Proceedings of the World Congress on Engineering 2009 Vol I
WCE 2009, July 1 - 3, 2009, London, U.K.

Web-based Axial Fan Simulator using Supercomputer

Myungil Kim, Seungmin Lee, Jaesung Kim, and Sangmin Lee

***Abstract*— Recently, the importance and necessity of engineering analysis has shown a steady growth. However, researchers working in small and medium enterprises know little about the usefulness of engineering analysis and suffer from lack of technical knowledge. Axial fan is air fluid machinery in various fields of industry such as automobile, electric appliance, and heavy machinery. It is also a time and budget consuming equipment to develop the axial fan through physical experiments. In order to overcome this problem, we have designed and developed a web-based axial fan simulator using supercomputer. In our simulator, all of processes for engineering analysis including pre-process, solving, and post-process can be performed automatically without user intervention after transferring fan model(CAD files) made by user. After executing the simulator with some parameters, user can receive report including P-Q curves. In this paper, we introduce the architecture of our easy and efficient automated axial fan simulator, related techniques and result of development.**

***Index Terms*—Axial Fan, Fluid Analysis, Supercomputer, Simulator, Auto-Mesh Generation**

I. Introduction

Reducing the time and cost required for the development of a product is one of the latest topics in the industry. Reducing the time required for the design can be achieved by the use of the computing evaluation using CAE (Computer Aided Engineering) instead of experiments where trial and error is required. CAE is the use of information technology to support engineers in tasks such as analysis, simulation, design, manufacture, planning, diagnosis, and repair and is being adopted by many different industries. CAE was first introduced in the mid 80's around large enterprises and was spread through to the primary vendors in the auto-industry in the late 90's. Since 2005, industries with less than 100 million us dollar in annual sale have also started to adopt CAE. The latest growth rate in the CAE industry has reached about 20% annually [1].

Axial fan is the most common air flow machinery and is being used in various different industries such as for heavy machinery, home equipment and automobile [2], [3]. In designing an axial fan, the shape of the airfoil, type of sweep and the number of blade decide the shape and performance of the fan [4]. For the development of an axial fan, the process of design, mockup, experiment using measuring devices, and data analysis is required which are all time and money consuming processes. Therefore, to design the fan more effectively, the process of fluid analysis by using numerical analysis methods is required. However, this requires knowledge on CFD (Computational Fluid Dynamics) which makes it difficult to adopt by small and medium enterprise with little budget and technology.

A fan designer and a CFD engineer have to go through the process of design, analysis and examination repetitively in order to develop an axial fan as shown in Fig. 1. To improve on such low-efficient/high cost process, the designer must be able to design and analyze the fan by oneself. Many different functions such as the generation of CAD file, the repair of the CAD file, mesh generation, solving using supercomputer and post processing of the result are required and can be performed automatically to achieve this goal.

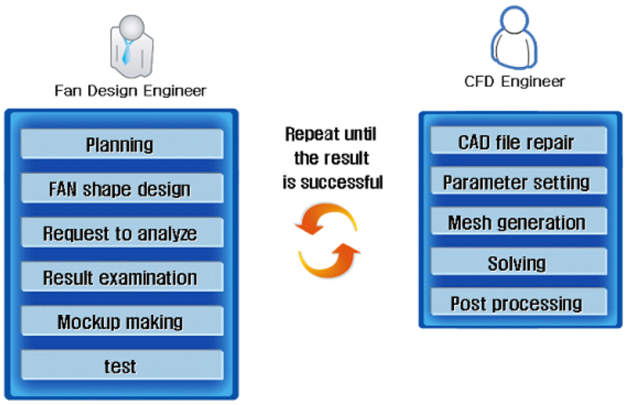

Fig. 1 Existing Process of Axial Fan Development

Automation of the 3D modeling for the axial fan design has been attempted before [5], [6], but the automation of the fluid analysis using a supercomputer has never been attempted. The axial fan simulator using a supercomputer supports the fan designer to easily perform the fluid analysis of the axial fan without the help of a CFD engineer. The supercomputer shows an outstanding calculation performance compared to a personal computer which enables the rapid and various analyses. In this paper, the automation technology, system design and implementation and the result of the implementation will be discussed.

Manuscript received February 23, 2009.

Myungil Kim is with Korea Institute of Science and Technology Information, Daejeon, Korea (phone: +82-42-828-5162; fax: +82-42-869-0769; e-mail: mikim@kisti.re.kr).
Seungmin Lee is with Korea Institute of Science and Technology Information, Daejeon, Korea (e-mail: smlee76@kisti.re.kr).
Jaesung Kim is with Korea Institute of Science and Technology Information, Daejeon, Korea (e-mail: jaesungkim@kisti.re.kr).
Sangmin Lee is with Korea Institute of Science and Technology Information, Daejeon, Korea (e-mail: smlee@kisti.re.kr).

II. AUTOMATIC PROECESES FOR FLUID ANALYSIS

The process for automating the fluid analysis of the axial fan is shown in Fig. 2. The fan designer designs the fan using a CAD program or CAD generation function of the system and makes an input to the simulator. The simulator creates the model for the design using this file and creates the mesh. The analysis is performed using a supercomputer before performing the post-processing operation on the result. Commercial software such as CADThru and SC/Tetra [7] have been used for the process.

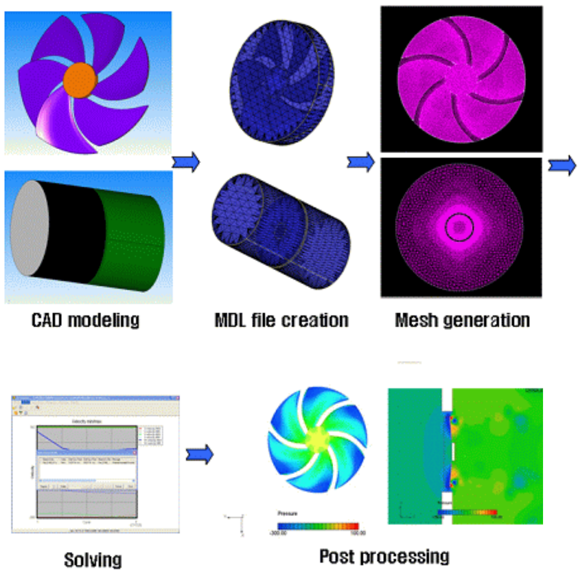

Fig. 2 Automated Process of Axial Fan Development

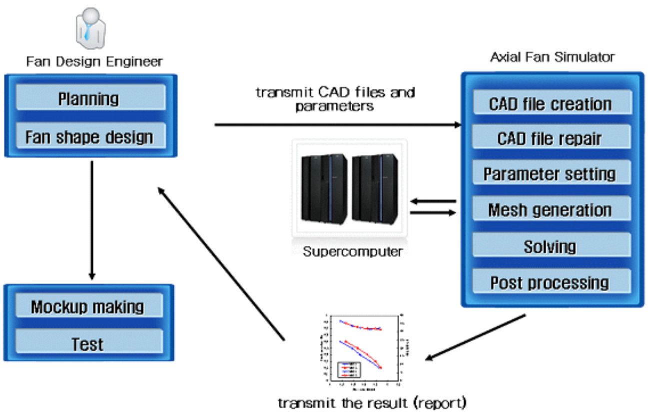

Fig. 3 System Structure and Processes

The axial fan simulator has been designed as shown in Fig. 3. There are two ways to send CAD file to the server: one is sending user-created CAD file to the simulator through the Web, the other is creating the CAD file using the automatic CAD generation function on the simulator. And then user sets up the related parameters. The simulator performs CAD file repair, mesh generation and boundary conditions setting up using the CAD file and sends the data to the supercomputer. The supercomputer performs the analysis and re-sends the result to the simulator. The simulator creates an image of the result and sends it to the designer. The simulator runs on Pentium dual 3.0 GHz, 3GB RAM hardware and WindowsServer2003 operation system. The IBMp595 with AIX 5L 5.3 as the operation system is the supercomputer used for the axial fan simulator.

III. DESIGN AND IMPLEMENTATION OF THE SIMULATOR

To automate the fluid analysis of the axial fan, each process requires to be automated. In other words, all of processes have to be performed without user's intervention. In this section, we discuss the details for automating each process and the implementation issues.

A. CAD File Creation

The simulator provides two methods for designing the fan shape: a detail design and a conceptual design. The former means that user can make a CAD file using any CAD software and send that file through the FTP to the simulator and the latter means that user can design the fan shape using the parametric design function on the simulator homepage as show in Fig. 4. User having insufficient knowledge about CAD even can design an axial fan shape using six parameters; diameter(tip), diameter angle ratio, pitch angle(tip), pitch angle ratio, number of blade and sweep angle. Then the simulator creates point data for making the fan shape using user parameter values automatically.

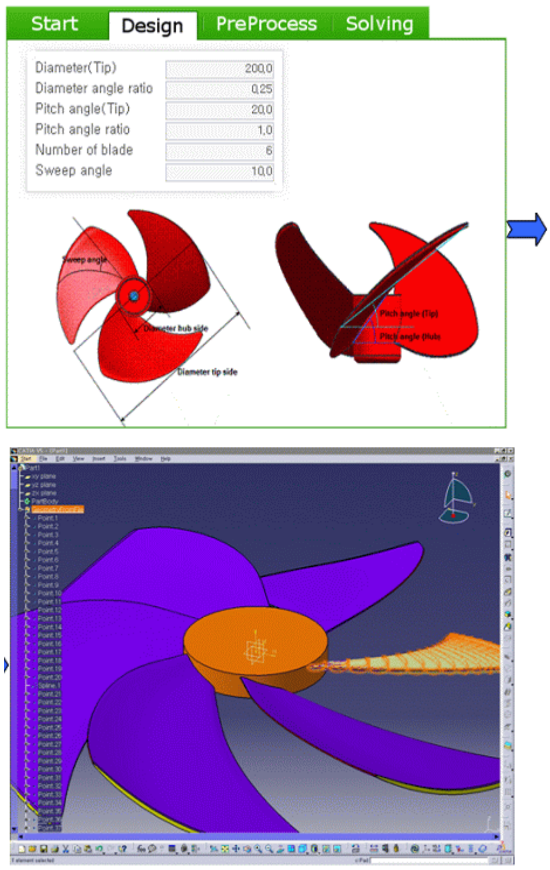

Fig. 4 an Example of Parametric Design

B. CAD Repair

The fluid analysis of the axial fan requires some complex setup procedure for the pressure at the inlet and outlet, flow rate, wall condition and RPM. To automatically implement this procedure in the simulator, a color is designated for each parts of the CAD file and the boundary condition is met to complete the procedure. In other words, the usual requirements for an axial fan analysis are setup and a color is put onto the location on the part of the CAD, as shown in Fig. 5. If the sliding shape, indicating the rotation of the fan, is named "cyl_i_b" with color RED, all the other RED parts are applied with the sliding condition. The color of the blade wall is set to PURPLE and the simulator can detect the blade automatically using the color. The hub area uses the color ORANGE and all the shapes in the CAD file colored ORANGE will be applied with the same requirements as the hub. By using the CADthru program, the CAD file is transformed into a "mdl" format file to automatically designate the name of the surface and the octree and the boundary conditions are put in according to that name. Therefore the fan designer has to perform the modeling by setting the color according to the RGB value shown in Fig. 5.

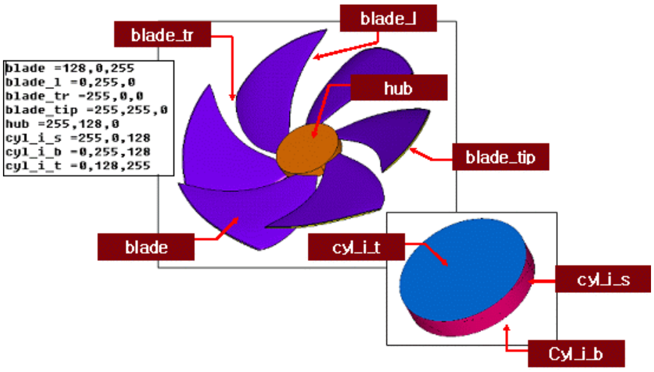

Fig. 5 Example of the Automatic Boundary Condition Setting using Color

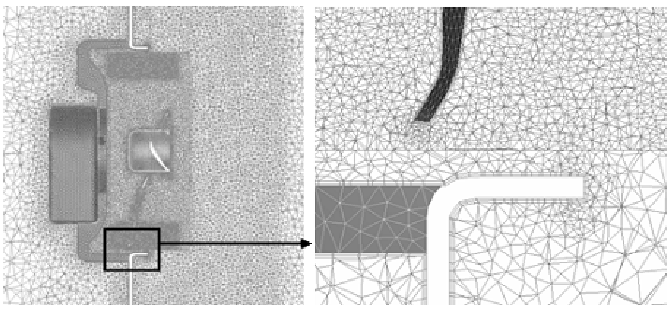

Fig. 6 Result of Mesh Generation around Fan Blade

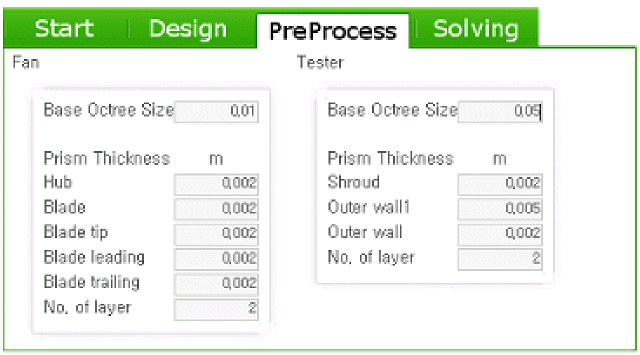

Fig. 7 Base Octree Input Interface

C. Mesh Generation

Experience, time and special knowledge on CFD are required for the accurate creation of the mesh. We had performed a large number of meshing and analyze for the axial fan and could acquire the best conditions for automatic mesh generation. Tetra, hexa, and prism are used together for the meshing and the prism is used for the wall, hexa for a large area, and a tetra is used for the space in between. The mesh generation method spreads the rectangle cube into the whole area and turns the important area into a small cube. Since the size of a cube decides the size of the tetra mesh, the process for deciding the size of the cube becomes a very important issue. The size of the cube in the more important parts of the fan, such as the front or back side, should be made as small as possible to make the size of the mesh small and even. Fig. 6 shows the result of the mesh generated by using the octree. As shown in Fig. 7, we also provide a designer with base octree input interface to set the base octree size of the fan and tester.

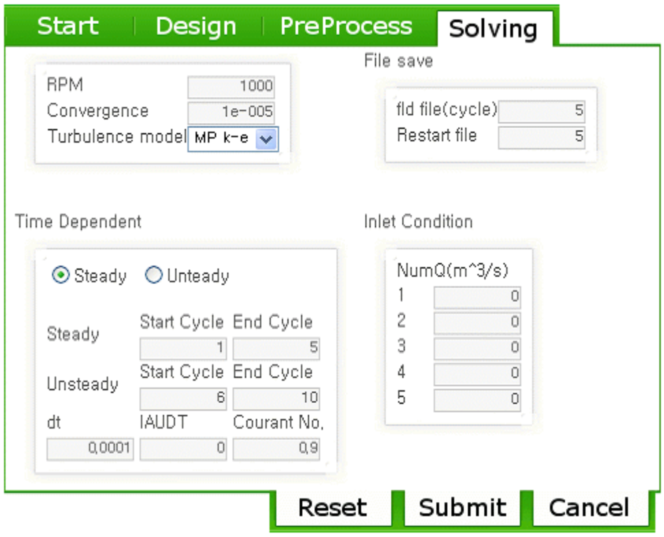

Fig. 8 Solving Conditions

D. Solving

After generating the model for the fluid analysis through the pre-processing, the boundary conditions required for the analysis have to be put in. However, the boundary conditions are also set to the optimal values to enable the user to only input the RPM of the fan and angle of the fan for each cycle to setup the *dt* value. Fig. 8 shows the interface for the input of the boundary conditions for the fluid analysis and we have identified each condition required for the analysis as follows.

- Base Conditions : RPM, convergence value, turbulence model (the simulator supports nine models such as Standard k-EPS, RNG k-EPS, MP k-EPS and so on)
- Time Dependence : problem type(steady or unsteady), total cycles setting according to problem type, time per a cycle(calculated by the number of rotation and cycle/degree)
- File Save : the number of file saving for the '*fld*' file for post-processing and the '*R*' file for roll-back.
- Inlet Condition : the flow rate required for the fan analysis(the P-Q curve can be obtained by using this value and pressure value which is the result of the analysis)

This analysis conditions are saved onto the '*S*' file, where all the commands are arranged using the analysis condition values and are used for the actual solving.

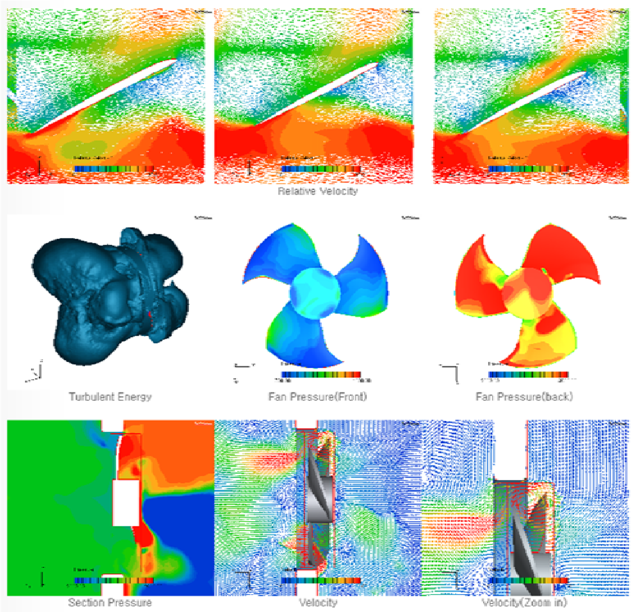

Fig. 9 Results of the analysis

E. Post Processing

For the implementation of the post-process function, we have used the method of using the "Status file" used in the CFD code. The Status file stores the pressure and speed information required to draw the picture based on the result of the CFD analysis model, as shown in Fig. 9. The designer can make the decision on whether the design is correct and where to look for the problem for the modification. The comparative speed at each section of the blade shows whether the fluid flow passes through the section or a separation occurs. Also, the effectiveness of the fan can be figured out by the pressure on the blade. The movement of the fluid flow can be found by measuring the distribution of the speed and pressure at the vertical surface of the fan.

IV. Conclusion

In this paper, we have discussed about the easy and efficient web-based axial fan simulator using supercomputer for the fluid analysis required in the development of an axial fan. The optimized and automated analysis process has constructed for improving the ineffectiveness of the traditional fan developing method. The CAD creation and repair, mesh generation, solving and post-processing are developed and applied for automating whole analysis process. Also, a web-based automation system, which uses supercomputer as the solving server, was constructed to minimize the limit on the mesh generation for improved accuracy and solving time. In the future, functions such as noise analysis and design optimization have to be added for service to public users.

References

[1] CAD & Graphics, February, 2007.
[2] Frank P. Bleier, *FAN HANDBOOK*, McGrawHill, 1998.
[3] Kim. W, Jeon. W. H, Cho. J. H, Shin. D. S, and Kim. H. J, "Numerical study on the noise generation of the axial fan in a refrigerator", *Internoise*, 2006.
[4] Kim. W, Jeon. W. H, Ahmad. I, and Cho. J. H, "Development of the virtual anechoic fan tester for axial flow fans," *The 9th Asian International Conference on Fluid Machinery*, 2007.
[5] Elgowainy. A, Feinstein. D, and Rodriguiez. I, "Performance analysis of axial fans in unitary air-conditioning systems," *Energy Conversion Engineering Conference*, pp.521-536, 2004.
[6] Ki-Sang. Lee, Kwang-Yong. Kim, and Samad. Abdus, "Design optimization of low-speed axial flow fan blade with three-dimensional RANS analysis," Journal of mechanical science and technology, V.22, No.10, pp.1864-1869, 2008.
[7] CRADLE Homepage, Introduction to Products [Online]. Available: https://www.cradle.co.jp/en/product/index_p.htm.