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

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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.

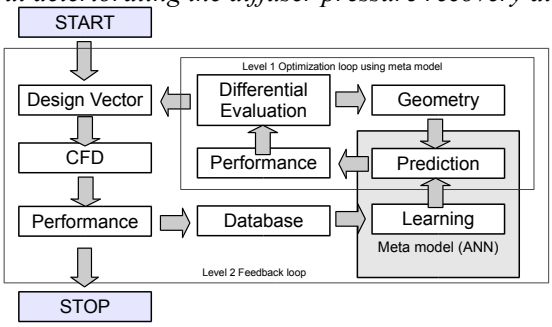

Fig.1 General layout of the VKI optimization system

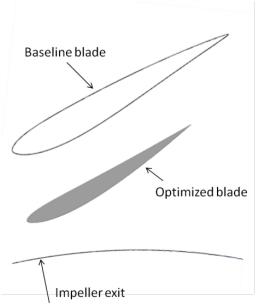

Fig.2 Optimized blade of LSD

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 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

2. 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

3. 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

4. Daisaku Sakaguchi, Multi-objective Optimization of a Low Solidity Cascade Diffuser in Centrifugal Blowers (in Japanese), Journal of Turbomachinery, Vol.42, No.10, pp633-641, 2014

5. 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
6. Daisaku Sakaguchi, Min Thaw TUN, Kanata Mizokoshi and Daiki Kishikawa, Flow Range Enhancement by Secondary Flow Effect in Low Solidity Circular Cascade Diffusers, Journal of Thermal Science, Vol.23, No.4, pp.391-400,2014
7. Daisaku Sakaguchi, Flow Range Enhancement of a Low Solidity Cascade Diffuser of Centrifugal Blowers by Multi-objective Optimization, The 5th International Conference on Science and Engineering (ICSE2014), Yangon, Myanmar, ME-13, pp.1-5, 2014
8. Min Thaw Tun, Daiki Kishikawa, Daisaku Sakaguchi, Numerical Investigation of Centrifugal Compressor for Turbochargers with an Optimized Ring Groove Arrangement, The 5th International Conference on Science and Engineering (ICSE 2014), Yangon, Myanmar, ME-03, pp.1-5, 2014
9. Min Thaw Tun, Daisaku Sakaguchi, Optimization and Validation of Secondary Flow Effect for Flow Range Enhancement in a Low Solidity Circular Cascade Diffuser, ASME-JSME-KSME Joint Fluids Engineering Conference 2015, AJK2015-FED, July 26-31, 2015, Seoul, Korea, AJKFluids2015-02174, pp.42-51 (2015)
10. Min Thaw Tun, Diasaku Sakaguchi, Flow Range Enhancement by Recirculation Flow Type Casing Treatmentin Centrifugal Compressors of Turbocharger, The 13th Asian International Conference on Fluid Machinery AICFM13, Waseda, Tokyo, AICFM13-135, pp.1-10, 2015
11. Daisaku Sakaguchi, Min Thaw Tun, Global Optimization of Guide Vane in Recirculation Flow Type Casing Treatment for Centrifugal Compressors, The 6th International Conference on Science and Engineering (ICSE 2015), Yangon, Myanmar, No.79, pp.1-5, 2015
12. Min Thaw Tun, Daisaku Sakaguchi, PIV Measurement of the Flow Structure in the Diffusers of a Centrifugal Blower, The 6th International Conference on Science and Engineering (ICSE 2015), Yangon, Myanmar, No.75, pp.1-5, 2015

13. Daisaku Sakaguchi, Min Thaw Tun, Ryusuke Numakura and Baotong Wang, Global Optimization of Recirculation Flow Type Casing Treatment in Centrifugal Compressors of Turbocharges, The 12th International Conference on Turbochargers and Turbocharging, London, UK, ICTT-140,pp.1-14, 2016
14. Min Thaw Tun, Daisaku Sakaguchi, Multi-point Optimization of Recirculation Flow Type Casing Treatment in Centrifugal Compressors, Journal of Thermal Science, Vol.25, No.3, 2016