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PARALLEL MODELING OF MAGNETIC MATERIALS WITH HYSTERESIS

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Abstract

The paper is focused on the optimization of the hysteresis modeling in Electrical Engineering CAD, using the parallel algorithms. The parallelization is made both for the threads on the same processor and for the multiprocessor architecture. The implementation of a vector Preisach model for magnetic recording media is tested on a Pentium III bi-processor, under Windows OS.

1. INTRODUCTION

An accurate numerical design or simulation of any electromagnetic device implies an adequate model of the material properties, which are used in the computation process, together with the Maxwell equations. One of the most complex material characteristics is the magnetic hysteresis, especially for 3D or dynamical problems [1]. A famous macroscopic model of hysteresis is Preisach model, including all its generalized versions (e.g. [2], [3]). The implementation of such a phenomenological model into a CAD software, based for example on Finite Elements Method, still remains an open problem, due to the complex numerical details which arise both in the model identification phase and in the electromagnetic problem computation.

For an engineer, a good hysteresis model signifies not only an accurate model but also an efficient model from the point of view of time and resources consumption. This is the reason of an extensive use of the scalar and static hysteresis models in Electrical Engineering CAD. But in a real magnetizing process, besides changing its value, the applied field could rotate generating a more complex material relationship - vector hysteresis.

2. VECTOR HYSTERESIS MODELS

A first class of vector hysteresis models is based on Mayergoyz idea [3] – building a vector model from a continuum of scalar Preisach models, uniform distributed in 2-D or 3-D. The input of each scalar model is the component in that direction of the applied field. The total output (i.e. the magnetization vector) is the vector sum of all the scalar model output. This model is probably the simplest of all models based on bistable relays and will be used in our implementation.

Another solution is to replace the rectangular loop of each scalar Preisach model by a displaced Stoner-Wohlfarth astroid [4]; the easy axes of the astroids are distributed in direction to represent the angular dispersion of the material being modeled [5]. In fact, the classical Stoner-Wohlfarth model was also shown [6] to be of the Preisach-Mayergoyz type.

In finite element analysis, the hysteresis model has to be applied to each element. The material constitutive relationship M-H must be evaluated many times for each element during the non-linear iteration process and the overall time evolution. Thus, the hysteresis model must be both memory efficient and fast. A solution could be the use of an artificial neural network [7] or the parallelization of the computing algorithm.

3. PARALLEL IMPLEMENTATION

A parallel program for a multiprocessor can be defined as a set of processes that may be executed in parallel and may communicate with each other to solve the hysteresis model identification problem or the model implementation in CAD software. In our case the parallelization is made on two levels. First level is defined by a set of processes which runs in parallel on the same processor. In this way the algorithm is run faster using the full power of the machine (the processor, the bus and the I/O and memory systems). The second level is made by dividing the number of initial jobs in sets of processes for every processor in the system. This level takes advantage of the multiprocessor architecture. Combining the both level of parallel computing (multithreading level on the same processor and multiprocessor architecture) we can obtain a complex support for solving the problem in efficient way, more quickly and with maximum precision.

Our algorithm was running on multiple threads (independent process) for obtain the maximum computing power from the hardware/operating system platform. Each thread runs the same algorithm with different data series as input (magnetic field) and outputs the result (magnetization) in different memory zone. At the end all the output data was print in a single data file. The user interface permits to limit the application to run on single processor to compare the gain of performance using multiple processors. In such case all the threads run in parallel on the same CPU. On our case, a hardware platform with two processors, the operating system distributes the computing effort on both processors in a uniform manner. The number of threads is not limited to the number of processors. The parallelization process is help by the multitasking environment offer by the operating system which permit to accelerate a program using multiple threads. Optimal number of threads (for optimal acceleration factor) is done by the hardware/statistical consideration. The number of threads can be increase till the saturation of the acceleration factor due to the limited amount of memory and computing power of the machine.

4. NUMERICAL TESTS

The software was developed using Microsoft.NET® Framework 1.0, the latest development platform and the future kernel runtime for the Microsoft Windows® operating systems. The user interface (fig.1) was design using Microsoft Visual Basic.NET®.

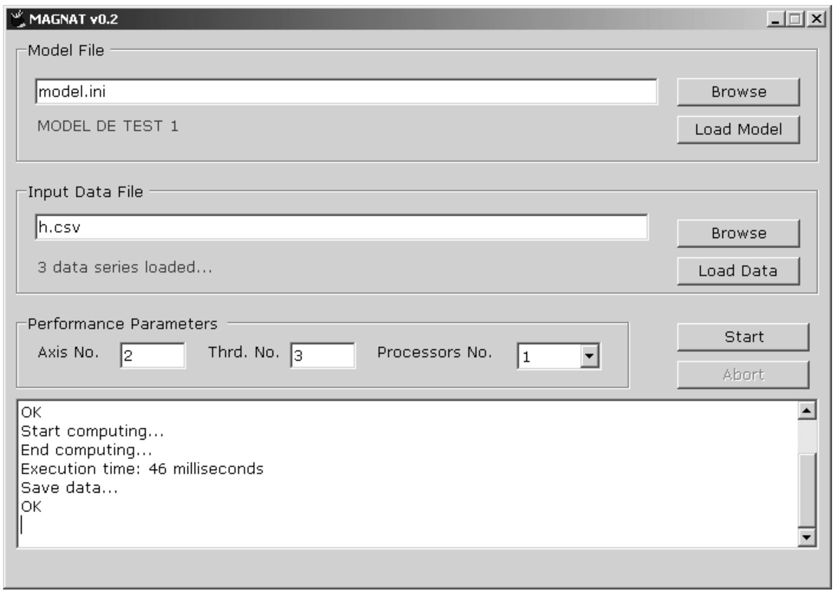

Fig.1. The software interface

The application was run on a HP KAYAK XM 600 workstation with two Pentium III processors at 866 MHz, 128 MB RAM, running Microsoft Windows 2000 Professional with SP4. The program allows to load the model (Preisach type), the input values (magnetic field vector for each instant and for each finite element) and the parallelization parameters (the number of axes for the vector Preisach model, the number of threads and processors), saving the result in a file. The time between computing start and the beginning of saving the result is displayed on the screen.

The numerical tests were made using the same hysteresis model, various numbers of series for data input file (length of the data series was constant) and different number of axis and threads using one and two processors. The hysteretic material – magnetic recording medium (floppy disk) - was measured on a LakeShore®VSM-7304 magnetometer in MAGNAT Research Center and the identification of the Preisach model parameters used a 20x20 cells mesh of the Preisach plane.

The tests show that the optimal parallelization depends on the computing resources. For example, the CPU time for 120.000 vector input (corresponding of the magnetic field vector computed with 120.000 finite element mesh), using an elementary decomposition on only 2 axes, is presented in table 1 and fig.2. The peak corresponding to 10 threads is due to the internal management of the operating system. The increasing of the axes number for vector Preisach model up to 36 (i.e. each axis is rotated with 10 degrees from the previous, in 2-D computation) increases almost proportionally the running time: 20 minutes vs. 67 sec. for 2 processors. Obviously, the parallelization will be more efficient if the processor number increases.

Table 1: CPU time (in sec.) for 120.000 finite elements and 2 axes

Threads	1 processor	2 processors
2	166,6 sec.	67,1 sec.
5	234,3 sec.	69,8 sec.
8	237 sec.	77,8 sec.
10	397 sec.	251,7 sec.
15	289,6 sec.	85,8 sec.
20	200,9 sec.	77,9 sec.

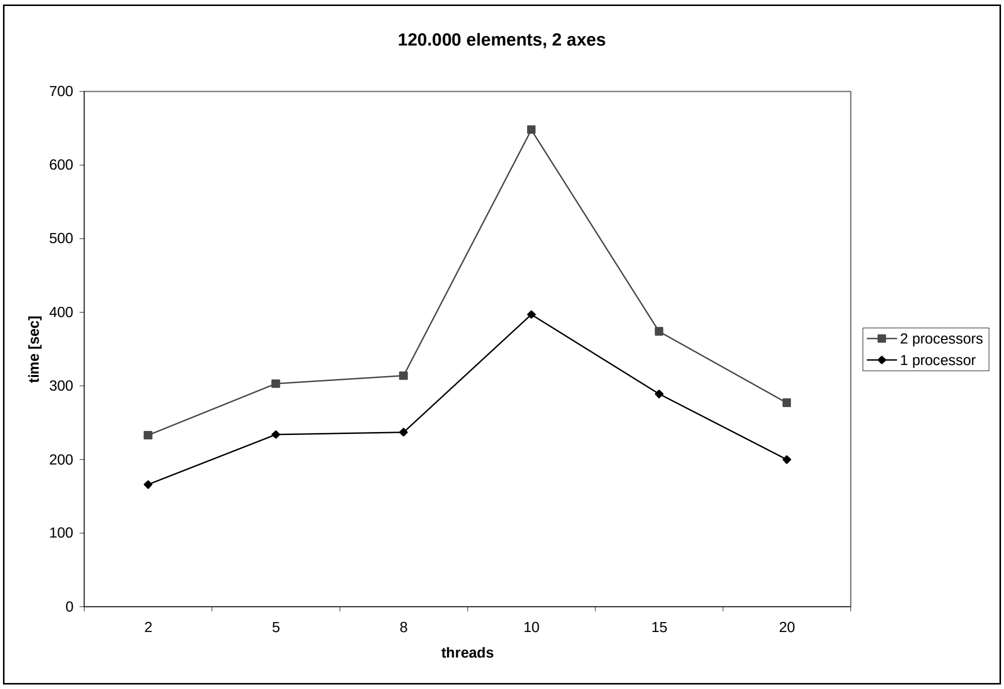

Fig.2. Parallelization efficiency

5. CONCLUSIONS

The results show a good efficiency of the parallelization procedure for the vector hysteresis models. The software interface allows testing different vector model, in order to decide the optimal values of the parallelization parameters (the number of threads, directions, processors). The model identification could be also parallelized but the aim of this work was to test the efficiency of the parallelization on the vector hysteresis model implementation into Electrical Engineering CAD software. In this manner, the use of an accurate vector Preisach model can be competitive from the computation time point of view. The next step of the research will be the implementation of our software on a computer network and the coupling with electromagnetic field computation software.

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