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# A Practical Approach to Introduce Computer Aided Design to Help Teach Electromagnetics*

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*The magnetics industry has experienced a dramatic change in the last few years. Many efforts in the field of magnetic materials have brought about a new generation of products, design and most importantly, ideas. This trend in development of new materials has created several new design alternatives.*

*At the present moment, old design methods are being stretched to fill the large gap between the progress of technology and the sophisticated and intricate design methodology needed. There is a great need to learn about new techniques for magnetic design and communicate these strategies to students in undergraduate/graduate schools. The industry is faced with a long ranging problem and will need to co-ordinate its efforts with Universities to produce the necessary engineering effort needed to compete in this rapidly advancing field. In this paper, a new computer-assisted design system is presented to help teach basic and modern electromagnetics. An original approach is proposed, which is aimed at being simple, practical, and extremely flexible, based on an existing Finite Element simulation program.*

## INTRODUCTION

WITH the development of the finite element technique for the analysis of electromagnetic fields, there has been a long and slow effort to introduce such tools to the magnetic industry [1–4]. It is only with the more recent developments of affordable computer resources that this effort is making a larger impact. At the same time, such programs have often been introduced to universities for research purposes with the hope that it might be used by graduating students. This could in turn lead to an increased use in industrial environments. It is no secret that this approach has been mainly unsuccessful. Very few graduate students come out of universities knowing very much about magnetics or even what tools are available to analyze magnetic designs. Unlike other fields in electrical engineering such as VLSI design, digital and analog electronics where students are aware of and apply the design tools, the students in the area of magnetic field lack the knowledge of such tools.

Computer simulation tools are unquestionably a strong part in any modern design. They are capable of producing better, more efficient designs at a reduced cost. There is also no doubt that the magnetics industry could benefit greatly from such resources. Universities can play a key role in bringing new technology into the industry. Any new subject introduced in a curriculum takes a lot of time, planning and money. The crucial part is the approach to introducing the advanced technology in an easily understandable and cost effective manner.

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For finite element software manufacturers to simply supply universities with computer programs is not enough. There needs to be a concerted effort on all fronts to make it as easy as possible to introduce new learning techniques. This needs a close consideration of the student environment and time, and it needs to support any faculty effort to use such facilities. In practical terms, there are always more subjects to teach than time. Hence, any new idea or system which involves students using computer facilities to learn a new subject needs to pay very close attention to its practical aspect, time.

## BASIC PRINCIPLES

There are four major principles that have to be respected at all times in order for a viable teaching system to be practical and accepted. First, students should not be deviated from their subject in using the system. This means that students should learn electromagnetics when working out problems not computer modelling techniques or numerical analysis methods. These are both very separate fields. Second, due to the generally large academic load on students, they cannot be expected to spend hours with the system to get their work done. It needs to be very easy to use and comprehend. Third, it should provide teachers with class work material, prepared lessons and projects. This is by far the hardest part and exactly the part that has been missing for a long time. Last but not least, the system should allow teachers to easily make up their own lessons and projects to focus on their particular interests.

## SYSTEM IMPLEMENTATION

The proposed system is based on a commercially available finite element program, MagNet,* which has been on the market for many years. The program in its commercial form is an extremely powerful tool for magnetic analysis. However, such flexibility and power can quickly lead to the infringement of the first two principles. Interestingly, with a few modifications, one can transform the program's flexibility into an amazingly efficient and easy-to-use teaching tool. A good review of other such software packages is given in [5].

The unique feature of the simulation program, which will allow the creation of the new teaching system, is its architecture. The entire program is based on a set of three major database files or libraries. The first library stores the geometric information relating to the computer model. A second library stores all the magnetic characteristics of various materials. These can include linear and non-linear material characteristics for steels, ferrites and permanent magnets, and all materials are recognized by name.

The last database is the actual prototyping and testing work bench. This is where a computer model geometry is selected from the first library and subjected to various tests. The user simply defines the material composition of the different parts of the geometry and interprets the results. Material properties are all stored in the second library. Defining the composition of a part of the model geometry is as simple as introducing the region and specifying the name of the material to be assigned to that region. To accelerate the creation of many tests, a sequence of 2 to 20 prototypes can be setup before running a simulation. The results can then be compared with each other.

The key to keeping the system simple is to provide students with a library of modern materials as well as a library of computer models already prepared. Generating computer models often requires specialized knowledge about the intricacies of the modelling method used. It would be a violation of the first principle to require students to learn such modelling techniques. An effective teaching tool should provide a number of computer models which can be readily used by the students. Providing a library of 'universal' models would provide even more simplicity and flexibility.

Universal models are a cornerstone of this new system. These models are merely general computer models which comprise many individual regions which can be combined to form a variety of shapes and forms. The principle is similar to the simple building blocks for children. A set of blocks with a few different shapes can be used to create a large number of more complex shapes. This can then lead to the ultimate objective of any teaching system, which is to promote imagination.

A lot of thought and imagination is needed in creating a useful universal model. Each model should be flexible enough to allow students to create many completely different magnetic circuits, simply by changing material assignments in different regions. It should also allow students to investigate a specific magnetic circuit layout and investigate the effects of small variations on that circuit. For example, the user could run tests for one magnetic circuit under a range of applied currents, coil sizes, shapes and positions, as well as different material properties. Such a teaching system can make it easy to learn magnetics by the simple fact students have easy access to computer simulation facilities. Being easy to use makes it specifically easy to document. In turn it makes it easy for teachers to create lessons and homework projects. Furthermore, numerical analysis and design classes can be used to generate universal models and basic lesson documentation, for more advanced students specializing in magnetics.

Finally, because the basic finite element program has been commercially available for such a long time, it is available on a wide range of computers, which includes PCs to large multi-user mini computers. This makes it practical to make it available on at least one computer in each university.

## USING THE SYSTEM

To demonstrate the principle of the system, a set of examples is included. All simulations are based on a single universal model. It intends to demonstrate the principle of a universal model as well as the level of imagination and creativity it offers a student.

Figure 1 shows a selection of different universal models. Figure 1(a) shows the model chosen for this example. Figure 1(b) illustrates another example of a universal model which involves design of a rotary system like motors.

Figure 1(a) shows a model which is subdivided into individual regions. When starting out, all regions contain AIR. In effect it is an empty design sheet. Each region is individually labelled and allows the user to assign any material property to each region, in any sequence. It also allows the user to represent any region or combination of regions as a coil or a permanent magnet. Figure 2 shows how a careful selection of material assignments can

* MagNet is a software product of Infolytica Corporation.

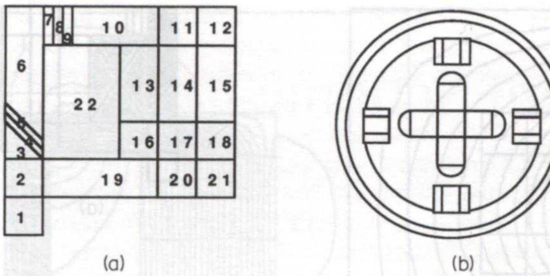



Fig. 1. Two different 'Universal' models. (a) illustrates the model used for the examples, (b) illustrates a universal rotary model.

create such devices such as; (a) bar electromagnet, (b) E-core magnet, (c) transformer core, (d) voice coil motor, (e) solenoid actuator.

All these models rely on symmetry to reduce the model sizes. The model in Fig. 1(a) is symmetric about its vertical axis. Figure 2(a) shows only half of the bar magnet and half of the coil. The other halves are assumed to be a mirror image with respect to the vertical axis, which in this case run through the center of the magnet bar.

Any number of test setups can be created before the simulation begins. The second part of the system is an analysis program which lets the user verify the results graphically. This type of analysis is often referred to as post-processing. The post-processor in this case is an easy to use menu-driven program with facilities to display information graphically as well as obtaining numerical information directly from the screen, interactively. Such facilities include flux plots, flux density calculations, direct on-screen field probing, field sampling and graphing capabilities.

Figure 3 shows some of the flux plots obtained from the post-processor. Flux plots are one of the easiest solutions to obtain from the post-processor and can yield substantial information about the behavior of magnetic fields. Other calculations and parameters available are: inductance values, reluctance, stored energy and directional field components.

## CONCLUSION

A new computer assisted design system is presented to help teach basic and modern electromagnetics. This new and original approach, which is aimed at being simple, is practical, extremely flexible, and based on existing Finite Element simulation programs.

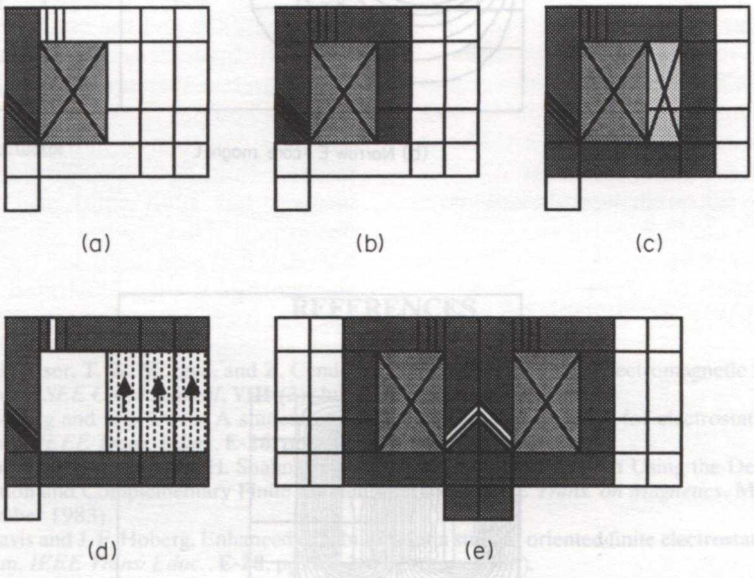



Fig. 2. Five possible magnetic circuits using one universal model. All models represent half the actual device due to symmetry. The last model shows how both halves form the full device.

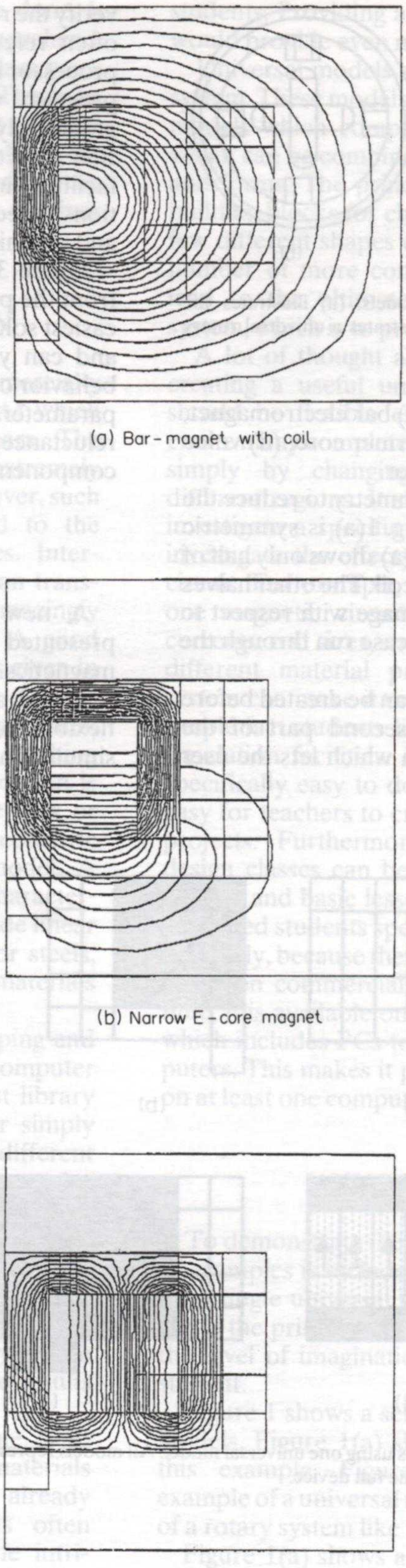
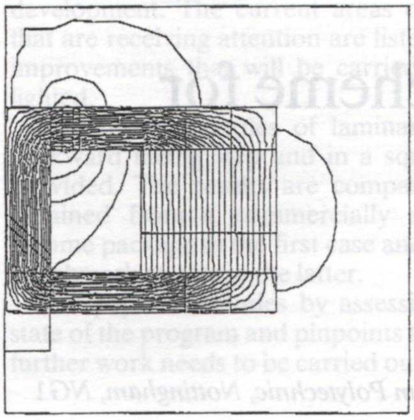
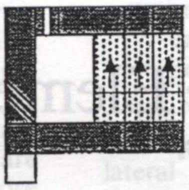


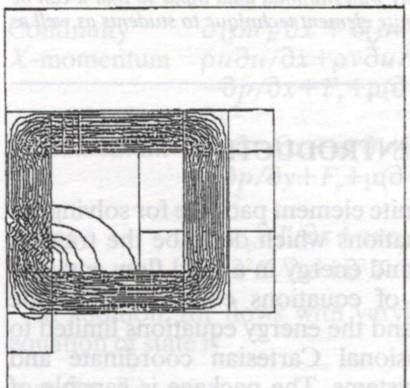

Fig. .3 Flux plots for the geometries shown in Fig. 2.

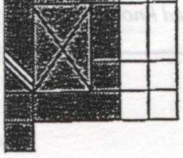




(d)

(d) Voice coil motor





(e)

(e) Solenoid actuator

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