Magnetization Properties

1. Objectives

Measure the magnetization curves of a variety of magnetic materials to understand the basic concepts of ferromagnetism. Understand the properties of different materials under different frequency, temperature. Learn the method of using X-Y recorder and oscilloscope.

2. Experimental results

2.1 Properties of specimens and different materials

The basic information of specimens is shown on Table 2.1 *Properties of specimens*.

Table 2.1: Properties of specimens

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Material | Type | Le m | Ae | turn | turn |
| Silicon steel | 6.5%Si |  |  | 30 | 30 |
| Amorphous | MB |  |  | 5 | 5 |
| Ferrite | H5A |  |  | 15 | 15 |

Where, is the average length of the inner and outer perimeters of the toroidal specimen, is the cross-sectional area, and turns are the turns of the coil.

Below are the equations to calculate:

|  |  |  |
| --- | --- | --- |
|  |  | (2.1) |
|  |  | (2.2) |

2.2 Measurement of the magnetization curves

The data from X-Y Recorder and B-H Curve Trainer is shown on Table 2.2 *Measurement result* *of X-Y Recorder* and Table 2.3 *Measurements of the AC B-H Curve Trainer*

Scale Factors of the coercivity H and the flux density B can be calculated using Equation (2.3) and Equation (2.4).

|  |  |  |
| --- | --- | --- |
|  |  | (2.3) |

|  |  |  |
| --- | --- | --- |
|  |  | (2.4) |

Example calculations for Silicon steel, we have:

|  |  |  |
| --- | --- | --- |
|  |  |  |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |

Table 2.2: Measurement result of X-Y Recorder

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| hgMaterial | X-Y Recorder | | Scale Factors | |
| Range  X axis  V/cm | Range  Y axis  V/cm | H A/m/cm | B T/cm |
| Silicon  Steel | 0.5 | 0.1 | 35.76 | 0.163 |
| 0.5 | 0.1 | 35.76 | 0.163 |
| 0.5 | 0.1 | 35.76 | 0.163 |
| Amorphous | 0.5 | 0.5 | 4.55 | 0.085 |
| Ferrite  (H5A) | 0.25 | 0.25 | 28.14 | 0.082 |
| 0.25 | 0.25 | 28.14 | 0.082 |
| 0.25 | 0.25 | 28.14 | 0.082 |

Table 2.3: Measurements of the AC B-H Curve Trainer

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Material | Hz | Temperature℃ | AC B-H Curve Trainer | | | |
| K1  Code number | K1  A/div | K2  Code number | K2  Wb-turn/div |
| Silicon  steel | 100 | 24 | 5 | 0.2 | 0.5 |  |
| 200 | 5 | 0.2 | 0.5 |  |
| 500 | 5 | 0.2 | 0.5 |  |
| Amorphous | 1000 | 24 | 4 | 0.1 | 0.5 |  |
| Ferrite  (H5A) | 1000 | 0 | 5 | 0.4 | 0.25 |  |
| 24 | 5 | 0.4 | 0.25 |  |
| 70 | 5 | 0.4 | 0.25 |  |

2.3 Readings from the graph and Measurement result

We can read the data from Fig. 2.1 *The hysteresis magnetization curve of silicon steel*, Fig. 2.2 *The hysteresis magnetization curve of amorphous* and Fig. 2.3 *The hysteresis magnetization curve of ferrite*, thus we have Table 2.4 *Readings from the graph and Measurement result* which contains values of coercivity Hc, the maximum magnetic flux density Bm, and the residual magnetic flux density Br.

Example calculation:

For Silicon steel of frequency 100Hz, Temperature of 24℃, we have:

Table 2.4: Readings from the graph and Measurement result

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Material | Frequency Hz | Temperature℃ | Reading from the graph | | | Measurement result | | |
| Hc  cm | Br  cm | Bm  cm | Hc  A/m | Br  T | Bm  T |
| Silicon  steel | 100 | 24 | 1.46 | 5.38 | 6.80 | 52.21 | 0.88 | 1.11 |
| 200 | 1.80 | 5.69 | 6.73 | 64.37 | 0.93 | 1.10 |
| 500 | 2.43 | 5.88 | 6.69 | 86.90 | 0.96 | 1.09 |
| Amorphous | 1000 | 24 | 0.58 | 7.08 | 7.11 | 2.64 | 0.60 | 0.60 |
| Ferrite  (H5A) | 1000 | 0 | 0.46 | 1.00 | 5.31 | 12.94 | 0.08 | 0.44 |
| 24 | 0.41 | 1.00 | 4.90 | 11.54 | 0.08 | 0.44 |
| 73 | 0.31 | 0.88 | 3.91 | 8.72 | 0.07 | 0.32 |

3. Discussion and Conclusion

3.1 Frequency dependency of the hysteresis curve

We can learn from Fig.2.1 that as the frequency dependency increases, the area of hysteresis curve (hysteresis loss) increases and the maximum magnetic flux density stays the same.

The derivation of the classic eddy loss frequency obtained equation2 can be expressed as:

|  |  |  |
| --- | --- | --- |
|  |  | (3.1) |

While is the resistivity in Ω m, d is the cross-sectional dimension in meters (thickness for laminations, diameter for cylinders and spheres) and is a geometrical factor which varies from =6 in laminations to =16 in cylinders and =20 in spheres, Bmax is the peak flux density in the cycle and f is the frequency in Hz.

And we can also learn Hysteresis loss in transformer’s Equation3:

|  |  |  |
| --- | --- | --- |
|  |  | (3.2) |

Where, Kh is the Hysteresis constant, Bmax is the peak flux density in the cycle and f is the frequency in Hz.

From Equation (3.1) and (3.2), we can learn that the loss increases when the frequency increases, hence the area increases as well.

3.2 Temperature dependency of the hysteresis curve

We can learn from Fig 2.3 that as the temperature increases, the maximum magnetic flux density Bm decreases. And the coercivity Hc and the residual magnetic flux density Br shows no connections with the temperature.

Oxides that contain ions are generally called ferrite1. Ferrite contains a strong magnetic property called ferrimagnetism which the material has populations of atoms with opposing magnetic moments.

And Spontaneous magnetization is the appearance of an ordered spin state (magnetization) at zero applied magnetic field in a ferromagnetic material below a critical point called the Curie temperature or TC.6

And the temperature dependence of spontaneous magnetization at low temperatures is given by Bloch's Law6:

|  |  |  |
| --- | --- | --- |
|  |  | (3.3) |

while M(0) is the spontaneous magnetization at absolute zero, and is the curie temperature which is around 771°C7. And we can also learn that the decrease in spontaneous magnetization at higher temperatures is caused by the increasing excitation of spin waves8.

And therefore, higher temperature would cause decrease in spontaneous magnetization, which means the decrease of maximum magnetic flux density

A Preisach model5 with parameter of temperature can be used to explain the effects of temperature on magnetic hysteresis. The temperature parameter was introduced into the existing model by adding parameters like curies temperature and critical exponent.

3.3 Relationship between the differences in shapes of the three samples

All the samples are made of ferromagnetic materials. And we can use different models to explain the differences in shapes of the three samples: Preisach Model, Globus Model, Jiles-Atherton Model9.

Different materials have different coercivity, and the differences in shapes can be explained by the differences of coercivity. For low coercivity materials, we call them magnetically soft (Hc ~ 1A/m), for example, the ferrite in the experiment. It has characteristics like high Permeability, low intrinsic coercive force and hence the hysteresis curve is narrow.

For high coercivity materials, which are called magnetically hard (Hc ~ 104 ~106 A/m), the remanence is high and the coercivity is strong, which makes the hysteresis wide.10

And for different Dynamic Hysteresis Curves, the shapes are related to the frequency and ranges of the magnetic fields. For example, as Bm and Hm in Fig 3.1. *Dynamic Hysteresis Curves,* we have the equation for amplitude permeability:

|  |  |  |
| --- | --- | --- |
|  |  | (3.4) |

While Bm and Hm is magnetic field and flux density.

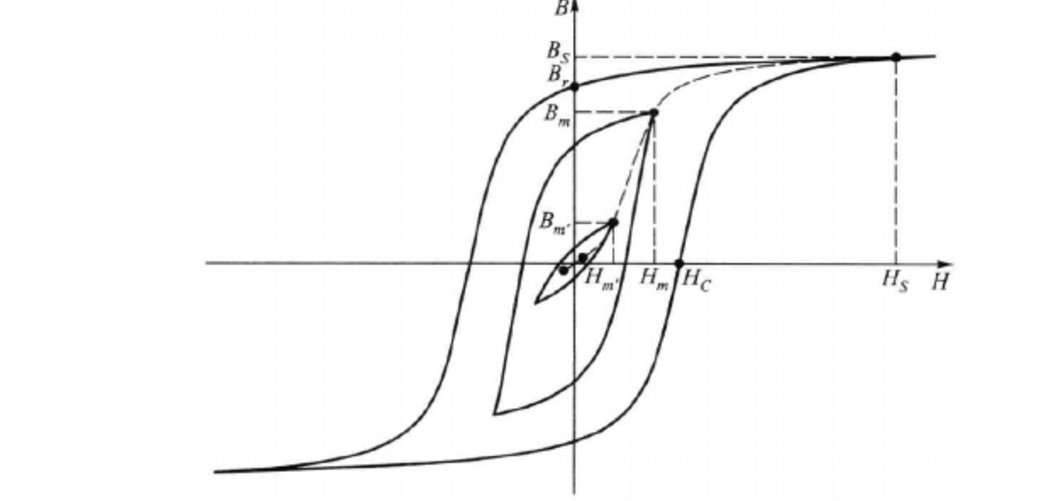


Fig. 3.1 Dynamic Hysteresis Curves

4. References

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