Comparison and Design Analysis of Pulse Transformer for HID Ballasts

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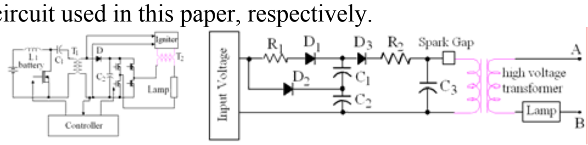
Abstract— In this paper, a transformer with small size and relatively insensitive to distributing parameter is present. Two types of four different high-voltage pulse transformers used in the igniter circuit of HID ballast are examined. This comparison concludes that the transformer with the smallest size using R core is optimal. Experiment results are used to validate the conclusion.

I. Introduction

Due to the need to have high amplitude and sufficiently long period, the generation of the starting voltage for HID lamp is one of the major issues in ballast design. Fig. 1(a) (b) give the HID ballast topology and the structure of igniter circuit used in this paper, respectively.



(a) (b)

Fig. 1 (a) HID Ballast Topology (b) The Igniter Circuit

II. Operation Principle and Design Analysis

A) Operation Principle

Referring to Fig. 1(b), the resistors R_1, R_2 are used to limit the circuit current. When the input voltage is applied, capacitor C_2, C_3 are charged up through the diodes D_1, D_2 and D_3. If the voltage of C_3 exceeds the switch voltage of the spark gap, a voltage pulse is generated to the transformer. The energy in one pulse must be high enough to cater for lamps having different individual characteristics, different operating thermal profile and spark gap lift-time. The charging time constant of capacitor C_3 and discharging time of C_2 are given as follows:

$$\tau_{c3} = (R_1 + R_2)C_3,\ \tau_{dc2} = R_2(C_1 // C_2 // C_3) \qquad (1)$$

B) Design Analysis

The magnetic flux is contributed by the conduction current and displacement current together, and the leakage inductance is calculated by Stokes' theorem

$$L = \frac{\psi}{I} = \oint_{C_i} A_j dl_i / I = \frac{\mu_0}{4\pi}\oint_{C_i}\oint_{C_j}\frac{dl_j dl_i}{R} \qquad (2)$$

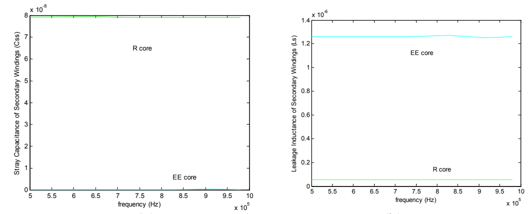
The following items was considered for high voltage design : Effect of distributing parameters including the leakage inductance and stray capacitance of transformer; Coupling Factor and flux saturation and that include the effect of the core type and the size upon the coupling factor and degree of flux saturation; size and cost of the optimal transformer.

III. Comparison of Different High Volt.Transformer

After designing 4 different transformers, the coupling factor, distributing parameters (leakage inductance, stray capacitance), flux saturation, size and cost are compared in this section.

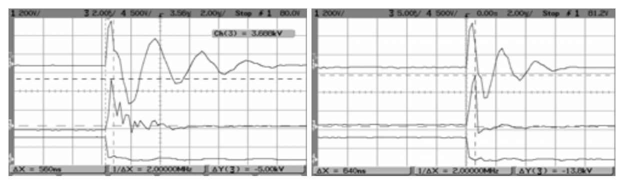
A) Comparison using Different Magnetic Cores

One type is with EE magnetic core (ETD29), the other has an R core (d=0.8cm, l=3cm). Fig. 3 shows the distributing parameters of different cores. Fig. 4 shows the experiment results (input, output voltage of the transformer and voltage of spark gap in a cold HID lamp).



(a) (b)

Fig. 3 Distributing Parameters (a) Stray Capacitance (b) Leakage Inductance



(a) (b)

Fig. 4 (a) Voltage of EE core transformer(b) Voltage of R core transformer (ch1: i/p volt. of xformer; ch3: o/p volt. of xformer; ch4: volt. of spark gap)

B) Comparison with Different Size

These three transformers have an R core with different lengths. Fig. 5 also shows the distributing parameters and Fig. 6 shows the experiment results in hot restrike.

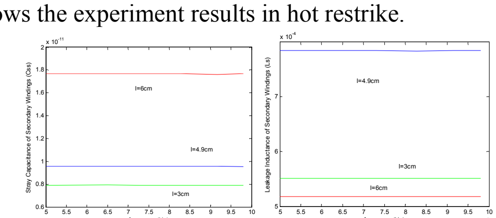
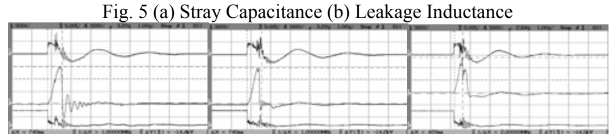


Fig. 5 (a) Stray Capacitance (b) Leakage Inductance



(a) (b) (c)

Fig. 6 (a) Voltage of R_1 core (d=0.8, l=3cm) (b) Voltage of R_2 core (d=0.8, l=4.9cm) (c) Voltage of R_3 core (d=0.8, l=6cm) (ch1: input volt. of xformer; ch3: output volt. of xformer; ch4: volt. of spark gap)

IV. Conclusion and Analysis

It is confirmed that transformer with EE core is easy to saturate. The stray capacitance decreases and leakage inductance increases with the length with R core. The output voltage is higher in the R core for the same number of turns.

Acknowledgement

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