STUDY AND DESIGN OF HIGH VOLTAGE FLYBACK TRANSFORMER FOR TV AND MONITOR

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Abstract-**This paper gives a fundamental study of the performance of Flyback Transformer(FBT), calculation based on 3D finite element method(FEM) has been done to investigate the influence of leakage inductance and stray capacitance on the transformer,the results have shown that the high voltage (HV) stage of the transformer plays a key role to affect its performance. This may be very useful in optimum design and manufacture of the FBT, and in the meantime we know that the computer modeling is an effective tool .The simulation shows good agreement with the experiment.**

I. INTRODUCTION

A high voltage flyback transformer(FBT) is a main component in the CRT display system, which is required to provide a stable anode accelerating voltage and a focusing voltage to the CRT ,to some extent ,the display image is affected by the high voltage greatly,when the high voltage changes 1%, the geometry distortion is about 5%, it will also cause the brightness to change ,this may be a serious problem in the area of novel CRT graphic displays, people concern on the stability of the images, so the high voltage stability is necessary ,the FBTs' high voltage output is about 26Kv ,the beam current is 1mA, all these require that the FBT has good voltage regulation ratio, as of known ,this ratio is determined by the higher order harmonic control[1]. Actually, many parameters such as : leakage inductance and stray capacitance etc.determine the regulation ratio, but the practical design process of FBT is a trial and error one,which largely depends on the experience of the engineers,this sometimes will lead to the sub optimal goal . So we think to know their role or their weight in the designation of FBT is necessary, for this will give clear guide to optimally design the FBT and give the performance prediction within a short period of time.

The FEM based on the solution of Poison's Equation has shown its validity and accuracy in the computational electromagnetic, it can deal with both the non-linear B-H characteristics and anisotropy of the core material, the 2D FEM has been widely used , but it is not enough to give the actual results when considering the leakage inductance working in high frequency, so we adopted 3D FEM software package to calculate the magnetic flux distribution, by this method the ,the accurate values of leakage inductance can be obtained .The calculated data and results are compared with the measured ones for several experimental transformers, the results will be presented and discussed in details in the following.

II. ANALYSIS MODEL

The diagram of the analyzed FBT transformer is shown in Fig.1. The model consists of a primary coil and a secondary one, also with a magnetic core ,the primary coil is low voltage coil, the secondary one is high voltage coil which is divided into 4 stages , between each stage there is a glass diode. All the coils are wounded in cylindrical shape, the ferrite core made of U16 type material is the magnetic circuit .The 4th stage

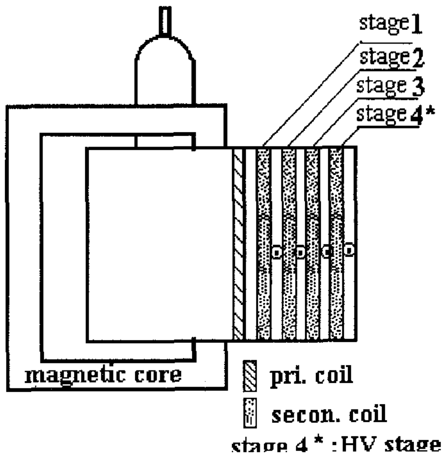

Fig.1 The diagram of the analyzed FBT model

is named high voltage one. According to the theory of FBT transformer, during the flyback period ,the HV output current is the sum of the bias current induced by the horizontal deflection yoke current and that of the current caused by the leakage inductance and stray capacitance ,the latter current can be utilized to control the harmonic output of the FBT effectively,nowadays, this harmonic is always designed to be at 13th order.So we have to calculate the stray capacitance and leakage inductance to know their importance in the FBT ,and give us much help in the practical design.

The FBT with this kind of winding has its special merits, its self-capacitance is small and because the AC pulse voltage at the counterpart position equals to each other,there is no capacitance current between the HV windings, hence in such FBT, although the capacitance between the windings is large , it has little influence on the harmonic control and losses, but it will be different concerning about the capacitance between the first stage winding and the low voltage winding, in that condition , the capacitance will down load the harmonic and increase the losses in FBT, in the experiment, we found that a diode connected between the GND and the first stage HV winding will overcome this shortcoming .

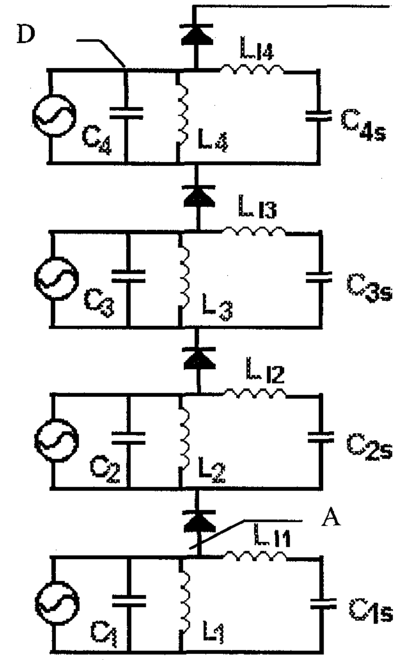

Fig.2 The equivalent circuit of the FBT's Secondary coil

The above Fig.2 is the equivalent circuit of the FBT transformer. Fig.3 is a sample of simulated waveforms at point A and D respectively.At point A, a sine -voltage harmonic source ,whose frequency is 1300kHz ,is superimposed to the first stage of the second winding, according to the simulation results given by PSPICE V5.4 , this harmonic doesn't transmitted to the fourth stage, this can be seen from the waveform at point D.

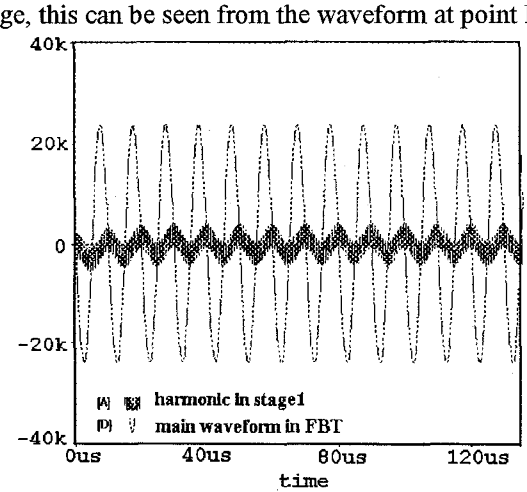

Fig.3 The simulated waveform at stage1 and stage 4

In order to clarify the influence of leakage inductance and stray capacitance of FBT ,We got four kinds of prototype FBTs, U-16 type magnetic core is used as magnetic circuit in all samples, and they have the same total number turns of primary coil and that of secondary coil.The number of turns of each primary winding is 100 turns, the total number of turns of secondary coil is 2700, but the number of each stage of the secondary coil varies in different prototype FBT, this means that the leakage inductance and stray capacitance may be changed to meet the experimental conditions.Table1.is the structure parameters of the FBT.

Tab.1 The structure parameters of 4 FBTs

	prim. coil	secondary coil (1)	(2)	(3)	(4)
A	100	700	800	600	700
B	100	700	700	700	700
C	100	800	700	700	600
D	100	700	700	800	600

III. COMPUTATION OF LEAKAGEINDUCTANCE AND CAPACITANCE

The basic equation of a 3D finite element method can be given as follows[2]:

$$\nabla \times \frac{1}{\mu} \times A = J \qquad (1)$$

$$B = \nabla \times A \qquad (2)$$

In which μ is the permeability, A is the magnetic potential vector, J is total current density, which includes source current , eddy current and dispatch current , B is the magnetic flux density. The calculation involves minimizing the functional :

$$F = \iiint \left(\frac{1}{2\mu} curlA \cdot curlA - \bar{J} \cdot \bar{A}\right) dV \qquad (3)$$

which is subjected to the prescribed boundary conditions, the calculation is performed by numerically using finite element method. The interesting region is divided into triangular elements, then based on the minimized function , a set of simultaneous algebraic equations interrelating the potentials at adjacent mesh-points. The equations are solved by iterative method to get the potential in each mesh-point.

1.capacitance Because the FBT works at high frequency band, it is necessary to take into account of the windings to windings and windings to ground capacitances named stray capacitance are computed by solving Laplace's 2D electrostatic equations using the FEM method[3] or by theoretical analysis to ground capacitance, such mentioned and empirical formulation.

2. Leakage inductance All inductances can be calculated from spatial magnetic energy distribution, in the simulation procedure, the following formula is often used to determined to the inductance [4];

$$W_m = \frac{1}{2} LI^2 = \frac{1}{2}\int \vec{A} \bullet \vec{J} dU \qquad (4)$$

where Wm is the spatial energy, L the inductance , U the volume , the leakage inductance is derived from the simulation of the loaded circuit, in condition of shorting the secondary coil, it can be calculated by such method [4]:

$$L = \frac{2}{i^2}\int_U \int_0^B H(b) \bullet db dU \qquad (5)$$

When carrying out the practical calculation, we first input the data about the FBTs' dimension and structure to the computer, then a software will do the pre-processing ,so the interested region will be automatically discreted into more and more fine triangle elements, after calculation , the software does the post processing, the unknown vector potentials are determined .The vector potentials are used to give the correct values of leakage inductances according to [4].

IV. RESULTS AND DISCUSSION

Four prototype FBT models have been simulated,their leakage inductance and stray capacitance are obtained, based on these data ,we calculated their harmonic period and compared with the measured ones, the results of inductance can be shown in Fi.g.4 capacitance in Fig.5 , the harmonic period in Fig.6,they have good agreement. From the simulation we found that although the stray capacitance is very large ,it doesn't affect the harmonic coefficient as described

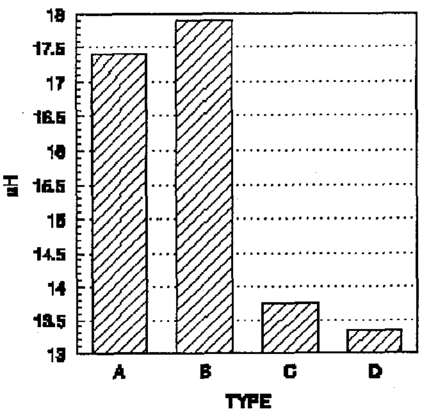

Fig.4 The calculated Leakage Inductance

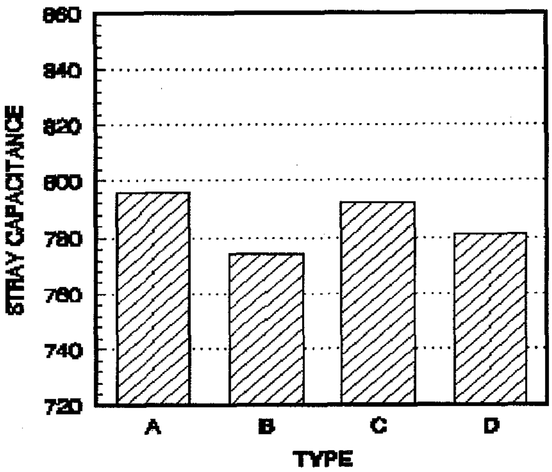

Fig.5 The calculated stray capacitance
(the unit of capacitance is pF)

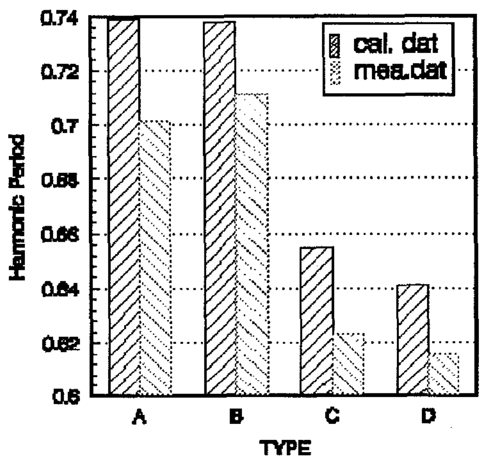

Fig.6 The calculated harmonic period with the measured one
(the unit of harmonic period is μ S)

in [1], instead ,the leakage inductance plays a key role in the harmonic control . From Fig. 6 ,we find only the high voltage stage affect the higher order harmonic control,so when we design a FBT for a TV set or monitor , according to the requirement such as high voltage and harmonic order,we can make total numer of turns of the secondary coil unchanged , which will assure the high voltage unchangeable, and we just changed the number of turns of the fourth stage (HV stage) , it will be easily to get the satisfactory goal.

V. CONCLUSION

From above discussion, we can conclude that in the design of a FBT, only the HV stage plays a key role in the harmonic control , but not the stray capacitance,it also demonstrate that the computer simulation is an effective way in performance prediction and design of FBTs.

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