

Numerical Optimization on a Centrifugal Turbocharger Compressor

Mingxu Qi, Chaochen Ma and Ce Yang
Beijing Institute of Technology

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ABSTRACT

Performances of a centrifugal turbocharger compressor are investigated and validated in this paper. Based on the validation results, numerical optimizations are performed using ANN and CFD methods. Different impeller geometry with free parameters controlling stacking laws, end-wall, blade sectional camber curves and corresponding performances are used as input layer of ANN in the optimization, while adiabatic total-to-total efficiency and total pressure ratio are used as output layer of the optimization cycle. With this method, the performances of the compressor investigated in this paper are improved notably.

INTRODUCTION

With the developments of CFD tools, the design procedure of turbomachinery blades is becoming more efficient and reliable compared to traditional experience-based design methods. However, even with the use of state-of-art CFD codes or tools, it's still somewhat a complicated task for a designer to perform a round design cycle on turbomachinery blades. The reason lies on the fact that most such design cycles include similar steps, i.e., transfer conceptual design results to CAD or other blade modeler tools and get the 3D blade geometry, with which full 3D CFD codes can be used to predict the performance and flow details of the blades, then the flow characteristics inner the blade channels are investigated and thus designer may find the working direction of improving the performance of existing blades. This is the so-called try-error method, and in most cases, the designer may run the cycle many times to reach the final blade geometry with satisfied performances, which is of course complicated and time-consuming. Another drawback of the try-error method is that it's very difficult for a designer to reach fully innovative blade geometries with top level performances, or even he can, he can

never guarantee that the blade performances are the "best".

After years' accumulation of technologies and experiences on turbomachinery blade design, the new generation turbomachineries are now working with higher and higher performances and it also becomes more and more difficult for designers to break through the bottleneck to design even better blade geometries. Since the flow behaviors in turbomachinery blade channels are so complex and so many aspects should be considered that even CFD experts sometimes are unable to point out the direction in which the modification should be performed on the blade geometry. Thus a revolutionary method should be used to free designers from the bundles. In recent years, new design cycles have been developed with the help of efficient optimization methods, which is bringing the turbomachinery blade design system to a new decade. Probably only with such reasonable cycle, fully innovative blade geometries can be designed to fit the challenges of next decades of turbomachinery design commands.

There are many kinds of optimization methods and as representatives, gradient-based method, genetic method and simulated annealing method and the most common used methods. These methods have their advantages and disadvantages when used directly in blade design cycle. For example, gradient-based optimization method is quite efficient on convergence, but it may not find the global optimized geometries (VanderPlaats, 1984), while genetic method offers the possibilities of finding the global optimum but is very weak on optimization convergence, which may need hundreds or even thousands' integrations (Goldberg, 1994). This almost wipes away the possibility of coupling genetic optimization and CFD together to be used for industrial design purposes. Demeulenaere(Demeulenaere & Hirsch, 2004) employees artificial natural network(ANN)

procedure instead of flow solver to evaluate the successive designs, which makes the genetic optimization working in a more efficient way. With this method, approximate model is built based on the knowledge of training database with ANN, and the performances of successive designs can be evaluated very quickly.

The wide use of turbocharger decreases the emission and improves the performances of engine significantly. A better design of turbocharger can further improve the engine performances, to this point, the key should be the better design of the rotating parts, i.e., the compressor and turbine impeller. Due to complexity of design process and blade geometry, there should be great potential for compressor improvements if efficient design and optimization cycles can be performed. Thus, to realize this purpose, a numerical optimization is performed on a centrifugal turbocharger compressor in this paper to find the way of improving performances in an efficient and simple way.

CASE DESCRIPTION

A 90mm turbocharger compressor is selected as research object (HU, 2007). The compressor has 7 main blades and 7 splitter blades for impeller and the vaneless diffuser is used. Figure 1 shows the 3D render view of the compressor and figure 2 illustrates the mean dimensions of the impeller.

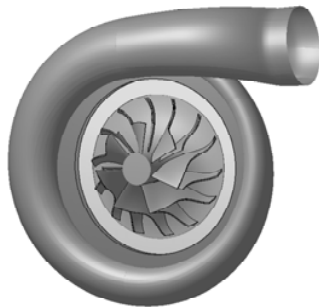


Fig. 1 Compressor 3D render view

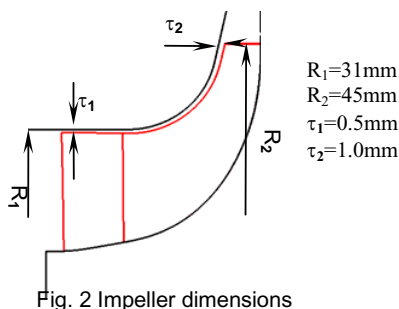


Fig. 2 Impeller dimensions

The compressor is tested in Turbocharging Technology Lab of BIT, focus mainly on global performances such as efficiency and pressure ratio. The design point of the compressor at rotating speed of 80000rpm corresponds

to performance of efficiency (total-to-total) and total pressure ratio being 74.9% and 2.16 respectively. The objective of this paper is to perform optimization on the design point of 80000 rpm by increasing compressor efficiency and total pressure ratio at the same time.

OPTIMIZATION ENVIROMENT

FINE/Design3D package (NUMECA, 2006) is used in this paper for numerical optimization procedure. The package is developed by NUMECA International, s.a., acts as an independent optimization environment. 3D blade modeler, mesh generator, CFD solver and postprocessor are coupled together in the package, which offers an integrated design and optimization cycle for turomachinery blades.

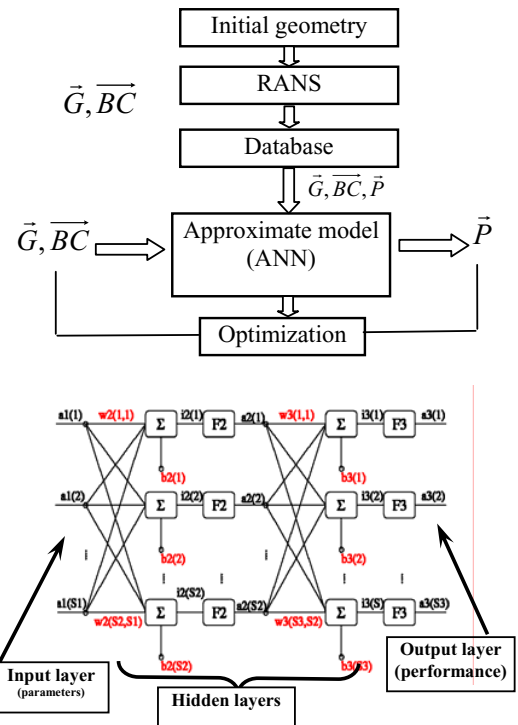


Fig. 3 Optimization cycle and ANN

Figure 3 illustrates the optimization cycle and ANN which is used for constructing approximate model. The optimization cycle starts with initial geometry in parametric model. With RANS solver coupled, different blade samples can be generated by specifying boundary condition and range of free blade geometric parameters. The samples constitute the knowledge database, in which, each sample has unique blade geometry (with different blade parameters) and performances (derived by RANS solver). The blade geometry and its performances are used as input layer of ANN system and then approximate model is constructed to evaluate successive blade geometry with better performances (output layer). Then RANS solver is again used to predict the reliable performances of the evaluated blade geometry. Final global optimum will be found if the performances evaluated by ANN and RANS solver