Exact Parameter Estimation of Impulse Magnetizer considering Contact Resistance

Pill-Soo Kim

Daelim College, 526-7 Bisan, Dongan Anyang, Kyunggi 431-715, Korea

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This paper describes the method for exact parameter estimation of impulse magnetizer system. As the detailed contact resistance of impulse magnetizer can be obtained, the efficient design of magnetizer which produce desired magnet will be possible using our estimation procedure. As the parameter estimation method of impulse magnetizer, two different estimation methods (a method considering contact resistance and a method using air-core test coil) are presented. The application example has been achieved using a high-voltage, middle-energy capacitor discharge impulse magnetizer and 2-pole iron-core fixture.

Key words: impulse magnetizer, contact resistance, magnetizing fixture, fixture resistance

1. Introduction

In a capacitor discharge impulse magnetizer system, a magnet is magnetized by the discharging current of capacitors. Among the factors determining a magnetizer system characteristics, the parameter factor and thermal factor, cost factor is very important¹⁾⁻¹¹⁾. Fully magnetizing and measuring the magnetic properties of high energy product, rare earth magnets has become increasingly more difficult because of their very high levels of residual induction B_r and magnetizing force H_c . Under these conditions the magnetizing fixture coil frequently used is only one-turn operating at several hundred thousand amperes and several volts. In this case, the problem may be aggravated by the inexact parameters of magnetizer system^{1),2),12)-14)}.

Consequently, it is also possible to account for the fact that the magnetizer system parameters required to produce the desired magnetizing field intensities can cause significant life-cycle and heating of a magnetizer system and hence appreciable changes to its resistance and the magnitude of the large current impulse, during the impulse period, particularly if it has small cross-section conductors. Therefore, exact parameter estimation of a magnetizer system is also critical in determining its practically, in terms of the magnetization cycle time. One of the most effective design methods to obtain the desired magnetic field is a exact parameter estimation of magnetizer system, i.e., internal resistance and fixture resistance^{1),2),13),14)}. Especially, among the above parameters, various contact resistance of magnetizer system components are very important. In some system for high-energy magnet, total contact resistance may be bigger than a fixture resistance. In this case, a significant portion of the energy stored in the capacitor bank would be lost in various

contact resistor.

The objectives of this study was to prescribe the contact resistance on the system components for exact parameter estimation of capacitor discharge impulse magnetizer system. As the another parameter estimation method, the internal resistance and internal inductance of the impulse magnetizer system have been estimated by using known air-core test coil.

2. Outline of Impulse Magnetizer

The equivalent circuit of a capacitor discharge impulse magnetizer system equipped with a discharging switch (=SCR2) is shown in Fig.1. Since a typical magnetizing fixture is essentially a fixed configuration of wire loops, its impedance can be modeled as a series R-L circuit shown in Fig.1. The rectified power supply providing the initial charge for C_B and the gate triggers for the SCRs are not shown in the figure⁸⁾⁻¹⁴⁾.

Fig. 1 Block diagram of impulse magnetizer system

3. Method of the Parameter Estimation

3.1 Parameter estimation considering contact resistance concepts

Figure 2 shows the discharging circuit of impulse magnetizer system included contact resistance region. The region I and region II enclosed by the broken line corresponds to the magnetizer system and magnetizing fixture each. Here C_B , R and L are the capacitance of capacitor bank, the resistance and the inductance of magnetizing fixture. Also, R_w and L_w are the winding resistance and winding inductance of the winding outside the magnetizing fixture. In Fig.2, we used a magnetizer system that consisted of two major region : 1) region I, 2) region II.

1) region I :

- i) contact resistance across the capacitor bank C_B ; CR_{i1} and CR_{i2}
- ii) contact resistance across the recovery diode D ; CR_{i3} and CR_{i4}

- iii) contact resistance across the capacitor bank in case of parallel and serial connection ; CR_{CB}
- 2) region II
 - i) contact resistance in a case terminal ; CR_{m1} and CR_{m2}
 - ii) contact resistance between the lead wire and the magnetizing fixture wire ; CR_{o1} and CR_{o2}
 - iii) contact resistance in case of serial connection of measuring devices ; CR_{md}

Fig. 2 Discharging circuit of impulse magnetizer included contact resistance region

Fig. 3 Measurement system for various contact resistance

Table 1 Measurement values of contact resistance

Measurement Region	Measurement Values	Conditions
Region I	CR _{i1}	0.0025 [ohm] Bolt-Nut
	CR _{i2}	0.0021 [ohm] Contact Point
	CR _{i3}	0.0009 [ohm] Lead
	CR _{i4}	0.0008 [ohm] Contact Point
	CR _{CB}	0.032 [ohm] 400[μF],1200[V], 2×2 Conn.
Region II	CR _{m1}	0.0027 [ohm] Bolt-Nut
	CR _{m2}	0.0031 [ohm] Contact Point
	CR _{o1}	0.0032 [ohm] Bolt-Nut
	CR _{o2}	0.0029 [ohm] Contact Point
	CR _{md}	0.0063 [ohm] Measuring Shunt Conn.
Wire Parameter	R _w	0.0855 [ohm] Length : 3[m]
	L _w	0.075 [mH]

Also, Figure 3 shows the measurement system for various contact resistance of the magnetizer system. Using a 4-terminal clasper as shown in Fig.3, the test direct current I passes through a unknown internal resistance R_x . Especially, in this case, 4-terminal clasper prevents the voltage drop from current terminal C_1 and C_2 , thereby ensures that error-free of a internal resistance is produced for all cases of the measurement. The measurement value of various contact resistor of the this method is given in Table 1.

3.2 Parameter estimation using air-core test coil

As the another parameter estimation method, the internal resistance and internal inductance of the impulse magnetizer system have been estimated by using known air-core test coil. In this method, by manually matching the test-data transient to the computed transient, the internal resistance R_i and internal inductance L_i can be roughly determined. The manufacturer was unable to supply the internal resistance R_i and internal inductance L_i . Therefore, a test fixture was constructed that had a known inductance and resistance. By discharging the capacitor bank into this known test fixture the parameters of the impulse magnetizer could be inferred²⁾.

The test fixture is a simple air-core solenoid (mean radius 115[mm] would with 50[turns]) of about 1[mm] diameter wire.(Fig.4) The inductance may be computed from

$$L = \mu_0 \cdot N^2 \cdot a (\ln (16 \cdot a / d) - 7/4) \quad (1)$$

where $d \ll a$ and L inductance [H]
 $\mu_0 = 4\pi \times 10^{-7}$ [A/m]
 N number of turns in toroidal bundle
 a mean radius of the coil [m]
 d mean diameter of the wire bundle [m].

Taking the approximate diameter of the wire bundles as 230[mm], the inductance turns out to be 12.22[mH]. Finite Element Analysis (FEA) using field analysis program, produced a result of 12.54[mH]. The measured inductance was 12.72[mH]. The resistance of the test coil was calculated to be 0.292[ohm], and the measured value was 0.314[ohm].

Fig. 4 Cross-section of test air-core coil

Therefore, internal resistance R_i and internal inductance L_i were obtained by adjusting the total resistance R_t ($= R + R_i$) and inductance L_p ($=$ the total inductance below saturation) until the computed result closely matched the amplitude and shape of the experimental data.

Consequently, a impulse magnetizer system has been found to have a internal resistance of 0.158[ohm] and a internal inductance of 0.075[mH].

4. Results and Discussions

As a application example for experimental model of the magnetizer system consider the magnetizing fixture for stator magnet of car air-cleaner DC motor. The charging voltage and capacitor bank of magnetizer system are 1200[V] and 1600[μF] each. The magnetic material of the 2-pole stator magnet is ferrite. The core of the fixture is steel and the slot contains 32 conductor of about 1[mm] diameter wire bonded together with epoxy. A sketch of the experimental results of the application example is presented in Fig.5.

Fig. 5 Experimental results in case of single impulse magnetization

On the other hand, in case of the parameter estimation considering contact resistance, the contact resistance in region I and region II indicates values of 0.0383[ohm] and 0.0182[ohm] each. Also, the wire parameter in the wire indicates values of 0.0855[ohm] and 0.075[mH] each. Therefore, the total internal resistance is about 0.142[ohm]. This internal resistance shows a little difference with the measurement value in estimation using air-core test coil of 0.158[ohm]. The difference between the two cases may, in part, be attributable to the discordance of the experimental data graph encountered in the estimation of the air-core test coil. The accuracy of this estimation method considering contact resistance is propotional to the exact measurements of the contact resistance. This method offer potential exact design advantages compared to the method using air-core test coil. Another potential benefit of this method is that its relative easiness may be significantly reduced in relation to a method using air-core test coil, often an factor when considering design or construction of magnetizer system in case of a producing of strong multi-pole magnet.

Therefore, it can be said that the parameter estimation considering contact resistance is more suitable than the parameter estimation using air-core test coil for producing strong multi-pole magnet.

5. Conclusion

The method for exact parameter estimation of impulse magnetizer system has been presented. Application example of a magnetizer system coupled to a 2-pole magnetizing fixture is shown. One of the most effective design methods to obtain the desired magnetic field is a exact parameter estimation of magnetizer system, ie., internal resistance and fixture resistance. Especially, among the above parameters, various contact resistance of magnetizer system components is very important. As the parameter estimation method, the internal resistance and internal inductance of the impulse magnetizer have been estimated by considering cinctact resistance and using air-core test coil.

The choice if the estimation method considering contact resistance appears to be particularly attractive from an design point of view. Although this study not considered, another potential problems of contact resistance for the producing multi-pole magnet are taken into consideration.

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