Optimal Design for Synchronous Motor by using 3-D FEM with Embedded Parallel Genetic Algorithm

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Abstract — In this paper, the 3-dimensional finite element method were connected by using the Shell script for automation pre-process such as the modeling and mesh generation, and the genetic algorithm was embedded. Moreover, the main-process was programmed to assign the analytical model of each generated gene to several computers for parallel processing, and the computing time was shortened. In this paper, the decrease of the cogging torque of the SPM motor was picked up as a simple analytical object model could to decrease by about 30%. And the capability of this program was verified.

I. Introduction

Recently, the 3-dimensional finite element method is mainly used as for the design of electromagnetic machines. The advantages of 3-dimensional finite element method are to obtain a highly accurate solution and to apply the complex shapes. However, the computing time becomes longer because the mesh number is became hugeness, and the nonlinear calculation is necessary. Therefore, it is difficult that genetic algorithm [1]-[3] is embedded to 3-dimensional finite element method. In this paper, analysis flow is modified to automate pre-process that is the modeling and mesh generation of the 3-dimensional finite element method, and genetic algorithm is embedded to this program by using Shell script. And the utility of this program is verified that the decrease of the cogging torque with the SPM motor is picked up as a simple analytical object model.

II. Algorithm

The method of distributing the gene in the range of the search is shown in Fig. 1. It is divided into 0-9 because the gene code is processed by the decimal number in this time. When the part of division into 9 is combined and optimized by 4 places, the chromosome structure becomes the chromosome of 4 digits such as 1425, and 5346 and so on. Moreover, the flow chart of this algorithm is shown in Fig. 2. First of all, the numbers of individuals, the intersection rate, and the mutation rate, etc. are set by setting the GA parameter.

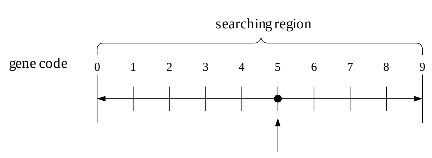


Fig.1 Genes cording

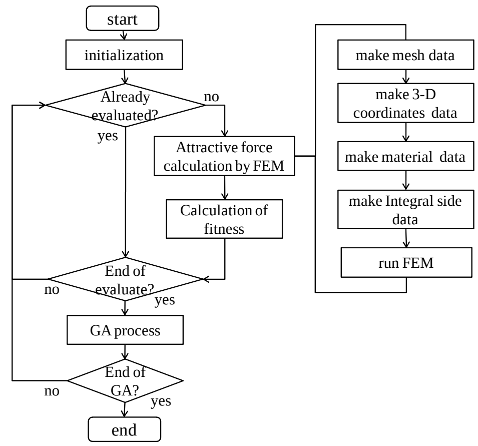


Fig.2 Flowchart of the shell script

III. Parallel GA and Computer Environments

Linux is used for OS, and bash (Bourne-Again Shell) used for the Shell script that is to connect the application. Shortening at the computing time can be expected by distributing each gene against two or more PC so that GA has to evaluate, and to compare two or more genes. Fig. 3 shows the flow chart of making the parallel processing.

Fig. 3 shows consistent of two scripts; one is Controller script that calculates the fitness. Other one is Server script that calculates the electromagnetic field. And it is an instruction set that executes the evaluation block in the flow chart in Fig. 2 at the same time in two or more independent Server scripts.

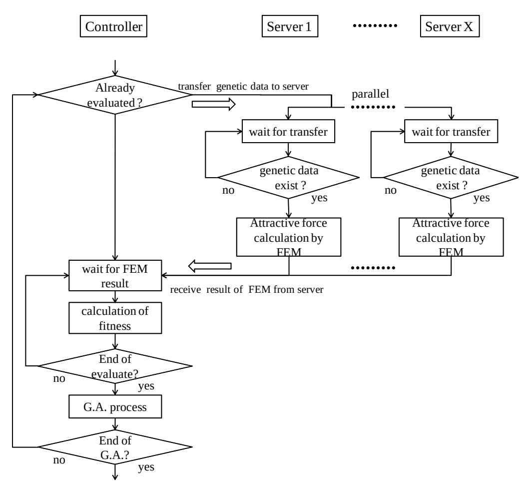


Fig.3 Flowchart of GA with parallel processing

IV. Analysis and Results

GA is aimed at in 1/8 models of three aspect 4 pole SPM motor shown in Fig. 4 (surroundings direction 1/4 and axially 1/2) by using the script of Fig. 3, and fitness target is the decreasing of the cogging torque. The range of the search is given to shape in the stator core [4] in order to exert a large influence on the cogging torque.

The flux density vector of the optimized shape and the initial shape obtained by GA was shown in Fig.5 and the comparison of the cogging torque wave was shown in Fig.6. It increased to 1.35 times that of fitness 0.553 in the optimized shape compared with fitness 0.410 of the initial shape from Fig.7. Also, cogging torque was decreased about 30% as maximum amplifier. Moreover, the total calculation time of GA was 16 hours and 10 minutes, and the total calculation time by one PC was 34 hours and 7 minutes. Therefore, the computing time was 47.4% up to compare with one PC. Comparison computing time between one and three PCs was shown in Fig. 8.

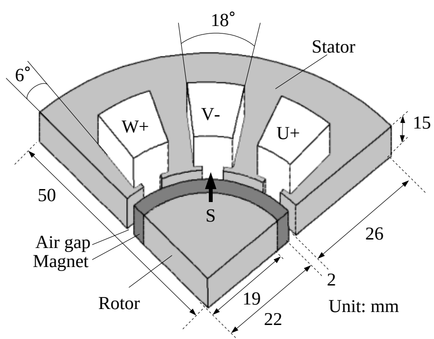
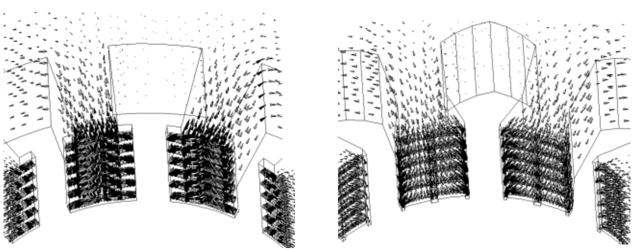


Fig.4 Analysis model



(a) Initial shape (b) Optimized shape

Fig.5 Comparison the shape between initial and optimized model

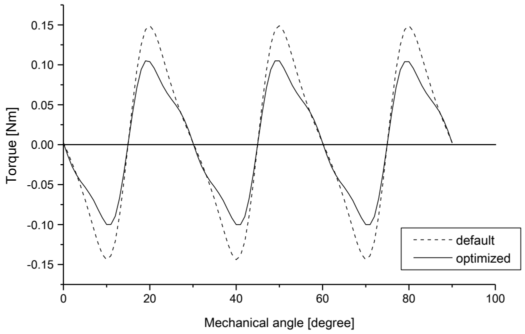


Fig.6 Comparison cogging torque waveform between initial and optimized model

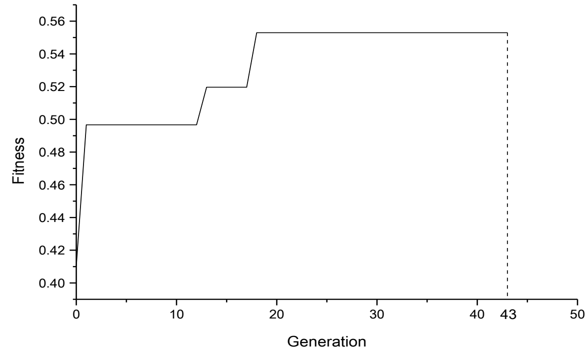


Fig. 7 Evolution process

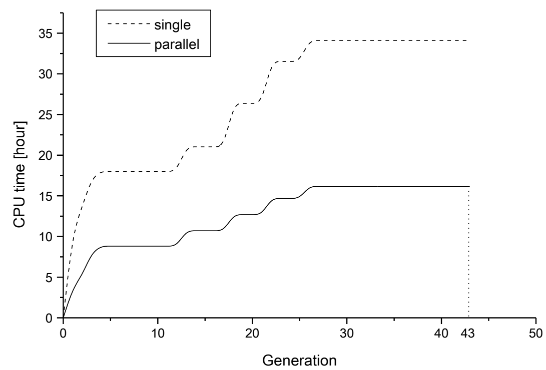


Fig.8 Comparison CPU time between single mode and parallel model

V. Conclusions

The cogging torque of SPMSM has been decreased by 30% by embedding the 3-dimensional finite element method into GA, and using the analytical result as fitness. Moreover, GA was able to be made parallel by distributing the gene to several PC, and the total calculation time was able to be shortened by below 1/2. It will have to evaluate not only the cogging torque but also the steady torque. And it will be corresponding to other electromagnetic equipment such as IPMSM and the induction machines and actuators in the future.

VI. References

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