Strategic Infrastructure for the Development of Advanced CAE Technology

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Analysis Technology Research Center has contributed to reliable and sophisticated product design and the optimization of manufacturing processes in Sumitomo Electric's five major business fields through the use of computer-aided engineering (CAE) technology. CAE analysis technology is now increasingly important, since it is the key to developing competitive products. Nevertheless, establishing CAE technology takes a significant amount of time due to the fact that the process from building a mathematical model to experimental validation can take up to several years. In order to shorten this period, we decided to introduce powerful infrastructure including both hardware and software. We devoted our attention to the results of a survey we had conducted to determine the CAE technology requirements of the Sumitomo Electric Group, and investigated the performance of newly developed software in the fields of "structural analysis," "high-frequency electromagnetic analysis," "fluid dynamics," and "molecular design." Furthermore, we conducted several benchmark tests for large-scale parallel computer systems to select suitable equipment. In this paper, we describe how we settled on our infrastructure building direction and how such an infrastructure system can be utilized effectively in various business fields.

1. Introduction

Analysis Technology Research Center (ATRC) of Sumitomo Electric Industries, Ltd has been actively involved in research projects throughout .the company's five major business segments (Automotive; Information & Communications; Electronics; Electric Wire & Cable, Energy; and Industrial Materials), as well as in new business segments, in a bid to establish a core computer simulation technology, computer-aided engineering (CAE), for the entire Sumitomo Electric Group. In recent years, CAE technology has become increasingly important since in some cases, the level of CAE-based product design, development, and evaluation determines whether or not products are ordered. At the same time, however, the establishment of analysis technology, which is the key to product development, can take several years from the building of elemental technologies to experimental validation. To enable the company to achieve its mid-term business plan, VISION 2012, it is essential that we shorten the development period while enhancing our technological strength. In order to develop the core technology needed to accomplish the plan and achieve results using such technology by 2012, the question of whether or not we would be able to establish infrastructure (software and hardware) capable of meeting future technological requirements in fiscal 2008 – the first year of the mid-term business plan – assumed the utmost importance.

It was against this background that in fiscal 2007, the ATRC conducted a survey on the demand for CAE technology among users of such technology, i.e., the company's production divisions and research laboratories, and has since taken action based on the survey findings. We investigated the performance of newly developed software in fields where the in-house survey indicated that analysis technology was most needed, namely, "structural analysis," "high-frequency electromagnetic analysis," "fluid dynamics," and "molecular design" (**Table 1**). We found that a number of software applications with dramatically improved and ultra-high performance have become available. As such software applications are expected to become increasingly fast and precise, we concluded that their introduction and use will determine the company's product development capability. On the hardware side, in July 2008, we introduced large-scale parallel computer systems, which are vital to accelerating the dissemination of CAE technology, and put them into operation accordingly. Because

Table 1. Examples of analysis

Technology	Key themes
Structural analysis	Analysis of solderless terminals for automobiles Stress analysis of powder metal components Wire drawing analysis for conductive products
Electromagnetic field analysis	High-frequency analysis of optical links Electromagnetic field analysis of automobile parts. Electromagnetic field analysis of reactors
Thermal-fluid analysis	Radiation design analysis of electronic devices Semiconductor epitaxial process analysis Fiber process analysis
Material design	Elucidation of semiconductor laser deterioration mechanisms
Optical analysis	Optical analysis of optical transmitters/ receivers Optical analysis of optical communication devices Analysis of optical parts for laser processing
Service life/ reliability	Life prediction of automobile harnesses Solder reliability analysis Life prediction of wiring materials for cell phones

these systems are essential for the development of high-precision, large-scale CAE analysis technology, which had previously been impossible, there has been strong demand for shared use of these systems by different functions. This paper reports on the progress made in our efforts to develop infrastructure as part of the ongoing initiative to build the foundations required for CAE technology and promote its use by different functions.

2. Objectives of CAE Technology Enhancement

ATRC has been involved in the development and practical use of a broad spectrum of analysis technology for Sumitomo Electric products in many different business segments, ranging from general-purpose analysis, such as electric field analysis of power cables, strength analysis and design optimization for powder metal components, and the design of hybrid products, to process analysis and manufacturing equipment optimization involving the application of fluid analysis technology. This diverse range of business activities also includes product design for optical communication devices and equipment, and more original forms of analysis, such as life prediction of wiring harnesses and reliability evaluation of lead-free solder [(1), (2)].

Last year, ATRC conducted a fact-finding survey on the use of CAE technology within the company. According to the survey, many groups have introduced and utilized CAE technology, including ATRC and other R&D laboratories and business units such as Automotives Business Unit, Infocommunications & Systems Business Unit, and Electric Wire & Cable, Energy Business Unit.

Meanwhile, we identified the roles that ATRC is expected to play, while comparing notes concerning issues encountered by each member during daily operations. As we began to arrive at a clear picture of what is expected of us as a driving force behind CAE promotion in the Sumitomo Electric Group, we came to the conclusion that rather than merely reporting analysis results for individual projects, our general roles are threefold. They are: 1) being capable of developing core technologies that the company needs; 2) serving as a coordinating function in promoting the dissemination and use of CAE; and 3) developing infrastructure, including the computing environment (**Fig. 1**). In practice, we have intensively allocated our resources to the fulfillment of these three roles, although it has not been easy to make a substantial investment in infrastructure development. With VISION 2012 in mind, we have drawn up a full-scale infrastructure development plan so that we can better prepare ourselves for the future. This paper describes our ideas on system construction and our strategies for introducing hardware and software, as well as their expected effects.

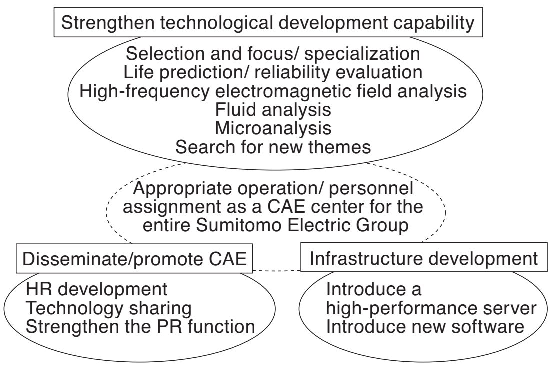

Fig. 1. Three pillars for strengthening CAE

3. Introduction of a High-performance Server

The requirements for developing large-scale, high-precision CAE technology with a computing system are a high computing speed and the degree of versatility required to run the programs needed for CAE. By building a configuration which combines both of these requirements and connecting it to a high-speed network, each business unit will be able to access the system as if it were right there in front of it. Our goal is to create a highly reliable system which satisfies a number of requirements, such as several hundred gigabytes of memory, high-speed storage, and redundancy for stable operation (see **Fig. 2**).

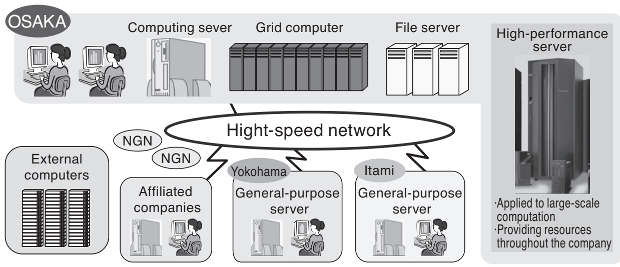

Fig. 2. A system including a high-performance server

3-1 Versatility

Roughly speaking, the “versatility” of a computing system is determined by two things: its compatibility with commercially available programs and the environment necessary for developing and executing in-house programs. Since seventy to eighty percent of the programs used at ATRC are commercially available CAE applications, the former is extremely important (**Table 2**).

As CAE applications have recently become increasingly advanced and complicated, it is very likely that unknown defects will arise, even if the catalog says that the system is compatible with them. Because of this, it is important to purchase systems from a vendor who can offer competent technical support when necessary, for example, by verifying operations or troubleshooting. Regarding in-house programs, which account for twenty to thirty percent of all programs used at ATRC, to minimize the burden of development, it is desirable to use a system with few restrictions on memory regions, registers, etc. Given that we expect that a model with several hundred million elements will be required in the next few years, a system with a main memory capacity of 256 GB or greater is preferred.

Table 2. CAE required software

Technology	Vendor	Title
Stress analysis	MSC Software MSC Software Dassault Systems Simulia Corp.	MSC. Nastran
		MSC. MARC
		Abaqus
Thermal/ fluid analysis	ANSYS Japan K.K. Terrabyte Co., Ltd.	FLUENT
		FLOW-3D
Electromagnetic field analysis	JSOL Corporation Hokkaido University	EMC Studio
		Jet-FD TD
Materials design	Gaussian Inc.	Gaussian 03

3-2 Computing speed

Computing speed is a requirement that can never be completely fulfilled. In order to improve computing speed, two approaches can be taken, namely, increasing CPU speed and using parallel computing. In the past, CPU speed was improved by increasing operating frequency. More recently, however, it has become increasingly difficult to achieve material performance improvements given the increasing number of circuits for which it is necessary to improve clock frequency and the subsequent increase in power consumption. Given these circumstances, efforts to increase CPU processing speed have almost been taken to the limit in recent times, which in turn has elevated the importance of using more than one CPU to perform parallel computing. There are two programming models for parallel computing: 1) shared memory architecture; and 2) distributed memory architecture. Each model has its own advantages and disadvantages, but when using the same number of CPUs, it is generally believed that shared memory architecture results in faster computing speed. However, one of the drawbacks of shared memory architecture is that the number of CPUs that can be used is often limited, so distributed memory architecture is preferred if the number of CPUs used in parallel is to be increased. Furthermore, when considering large-scale computers for which the throughput is among the top 500 super computers [(3)], neither option is considered in isolation. Rather, the most common solution is to compose a unit of one node by connecting relatively small-scale (16-256 CPU) computers using shared memory architecture and connecting each node with a distributed memory architecture.

3-3 Selection of hardware

Following a series of discussions held to select hardware which meets the above requirements, including benchmarking, information gathering, and bibliographic research [(4)-(7)], we have decided to introduce the IBM System p570 (**Fig. 3**).

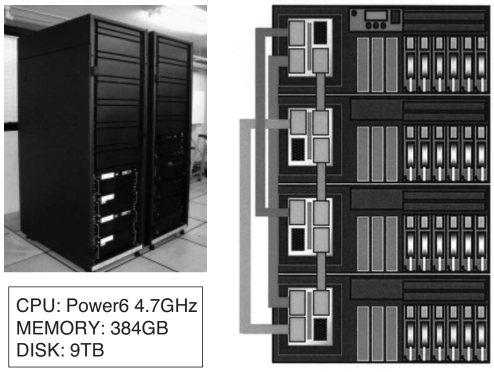

Fig. 3. IBM System p570 (right: modules)

Using the UNIX-based operating system AIX, the p570 is compatible with a larger number of analysis software applications and provides a powerful development environment. With a main memory of 384 GB, it is more than capable of meeting the requirements of larger-scale CAE models for several years to come. With regard to computing speed, the p570 uses Power6 CPUs running at 4.7 GHz, which are expected to achieve high performance. As it uses shared memory, it is possible to exploit its potential with relative ease when used in combination with analysis software and the in-house programs that are most commonly used at ATRC. Another important factor in choosing the p570 was its stability, particularly given the fact that CAE computers run 24 hours a day, 365 days a year, and regularly perform computing operations spanning several days.

The following is a report on a case analysis undertaken following the introduction of the system.

ATRC is working on developing technology for analyzing solderless terminals, which is necessary to predict the reliability of automobile harness connections. In order to shorten the time required to develop new types of terminals, CAE is an essential technology. Because a large bore terminal like the one shown in **Fig. 4** is connected to a large number of electric wires, the scale of analysis tends to be large; conventional servers require an unfeasibly long computing time (several weeks to several months), making it virtually impossible to conduct an

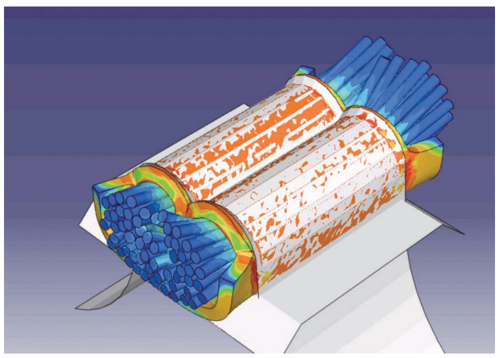

Fig. 4. Analysis of large solderless terminals

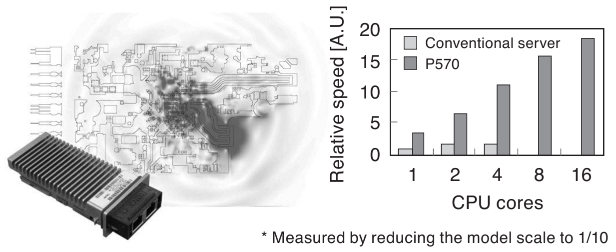

Fig. 5. Electromagnetic field analysis of high-speed optical links and computing speed

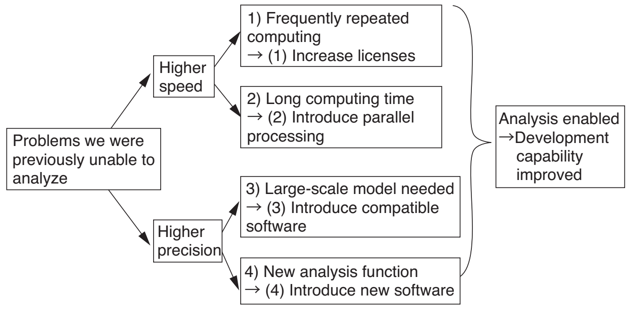

Fig. 6. Approaches to higher speed and precision

analysis. The p570, on the other hand, can perform such analyses within several days. For optical link modules used for high-speed signal transmission/receipt, electromagnetic field analysis is conducted (**Fig. 5**) to predict the intensity of electromagnetic radiation noise. Because the electromagnetic wavelength decreases for high-speed communications of 10 Gbit/s or faster, analyzing such high-speed modules tends to be a large–scale project, with a main memory requirement of 100 GB or larger, which is impossible for conventional servers. The p570, however, can perform this job within the more realistic timeframe of one day. As described above, the p570 has achieved a computing speed significantly faster than that of conventional computing servers, and its performance when used in combination with analysis software, which is frequently used at ATRC, has lived up to our expectations. Since the commencement of full-scale operations in October 2008, the p570 has been running at nearly full capacity. In order to further promote progress in and the dissemination of CAE, it is desirable to develop practical technology for next-generation applications which enable efficient parallel computing. It is also necessary to develop an environment in which each company department can avail itself of these powerful computers. To address this need, we are preparing for the introduction of a computer with a distributed memory architecture which is capable of performing a greater amount of parallel computation. We are planning to introduce a machine with 100 or more CPU cores and to take up the challenge of large-scale parallel computing using 16 or more CPUs. We also plan to introduce a machine for shared use within the company.

4. Introduction of Software

By introducing new software, we hoped to make it possible to perform analyses which had previously been impossible due to analysis time restrictions and lack of precision, thereby making tangible contributions to each business segment. Our approach to the current issue of increasing software speed and precision is explained below (**Fig. 6**).

There are two major issues related to higher speed requirements: 1) computing time is not long, but its frequency is high; and 2) computing time for individual jobs is unacceptably long. These issues can be resolved by (1) increasing the number of licenses needed for computation and (2) introducing a parallel processing function, respectively.

The issues relating to higher precision can be described as follows: 3) the analysis object is so large that its detailed shape cannot be modeled due to software restrictions; and 4) it is necessary to take into account physical phenomena which are not supported by current analysis software. The former issue can be addressed by (3) introducing software capable of supporting large-scale problems and, when necessary, introducing a parallel processing function, while the latter issue can be addressed by (4) introducing software that is specialized in certain areas.

In light of these aspects, we introduced software that we hoped would accelerate technological development in relation to highly urgent and relevant themes that are expected to benefit greatly from higher speed and precision, thereby reinforcing the foundations of our CAE technology.

The following are two specific examples of new software introduction (see (4) above).

In the first case, thermal-fluid analysis software, FLOW-3D, was introduced. Using the VOF method [8], this software is distinguished by its ability to analyze behavior on a free surface precisely, and is capable of reproducing a broad range of physical phenomena, including the flow of gas and liquid, as well as solidification phenomena, which is difficult to handle using other general-purpose fluid analysis software. A case involving the application of FLOW-3D to VAD glass [9] has already been reported within the company. In addition, thanks to its ability to analyze the complicated behavior and flow of heat when an object moves within the analysis region, it has become possible to predict the behavior of thermal fluids including moving objects, such as the antenna drive for a high-resolution meteorological radar [10] (see **Fig. 7**).

In the second case, analysis was conducted in a more microscopic analysis region at the atomic and molecular levels by introducing Gaussian 03 [11], a de facto standard in the field of molecular orbital calculation. Covering a broad range of calculation techniques from the basic technique applicable to compounds of several hundreds of atoms to the latest technique which requires a vast amount of computing time, this software is becoming an essential tool for the development of organic compounds and other materials. At Sumitomo Electric, we expect it to be applied to insulating materials and other polymeric materials. Investigations have already begun regarding its application to additives which can enhance the characteristics of insulating materials (see **Fig. 8**).

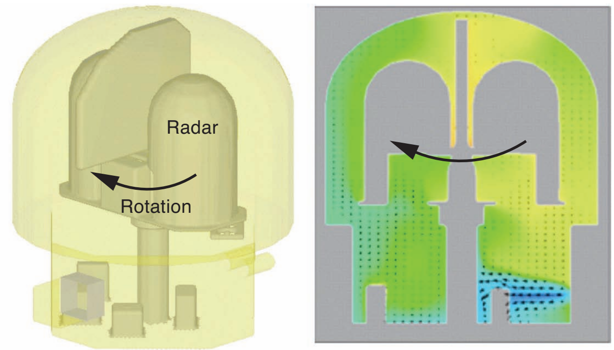

Fig. 7. Thermal-fluid analysis of high-resolution meteorological radar

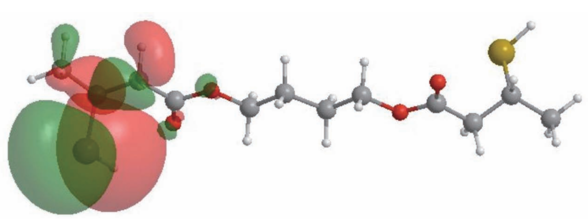

Fig. 8. Highest occupied molecular orbital (HOMO) calculation diagram of a polymeric additiv

5. Conclusiont

ATRC is promoting the development of both hardware and software infrastructure in order to strengthen CAE technology applicable to the company's various business segments. In this regard, a strategic policy was formulated on the basis of the findings of a survey on user demand for CAE and the future objectives of the company's product development activities. Accordingly, the IBM System p570 has been introduced, as it offers high levels of versatility, throughput, and stability. This system is currently running at full capacity and performing as expected. On the software front, in addition to the introduction of the analysis software reported here, the scope of analytical applications has been expanded by increasing the number of licenses and introducing a parallel processing function for existing software, gradually making it possible to conduct analyses that had previously been impossible. Going forward, we will make the most of the resulting computing environment to strengthen our technological development capability. We are determined to evolve even further to enable us to serve as a valuable asset for the Sumitomo Electric Group's business development activities.

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