

Computer-Aided Optimum Design of Magnetic Circuits with Permanent Magnets

ASHOK H. PRADHAN

Abstract—A computer-oriented method is developed for optimum design of magnetic circuits with permanent magnets. It consists of finding an electrical equivalent for the magnetic circuit and writing a computer program that evaluates the various circuit elements, solves the resulting network equations, computes the leakage and reluctance factors, and solves the design equations iteratively. The design can be coded out to satisfy criteria such as minimum magnet volume or minimum material cost. The program can also be used to obtain the expected performance of specified designs thus allowing the designer to evaluate his design ideas without iterative prototype building. The execution time is of the order of a few seconds, and the designer can use the program in interactive mode thus saving substantial engineering time.

INTRODUCTION

THE PHILOSOPHY¹ behind computer-aided, or automated, design is illustrated in Fig. 1. The designer inserts the necessary specifications from a triotype into a digital computer. A program stored in the computer computes the design, which could be optimum according to a prespecified criterion. The required design parameters and the expected performance are printed out on the teletype. The designer inspects these and, if necessary, makes changes in the input specifications. When the expected performance is acceptable, a prototype is built and its performance is measured. This process is repeated until acceptable measured performance is obtained. Because of the computer in the loop, the design time is considerably shortened and the number of prototypes required is also reduced.

One such computer program is described elsewhere [1]. This paper deals with computer-aided optimum design of magnetic circuits with permanent magnets.

Magnetic Circuit Design Using Permanent Magnets

The typical problem encountered in practice when designing magnetic circuits using permanent magnets can be stated as follows: "Find the magnet material and dimensions of the magnetic circuit having a desired geometry that will give the required flux density in an airgap of specified length at minimum material cost."

The geometry (shape, configuration) is usually dictated by the type of application. It could be one that is previously established or could be a novel one that the designer wants to try out. The required gap density is also dictated by the type of application, and usually has an acceptable range



Fig. 1. Computer-aided design philosophy.

Define the following quantities:

- B_m flux density in the magnet axial section;
- H_m magnetizing force corresponding to B_m ;
- A_m cross-sectional area of the magnet transverse to direction of magnetization;
- L_m length of the magnet along direction of magnetization;
- V_m volume of the magnet;
- B_g flux density in airgap;
- A_g cross-sectional area of gap transverse to flux lines in the gap;
- l_g length of gap along flux lines in the gap;
- σ leakage factor = $\frac{\text{total magnet flux}}{\text{useful gap flux}}$;
- τ reluctance factor = $\frac{\text{MMF applied by magnet}}{\text{MMF drop in gap}}$.

Then, magnetic energy supplied by the magnet over the demagnetizing region of the B - H curve

$$\begin{aligned}
 &= \frac{1}{2} \text{MMF} \times (B_m) \\
 &= \frac{1}{2} (H_m L_m) \times (B_m A_m) \\
 &= \frac{1}{2} (B_m H_m) \times V_m.
 \end{aligned} \quad (1)$$

Therefore, in order to get a certain magnetic energy for minimum volume of magnet, the product $B_m H_m$ for the magnet, commonly known as the "energy product," should be maximum. This is the starting point for design of magnetic circuits with permanent magnets. Practical limitations of the present operation of the magnet at its maximum energy point, is that one, since the energy product starts to decrease, the operating point should be as close as possible to the maximum. There are

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The author is with the Westinghouse Research and Development Center, Pittsburgh, Pa.

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Computer-aided Design of Magnetic Circuits Alexander Kusko, Theodore Wroblewski, 1969 *Computer-Aided Design in Magnetics* D.A. Lowther, P.P. Silvester, 2012-12-06 Computer aided design has come of age in the magnetic devices industry From its early beginnings in the 1960s when the precision needs of the experimental physics community first created a need for computational aids to magnet design CAD software has grown to occupy an important spot in the industrial designer's tool kit Numerous commercial CAD systems are now available for magnetics work and many more software packages are used in house by large industrial firms While their capabilities vary all these software systems share a very substantial common core of both methodology and objectives The present need particularly in medium sized and nonspecialist firms is for an understanding of how to make effective use of these new and immensely powerful tools what approximations are inherent in the methods what quantities can be calculated and how to relate the computed results to the needs of the designer These new analysis techniques profoundly affect the designer's approach to problems since the analytic tools available exert a strong influence on the conceptual models people build and these in turn dictate the manner in which they formulate problems The impact of CAD is just beginning to be felt industrially and the authors believe this is an early but not too early time to collect together some of the experience which has now accumulated among industrial and research users of magnetics analysis systems *Computer-aided Design of the Clutch/brake Using Nonlinear Magnetic Circuit Analysis* Khashayar Khorasani, 1983 *Scientific and Technical Aerospace Reports*, [Magnetics Engineering Fundamentals and Computer-Aided Design Solutions](#) Fred Lilienstein, 1993-04-15 A text software combination for novice or seasoned magnetics specialists on using computer aided methods to design magnetic devices for electro mechanical equipment and appliances The first half of the volume reviews the basic principles the relevant formulas and both the formal and informal terminology the second half consists of dialogues with the several programs included on the 5 25 disk for IBM or compatibles Some previous experience with programming is helpful but not necessary Annotation copyright by Book News Inc Portland OR *Second Conference on Advances in Magnetic Materials and Their Applications, 1-3 September 1976* Institution of Electrical Engineers. Science, Education, and Management Division, 1976 *A DDC Bibliography on Computer-aided Logical Processes* Defense Documentation Center (U.S.), 1969 *Use of Engineering Literature* K. W. Mildren, 1976 **Methods in Biomedical Magnetic Resonance Imaging and Spectroscopy** Ian Robert Young, 2000 These volumes are an abstraction from the Encyclopedia of Nuclear Magnetic Resonance of articles concerned with magnetic resonance imaging and spectroscopy The volumes cover imaging in all its forms and spectroscopy in as far as it relates to in vivo studies and clinical applications involving in vitro investigations of tissue The various articles which comprise these two volumes are organised into topic based sections Some of the articles appear as they were originally presented in the Encyclopedia where there is little new information and some have been more or less substantially revised in the light of what

has happened since the articles were first written A number of new articles have been added where topics have either developed from fragmentary discussions in the early 1990s or have been created ab initio since the publication of the Encyclopedia These extensive volumes are unique in their coverage with a balance between imaging physics spectroscopy and clinical studies In many ways they reflect the scope covered by the major international in vivo NMR Societies with a conscious effort to allow the reader to understand all the elements that make up modern clinical magnetic resonance Equally the topic is so huge and still evolving so fast in detail rather than concept that they can act as no more than an introduction though at quite a demanding level The reader will appreciate the extent nature and dynamics of human and animal magnetic resonance and will have the route map to allow them to find any further information they may need

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Computational Magnetics Jan Sykulski,1995 This book fills the gap between theory available computational techniques and engineering practice in the design of electrical and electromechanical machines The theory underlying all currently recommended computational and experimental methods is covered comprehensively including field analysis and synthesis magnetic fields coupled to stress and thermal fields The book is very practically oriented and includes many examples of actual solutions to real devices

New Magnetic Applications in Clinical Dentistry Minoru Ai,Yuh-Yuan Shiau,2004 New edition of the original Japanese title Construction of Removable Partial Dentures by Using Magnetic Attachments 1st edition c1994 Gives the basis of and presents clinical cases of magnetic stud attachments Also discusses clinical applications and attachment technology Abundant full color and halftone images 1977 Digests of the Intermag Conference ,1977 *EDN.* ,1977 BTL Talks and Papers Bell Telephone Laboratories, inc. Technical Information Libraries,1969

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