed. It is found that the optimized casing design provides optimized recirculation flow rate, in which an increment of entropy rise is minimized at grooves and passages of the rotating impeller. In the third research work, global optimization of two-dimensional guide vanes inside the recirculation flow type casing treatment has been performed. Excessive pre-whirl based on recirculation flow is suppressed by the optimized guide vane, and velocity distortion at impeller inlet has improved. It is found that improvement of the efficiency in the case of the optimized guide vane is supported by proper distribution of flow at impeller inlet.

In Chapter 5, two research works studying on performance improvement for a centrifugal compressor of a commercial turbocharger are presented. In the first attempt, a global optimization of a recirculation flow type casing treatment has been done. The selected individuals show the improvement in adiabatic efficiency for entire flow rate range without static pressure rise penalty. In the second attempt, three-dimensional parameterization of guide vanes inside the recirculation flow type casing has been introduced. Application of the optimized guide vane shows improvement in adiabatic efficiency and static pressure rise by suppressing the excessive pre-whirl at impeller inlet at off-design condition.

In Chapter 6, the research works are summarized, major achievements are discussed, important design variables and parameters for performance improvement and flow range enhancement are pointed out and future research directions which has potential to improve further in designing the radial compressors are described.