Shape Optimization of Valve Channel with Incompressible to Compressible Simulation for Pressure Loss Calculation

- application for reciprocating compressor

Mr. Seiji Kubo, seiji_kubo@ihi.co.jp	IHI Corporation 1, Shin-Nakahara-Cho, Isogo-Ku, Yokohama 235-8501, Japan

Abstract

Reciprocating compressors are used in LNG (Liquid Natural Gas) plants so as to compress the BOG (Boil Off Gas), which is generated by the heating from the environment. Among many components of the reciprocating compressor, the suction/discharge valves are the most important part. There are two main required performance of the valves: reliability and low pressure loss. Furthermore, the valves need to maintain the performance stably within the expected wide range of usage, which is the very reason that the reciprocating compressors are employed. In this meaning, the reliability of the suction/discharge valves can be said to be equal to the high robustness. Therefore, the design of the valves have to be the optimal robust design, which assures sufficiently low pressure loss under whole operation range.

At present, a lot of optimal and robust design tequniques are used for designing the industrial machineries. Taguchi method [1] is one of the well known techniques in robust design discipline. In this study, the valve channel (Fig.1) is optimized to the robust design using Taguchi method, focused on the reduction of the pressure loss in the channel under wide range of input conditions.

In the part of flow simulation, OpenFOAM-1.6 is utilized instead of commercial softwares. This simulation part is composed of two steps. At the first step, the static pressure and the mass flow rate are obtained from the result of incompressible flow analysis using SimpleFoam, for every design point of the L36 orthogonal array. In the second step, the pressure loss is calculated as the difference of total pressure between inlet and outlet, using the rhoSimpleFoam for the simulation of the compressible flow. In this step, the value of outlet total pressure, which is the boundary condition on valve outlet, is automatically tuned iteratively by customized main program of rhoSimpleFoam so that the mass flow rate of incompressible flow is established. Fig.2 shows the convergence history of the ratioMassFlow, which is the disagreement from the target mass flow rate, in a simple case for the code verification. The ratioMassFlow converges to zero.

The variation of temperature and mass flow rate for the inlet boundary condition are employed as the noise factor which reproduces the wide range of operation in which the robustness must be established. Therfore 432 cases (36 initial cases $\times$ 3 inlet velocity $\times$ 2 temperature $\times$ 2 mass flow rate) are needed for this optimization. The whole steps, which are the initial grid generation, incompressible/compressible flow analysis and calculation of pressure loss, and 432 times repeat of these, run automatically. This automization can reduce the time to get the 432 solutions to one hundredth of a manual process. The optimization with OpenFOAM is currently working. We expect to obtain the pressure loss of optimal valve channel 20 % lower than that of the original, while maintaining sufficient robustness.

Parallel computation of OpenFOAM is very effective for hundreds of cases. OpenFOAM would take an important role of the optimization tool because of the low cost availability and customization flexibility, which are the advantages of open source software.

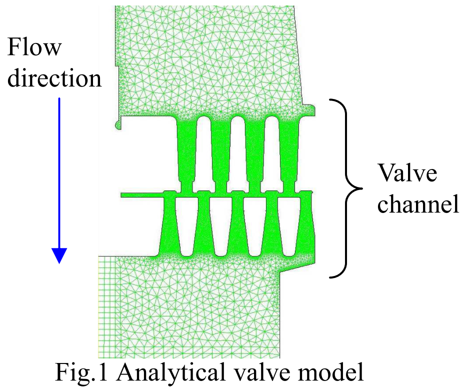

Fig.1 Analytical valve model

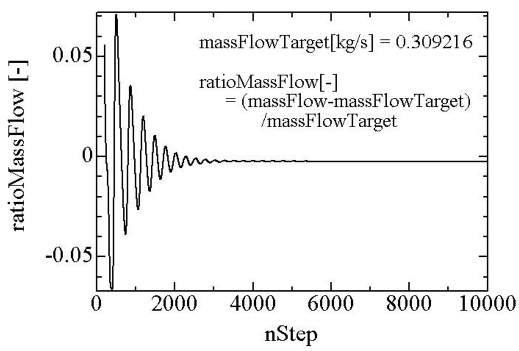

Fig.2 ratioMassFlow convergence history

Key words: Valve, Optimization, Robustness, Taguchi method, Pressure loss, OpenFOAM, Target mass flow

References

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