

Strategic Young Researcher Overseas Visits Program for Accelerating Brain Circulation 2011

“Development of Young Researchers Based on International Joint Research on Green Energy Systems” Progress Report

1. Name: Daisaku Sakaguchi
2. Title: Associate Professor
3. Host Institution: Von Karman Institute for Fluid Dynamics (Belgium)
4. Host Researcher: Professor Tony Arts
5. Duration: 06-March-2012 – 15-March-2013
6. Research Topic: Multidisciplinary Optimization of a Centrifugal Compressor
7. Overview of the Results of the Collaborative Research:

A multidisciplinary optimization technique is applied to the design of a low solidity cascade diffuser (LSD) in centrifugal compressors. An optimization code which is developed by von Karman Institute for Fluid Dynamics (VKI) is operated by a meta-model assisted evolutionary algorithm. An artificial neural network (ANN) is used as the meta-model for evaluating diffuser performance in each generation. The performance of the best shape of the LSD blade from the evolutionary algorithm is confirmed by a Reynolds Averaged Navier-Stokes Simulation (RANS). The result of RANS analysis is stored in a database and the meta-model is re-trained by the new database. Two kinds of static pressure coefficient are applied for the objective functions, one at a design flow rate, and the other at a small low rate. The lift coefficient of the LSD blade is analyzed at several flow rates. The slope of the

lift coefficient as a function of the flow rate is applied as a constraint of optimization. Moreover, small tip clearance of the LSD blade is applied in order to stabilize the secondary flow effect at low flow rates. It is found that the optimized shape of the LSD blade shows good improvement of lift coefficients in whole flow rate ranges, and flow separation of the LSD blade is successfully suppressed by the secondary flow effect at low flow rate conditions. The operating flow rate range is extended to the low flow rate without deteriorating the diffuser pressure recovery at the design flow rate.

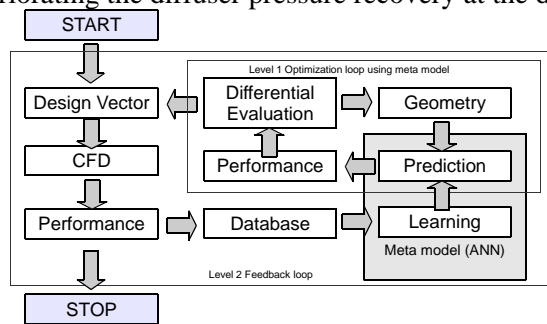


Fig.1 General layout of the VKI optimization system

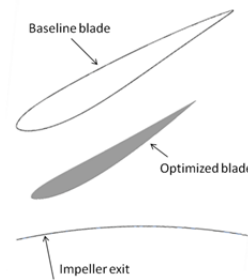


Fig.2 Optimized blade of LSD

8. Deployment Plans for Future Collaborative Research:

The primary technical issue regarding energy saving in industrial plants is the improvement of a turbomachinery, such as compressors, turbines, fans and blowers. Numerical simulation is widely used as a turbomachinery design procedure. In most cases, several kinds of performance parameters are required to improve simultaneously, such as aerodynamic efficiency, compactness, a reduction in stress, improved heat resistance, and increased operating range. However, the cost of the numerical simulation is relatively high during the practical design process, and it is difficult to confirm the design which is combined with many parameters. The multi-disciplinary optimization technique is one the idea that has been proposed solve the problem in the practical design process. An optimization code developed by von Karman Institute for Fluid Dynamics (VKI) is the state of the art optimization system with a meta-model assisted evolutionary algorithm. The multi-disciplinary optimization technique with meta-model is effective idea to reduce the simulation cost. It will be the practical design tool for developing turbomachinery, including fans, blowers, compressors and turbines. Moreover, the multi-disciplinary optimization technique is an effective tool for research work. Statistical results from database of the multi-disciplinary optimization technique will bring a significant amount of information to create new innovative designs. In this program, the optimization code was successfully implemented to the CFD code ANSYS-CFX and applied towards the

development of a low solidity cascade diffuser. Future collaborative work between VKI and Nagasaki University is development of a novel type of turbomachinery by means of the aforementioned optimization code which is developed by this project. The collaborative research work will contribute to energy savings for turbomachinery all over the World.

9. List of Collaborative Research Progress:

Conference Presentations

1. Daisaku Sakaguchi, Multidisciplinary Optimization of a Low Solidity Cascade Diffuser, Lecture note of the 4th subcommittee meeting of Turbomachinery, 2013
2. Daisaku Sakaguchi, Multidisciplinary Optimization Design of a Low Solidity Cascade Diffuser (Simultaneous improvement of the aerodynamic performance at design and small flow rate) (in Japanese), Proceedings of the 69th annual meeting of Turbomachinery, pp.1-7, 2013
3. Daisaku Sakaguchi, Kanata Mizokoshi and Daiki Kishikawa, Multidisciplinary Optimization of a Low Solidity Cascade Diffuser in a Centrifugal Blower, Proceeding of the 12th Asian International Conference on Fluid Machinery, Yogyakarta Indonesia, AICFM12-052, pp.1-9, September, 25 – 27, 2013
4. Daisaku Sakaguchi, Takuma Eida and Kanata Mizokoshi, Multidisciplinary Optimization Design of a Low Solidity Cascade Diffuser (Experimental Validation of the Optimized Blade) (in Japanese), Proceedings of the 70th annual meeting of Turbomachinery, pp.1-7, 2013
5. Daisaku Sakaguchi, Daiki Kishikawa and Kanata Mizokoshi, Multidisciplinary Optimization Design of a Low Solidity Cascade Diffuser (Stabilization of Secondary Flow by Tip Clearance) (in Japanese), Proceedings of the JSME FED Conference, Paper No.0417, pp.1-2, 2013
6. Kanata Mizokoshi, Takuma Eida, Xiangyu Zhang and Daisaku Sakaguchi, Measurement of Secondary Flow in a Low Solidity Circular Cascade Diffuser by a Particle Image Velocimetry (in Japanese), Proceedings of the 70th annual meeting of the JSME Kyushu Branch, Paper No.125, pp.1-2, 2014
7. Daisaku Sakaguchi, Kyoshiro Murakami and Daiki Kishikawa, Multi-objective Optimization of a Recirculation Type Casing Treatment in a Centrifugal Compressor (in Japanese), Proceedings of the 70th annual meeting of the JSME Kyushu Branch, Paper No.126, pp.1-2, 2014
8. Daisaku Sakaguchi, Multi-objective Optimization of a Low Solidity Cascade Diffuser in Centrifugal Blowers (in Japanese), Journal of Turbomachinery, (In press)

9. Daisaku Sakaguchi, Masahiro Ishida, Hiroshi Hayami, Lasse Mueller, Zuheyr Alsalihi and Tom Verstraete, Multipoint Multi-objective Optimization of a Low Solidity Circular Cascade Diffuser in Centrifugal Blowers, Proceedings of the ASME Turbo Expo 2014: Turbine Technical Conference and Exposition, Düsseldorf, Germany GT2014-26013, pp.1-10, June 16 – 20, 2014 (In press)