Application of SMS-AMG in Computational Electromagnetic Analyses

Studies conducted by Mu Tech Co., Ltd.

2003/01

Translated and edited by VINAS. Original report was prepared by MU TECH CO., LTD.

Introduction

Demand for faster computation of large scale problems in electromagnetic analyses is increasing as more engineers are trying to tackle more complex problems in wider variety.

Mu Tech has been involved in development of Computational Electromagnetic Analyses software in order to satisfy this demand, and is currently conducting a series of studies on possibility of using Super Matrix Solver (SMS-AMG) from VINAS as a core of our software.

This report summarizes application of SMS-AMG in electromagnetic analyses and discusses SMS-AMG's performance and advantages.

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Mu Tech’s Business Portfolio

1. Development, sales and support of Electromagnetic Analysis Software
    1) Development of μ-MF1
    2) Sales and support of μ-MF1 (planned to start in 2003)
2. Custom development of Electromagnetic Analysis Software
    1) Custom development based on μ- series
    2) Custom development from scratch
3. Commission-base electromagnetic analyses
    1) Analyses using Mu Tech’s proprietary software
4. Consulting on CAE mainly in electromagnetic studies
    1) Consulting on use of software
    2) Consulting of electromagnetic, heat and structural studies

SMS-AMG implementation test

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Implementation Test Objective

Super Matrix Solver-AMG (SMS-AMG), which is based on Algebraic Multi Grid method and is developed by VINAS, is implemented as a core matrix solver in Mu Tech's "μ-stat", an FEM program based on scalar potential method developed by Mu Tech.

Time needed to solve IEEJ(*) model by the software after implementation of SMS-AMG is measured.

Study of relationship between aspect ratio of finite elements and convergence performance, which is an important issue in electromagnetic analyses, is also conducted.

* IEEJ (The Institute of Electrical Engineers of Japan)

SMS-AMG technologies

- **Super Matrix Solver (SMS) technology**

  Basic technology developed by National Aeronautic Laboratory (NAL) of Japan was enhanced for higher speed and wider functionality by a joint effort of VINAS and NAL and was refined into an acceleration method for iterative matrix solvers.

- **Algebraic Multi Grid (AMG) method**

  An iterative solution method of simultaneous equations based on the latest mathematical theories established during 1980's and 90's. It is capable of solving problems considerably fast, but is not widely used due to the following limitations.

  - Difficulties in coding with need of advanced knowledge in mathematics
  - Difficulties in setting comparatively large number of parameters at the time of calculation

- **Super Matrix Solve-AMG (SMS-AMG)**

  SMS-AMG is a matrix solver in which SMS technology is applied to AMG method to overcome common AMG problems and to enhance speed and stability of computation.

μ-stat technology

μ-stat, an FEM program based on scalar potential method developed by Mu Tech, is a static electromagnetic analysis program which is planned to be implemented into an integrated electromagnetic analysis system "μ-MF1."

Mu Tech has already developed core matrix solvers using Skyline method, Gauss-Seidel method, CG method, ICCG method and an improved CG method (Mu Tech's original method), and Mu Tech's original improved CG method was used for comparison with SMS-AMG method.

Test Specification

Type of analysis: 3-dimensional static electromagnetic analysis

Test model: IEEJ’s static electromagnetic models for verification purposes

(iron core and coil model, one-eighth symmetric part)

Test hardware:

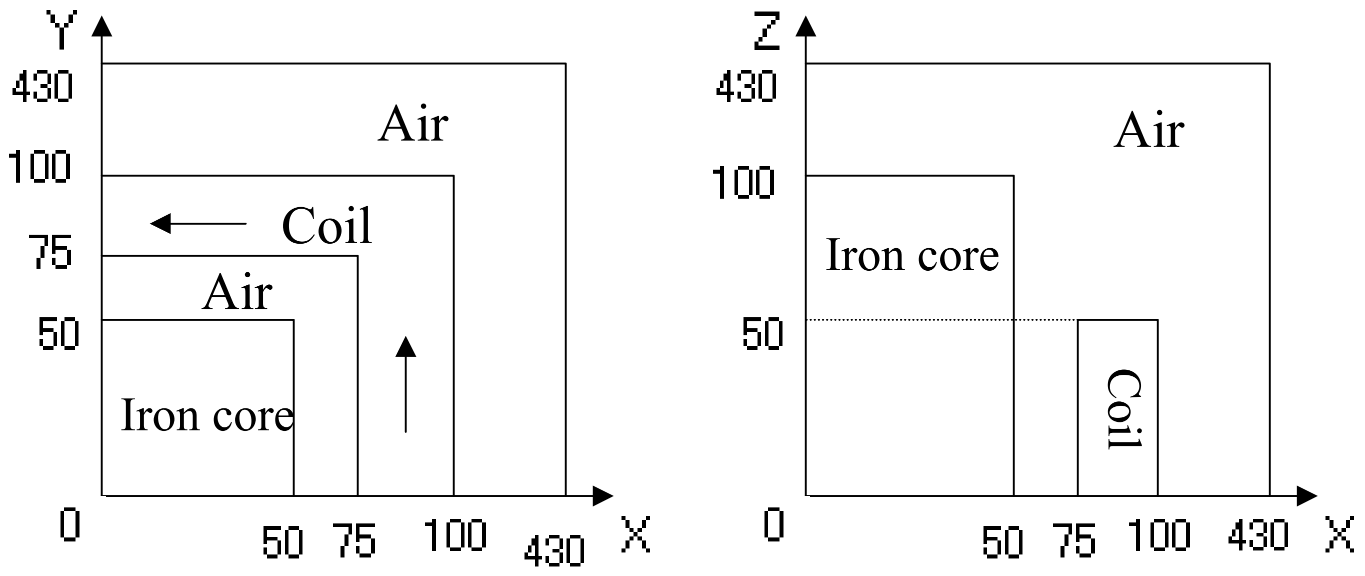
HP workstation x1100

Pentium4 2GHz

RAM 786MB, Hard disk 32GB

Test Model Specification

The test model consists of an iron core with rectangular bar shape surrounded by an exciting coil. Linear analysis was made with specific magnetic permeability of the iron core set to 1,000, and coil current set to 3,000AT. Configuration of the one-eighth model is shown in the figure below.



X-Y plane X-Z plane Unit: mm

Tested Programs

Following two programs are used for analysis calculation of the same model and the results are compared.

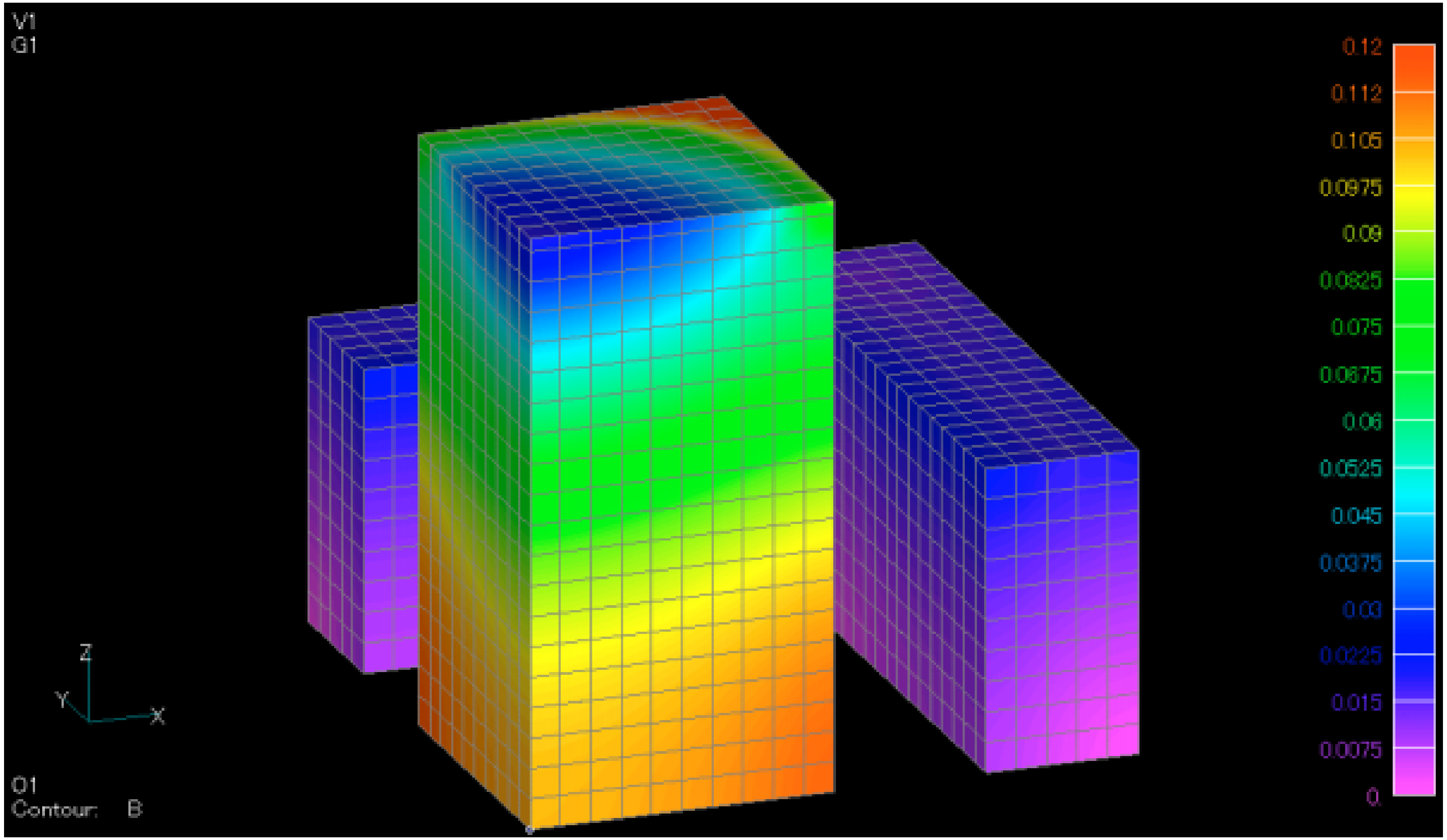
1) μ-MF1 with improved CG method by Mu Tech

2) μ-MF1 with SMS-AMG method by VINAS

Items of Comparison

- Time: Time needed for calculation is measured.
- Number of iterations: Number of iterations made by each solver to achieve same convergence level.
- Number of unknowns: Mesh data with 20,000 to 1,000,000 unknowns were used for comparison of two solvers.

Analysis Result 1 μ-MF1 w/ improved CG, B(T) contour



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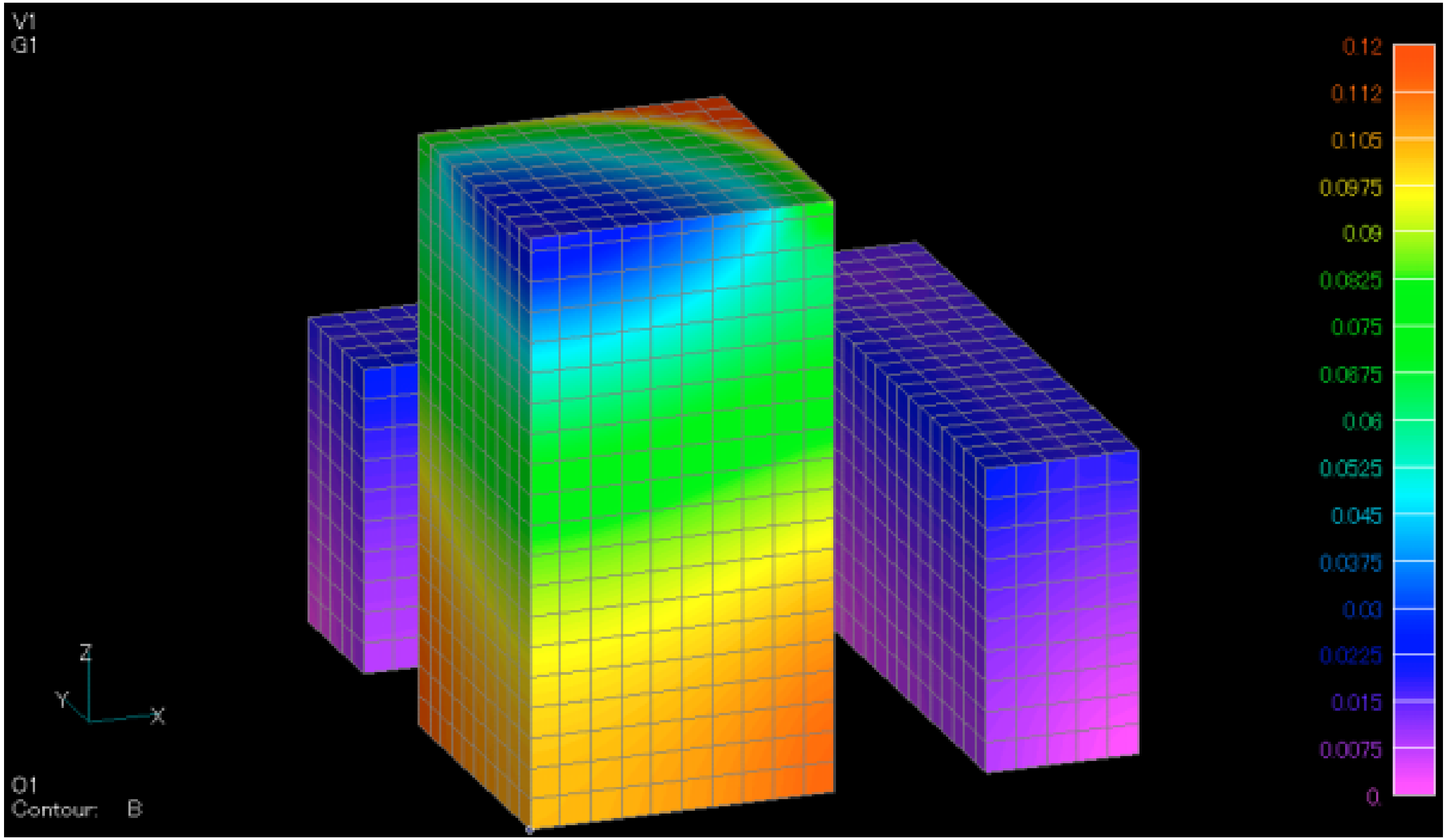
Analysis Result 2 μ-MF1 w/ SMS-AMG, B(T) contour



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Comparison of Accuracy

For validation purpose, results of analyses were compared against experimental data. (Analysis results of 20,000 points were compared.)

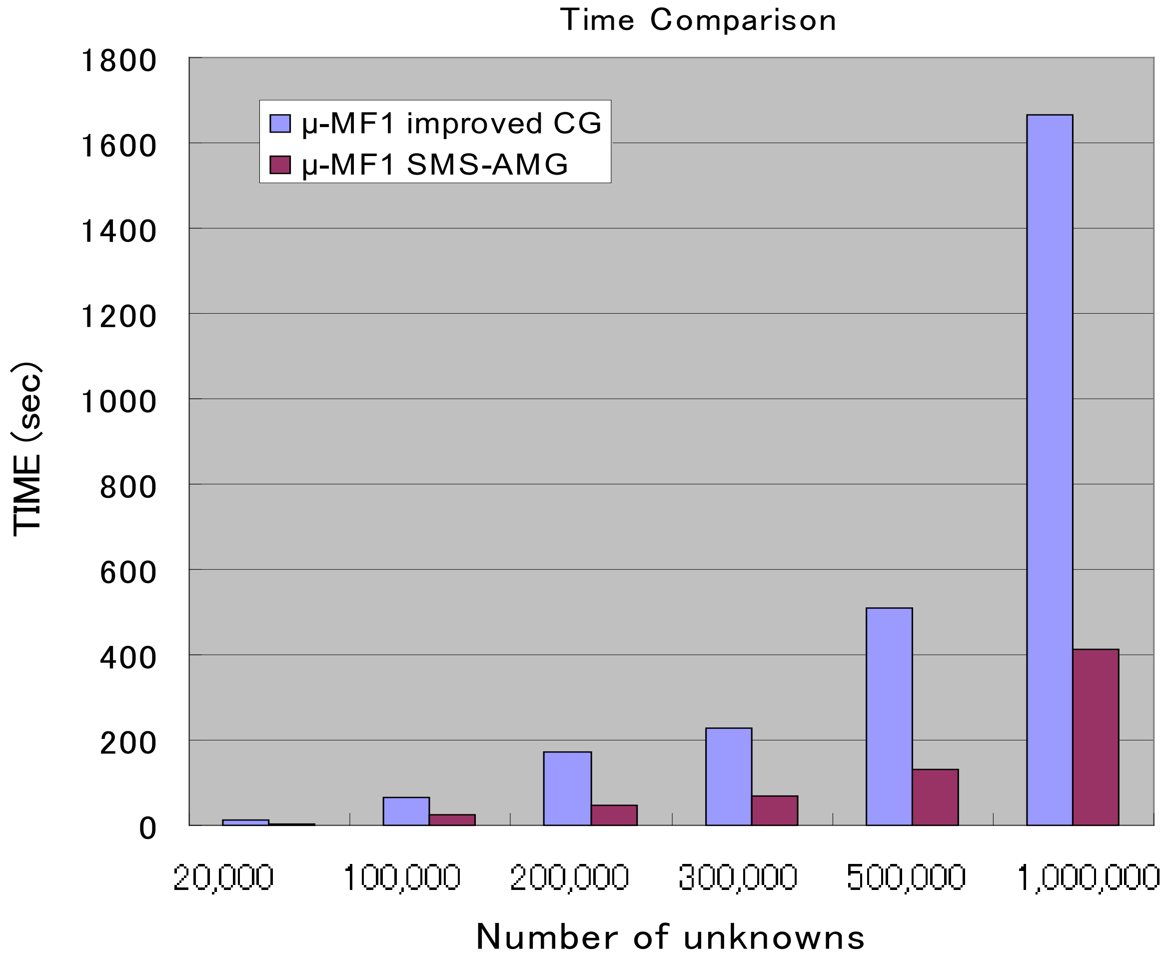
Measurement location: 10 mm above the magnetic substance.
Its coordinate is x=31.25 mm,
y=31.25 mm, z=110.0 mm.

Measured item: Z element of magnetic flux density (Bz)

Results :

Measured(G)	μ +CG	μ +AMG
241.9	240.1	240.1

Time Comparison



SMS-AMG is faster than Improved CG method by a factor of 4.1 !

(in analysis with 1 million unknowns)

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Aspect Ratio VS. Convergence

Effects of aspect ratio to convergence performance of solvers are studied.

In general, higher aspect ratio of finite elements necessitates longer time needed for calculation.

Using lower aspect ratio elements, however, necessitates increased number of elements and therefore longer time for calculation too.

It is comparatively common in electromagnetic analyses that finite elements of high aspect ratio are used because of geometry of analyzed model, and therefore solvers which are capable of delivering fast convergence to problems with high aspect ratio of finite elements are ideal for electromagnetic analyses.

Specification for Convergence Test

Type of analysis, analysis model, used hardware, and validation model are identical to Time Comparison Test.

Comparisons are made between μ-stat program with improved CG method and μ-stat program with SMS-AMG method in terms of:

- Time needed for calculation
- Number of iterations needed
- Accuracy of calculation results

Number of unknowns in the model was 200,000.

Items of Comparison in Convergence Test

In order to evaluate the effect of aspect ratio to speed of convergence and accuracy of calculation, four different models are prepared with different aspect ratios at a specific point near the iron core where severe change of magnetic field is expected.

	Number of unknowns	Aspect ratio	Mesh
CASE1	200000	1:1	Coarse
CASE2	200000	1:10	Moderately coarse
CASE3	200000	1:50	Optimum
CASE4	200000	1:100	Overly fine

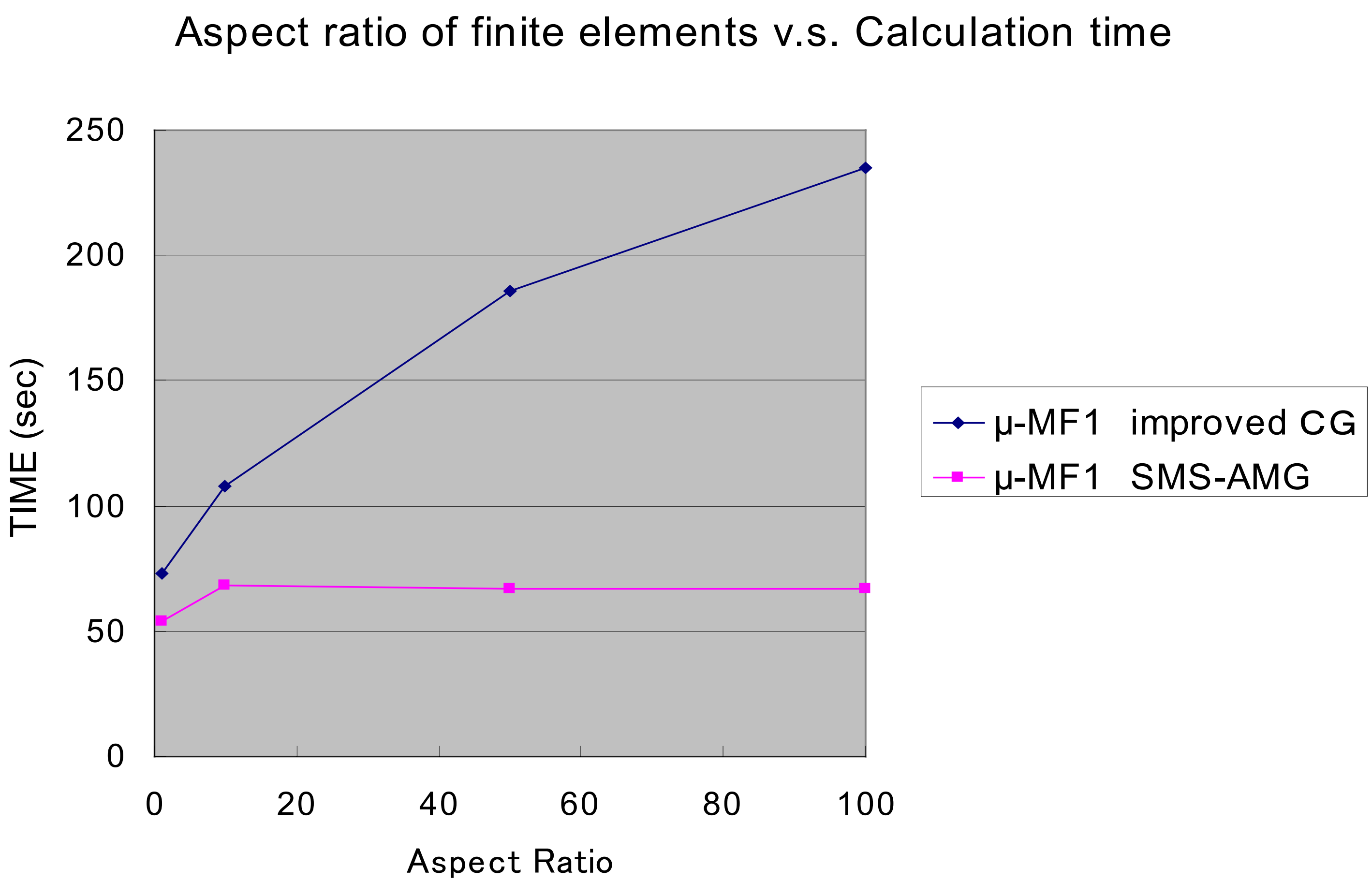
Results of Convergence Test

Results of convergence test for each case are as follows.

	Time needed (sec)		Iterations needed		Calculated value (G)	
	CG	AMG	CG	AMG	CG	AMG
CASE1	73	54	388	21	211.7	211.7
CASE2	108	68	692	24	196.0	196.0
CASE3	186	67	1323	26	200.0	200.0
CASE4	235	67	1747	25	200.6	200.6

Calculated values in the table are absolute values of magnetic flux density at a specific point. By using calculated value in CASE 3 as standard, CASE1 has deviation of 5.5%.

Aspect ratio and calculation time



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Conclusion

It was confirmed that PC version of SMS-AMG from VINAS is capable of delivering its high performance in electromagnetic analyses through our performance tests.

Speed of calculation, in particular, is far above what can be expected from conventional solution methods. With appropriate computer hardware, SMS-AMG is expected to be able to handle calculations with degrees of freedom exceeding 2 million.

It was also confirmed that iterations needed to reach convergence by SMS-AMG are independent of aspect ratio of finite elements. This characteristic is more notable than its calculation speed.