Computer Aided High Frequency Transformer Design
Using an Optimized Methodology

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Abstract - A new methodology for designing transformers has previously been developed. This model takes account of switching type waveforms encountered in switching mode power supplies, inclusive of high frequency skin and proximity effects. The selection of the transformer core has been optimized to minimize the core and winding losses. This paper will demonstrate a computer aided design package written for Windows to implement the optimized methodology for the first time. The package also incorporates formulas to find the optimum foil or layer thickness in a multilayer winding. These formulas apply to any arbitrary periodic current waveform. An overview of the adaptation of the underlying theory for use in computer aided design will be presented, along with a number of screenshots of the software in action.

I. INTRODUCTION

The movement towards high-density electronics has attached greater significance to high frequency magnetic components sharing circuit boards with traditional components. As a result, user-friendly computer aided design packages for these components are required. A robust method that leads to optimized core selection and winding selection from a user's design specifications has been proposed in [1], where new conditions for optimizing transformer design at high frequencies were established. This paper introduces a high quality graphics package that is currently being developed for the Microsoft Windows environment to implement the design methodology, inclusive of proximity effect calculations derived in [2], for the first time.

II. METHODOLOGY OVERVIEW

The design methodology is outlined in the flow chart of Fig. 1. Once the physical properties of the core and winding are established from the input specifications, detailed thermal and electrical models can be evaluated. The process begins with a set of desired specifications for the application in question (power output, frequency and temperature rise). Materials for the core and windings are selected at this point.

A critical point in the design occurs when the optimum flux density, B_o, for the input specifications is calculated (represented by the diagonal choice symbol in the flow chart, and illustrated by the graph in Fig. 2). If this optimum flux density is less than the saturation flux

density for the core material being used in the design, the maximum flux density allowed is set to the optimum value. This will lead to a particular size of core (based on the window area × cross section area product, A_p). But if the optimum flux density is greater than the saturation flux density, the maximum flux density is set to the saturation value, and thus a different route is taken which may lead to a different size core.

Core manufacturer catalogues are consulted to obtain the rest of the core data for a particular A_p value - cross-section A_c, window area W_a, the mean length of a turn MLT, and the core mass m.

Once the core has been selected, the number of turns for each winding and corresponding wire sizes are calculated.

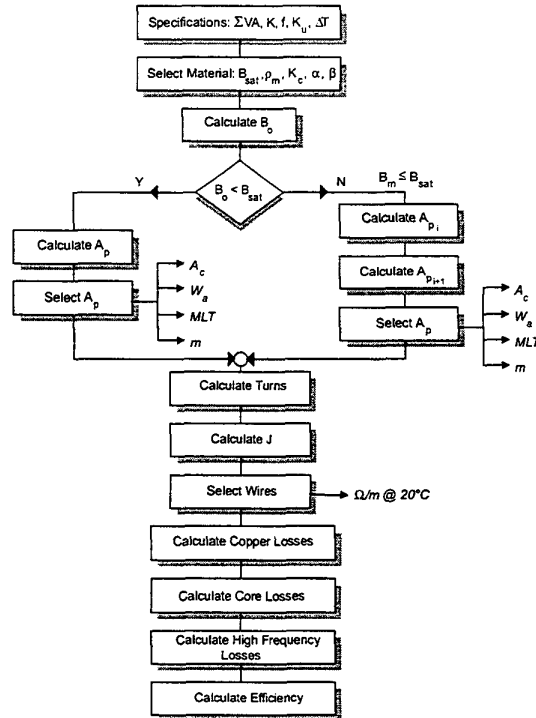Finally, the core losses, winding losses (ac or dc or both) and total losses are calculated.

Fig. 1. Flow chart of new design methodology.

III. SOFTWARE DESIGN

The two main considerations when writing this software were firstly the need for an easy-to-use GUI that would display a large amount of data, and secondly the ability to access various manufacturer's core and winding information from some sort of database. Visual Basic was chosen as the programming language for the software as it combines an easy-to-use environment for designing GUI intensive packages with the power to integrate and distribute the Access database engine.

The software was initially coded around the flow chart process as described in [1] and as shown in Fig. 1. As development progressed, it became apparent that certain stages in the process required more information than others and so needed a larger dedicated area for entering and displaying data.

This package contains over 250 controls or objects in the design window alone (including text boxes for both inputs and calculated outputs, labels describing each text box, option groups, grids or tables of data, graphs etc.).

A folder-like representation of data was therefore chosen to separate steps in the design process from each other. In all, there are 10 steps ranging from entering specifications (step 1) to calculating the optimum layer thickness (step 8) to adding custom cores or windings (step 10).

We will now give an overview of each of these steps.

1. Specifications

To begin, the user chooses one of the applications available: center-tapped transformer, forward converter or push-pull converter (in a future version, a general application will be added where basic characteristics can be modified by the user, e.g. waveform factor, power factor).

The user is then required to enter the following specifications (Fig. 4), common to each application:

- Output voltage
- Output current
- Input voltage range (upper and lower)
- Frequency
- Temperature rise
- Ambient temperature
- Desired efficiency

After entering the specifications, the user can choose from a range of core and winding materials already available in the software's database.

An "Expert Options" section allows the user to view more detailed information on constants / other factors used in calculations and to change some of these default values.

Once the specifications and materials are set, optimum area product and flux density values (Fig. 2) are calculated. As specifications, materials or expert options are varied, these A_p and B_o values are updated accordingly.
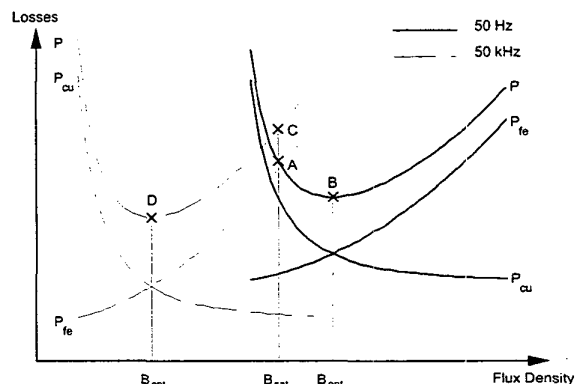

Fig. 2. Picking the optimum flux density.

2. Core Data

After finding the optimum A_p value, the next step in the design process is to select an actual core with a size close to that calculated. First the user selects the shape of core from the following - CC, EE, EI, UU, pot, or toroidal (Fig. 5). Core types with a matching shape and material (as chosen in the first step) are displayed.

The user must then select one of those core types to continue with the design procedure. Once the core type has been chosen, the software selects the core from that category with the most appropriate area product value (if one is available).

A core with an A_p value greater than or equal to that calculated in step 1 is automatically selected. An important feature of the software is that the user is not constrained to accept the core size (or the winding size in step 4) that is automatically suggested, a larger or smaller size can be chosen if necessary.

3. Turns Information

The turns information is displayed in step 3, based on the chosen (not automatically calculated) area product value from the previous step.

A feature recently added is the ability to override the calculated turns data and enter your own values.

4. Winding Data

As with the cores, the user first chooses the shape of winding required to display a list of matching types for that shape, as shown in Fig. 6. The user then chooses one of the types of winding to display a full list of windings in that category (one of which will be automatically selected). For example, the shape might be "Round Wire", the type "AWG Wire", and then "AWG 13" might be the size automatically picked by the software for a particular winding.

5. Winding Losses

The user can choose to display dc winding losses, ac winding losses, or all of the dc and ac losses combined (Fig. 7). For the ac winding losses calculation, the skin and proximity effect factors are multiplied by the dc losses to account for these high frequency effects.

6. Core Losses

The core losses are calculated automatically, based on the core loss equation with core weight, frequency, maximum flux density and K_c / α / β constants as variables.

7. Total Losses

Total losses are simply the sum of the winding and core losses previously calculated. The efficiency is then calculated from the output power and these losses.
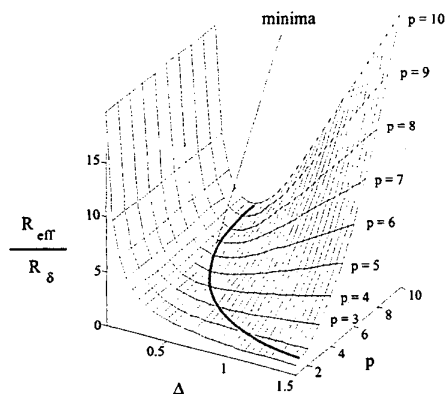

Fig 3. Optimizing the winding layer thickness

8. Optimum Thickness

Another interesting feature of the software is the step that performs the optimum winding thickness calculation. This is based on theory presented in [2].

By default, the frequency, duty cycle, number of layers and current waveforms for the application under design are displayed as in Fig. 8. The user can modify these values or the waveform type to view optimum thicknesses and minimum ac to dc resistance ratio values for multiple configurations if so desired.

The user can also choose to try a different value of layer thickness and view its effects on the ac to dc resistance ratio.

9. Leakage Inductance

The user can manually change the percentage height of the window available for windings to be wound on (usually reduced due to the presence of a bobbin). Leakage inductance is then automatically calculated, and expressed in μH.

10. Custom Addition

Finally, if a particular core or winding is not available in the database supplied with the program, the user can add custom data (Fig. 9).

The user begins with entering a customized or non-existent material. Then a new core or winding type is created, and the data for a corresponding range of cores or windings are entered.

CONTACT

A trial version of the Magnetic Component Designer (MaCoDe) software demonstrated in this paper can be downloaded from the http://perc.nuigalway.ie/ site.

The paper authors may be contacted by e-mail at john.breslin@nuigalway.ie and ger.hurley@nuigalway.ie respectively.

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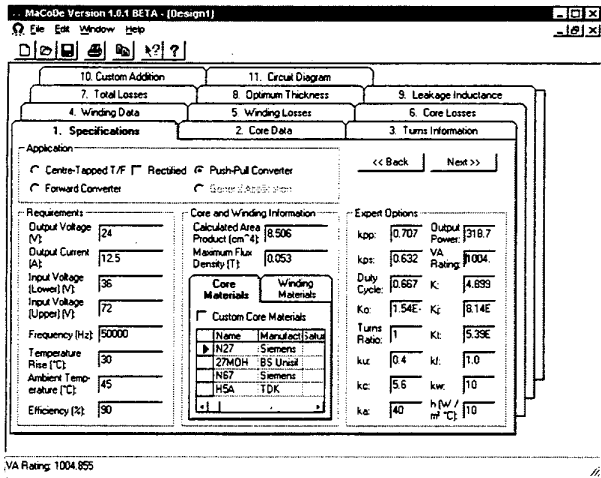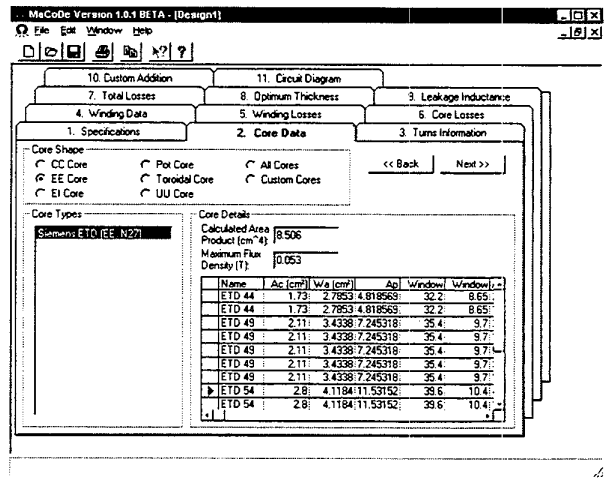
Fig. 4. Initial screen where specifications are input.

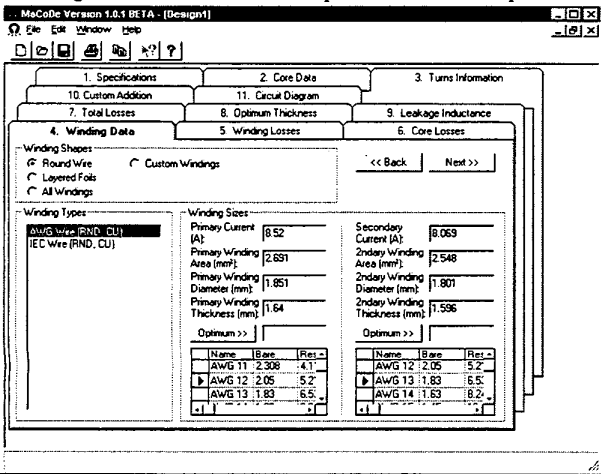Fig. 5. Selection of core shapes and types.

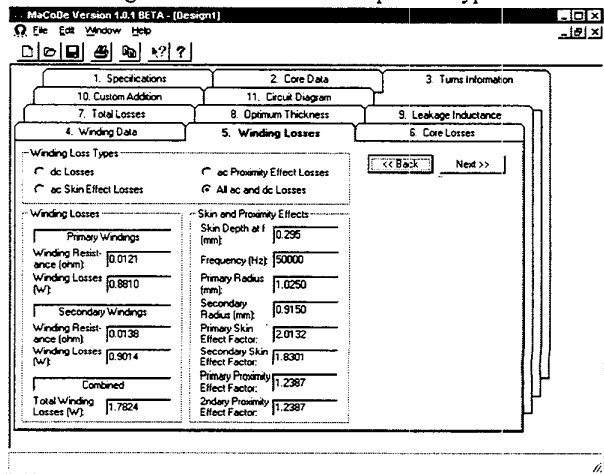Fig. 6. Data for primary and secondary windings.
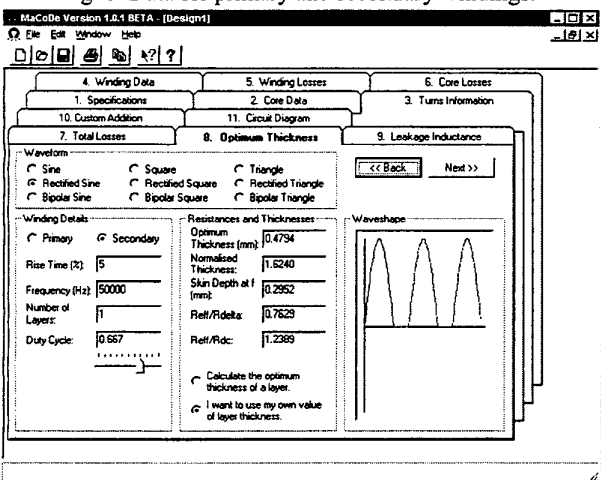
Fig. 7. Display of dc and ac winding losses.

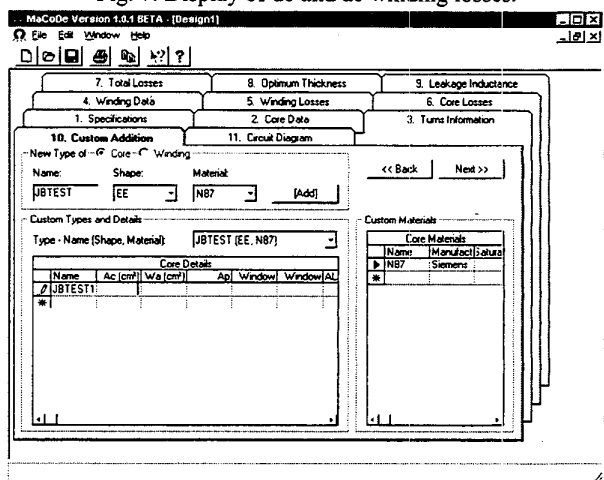Fig. 8. Optimum winding thickness for various waveshapes.

Fig. 9. Addition of new cores or windings into database.