CHAPTER I

INTRODUCTION TO FERROMAGNETIC MATERIAL

In eletrical engineering field, one of the most important material is the ferromagnetic material. Almost of the electric equipments are composed of forromagnetic material. If this material in dynamo-electric machinery power and audio-frequency transformers and hundreds of other electro magnetic devices lost their properties, these devices no longer function properly. It is very hard to immagine how with out these materials, the new designs can be made within a reasonable range of space and cost. In designing we always desire the substance which permits a large flux density for a specified magnetizing force or which makes possible the constraint of flux to definite desired paths is bound to be of inestimable value to the designer. These properties are found in certain forms of iron and its alloys with silicon, cobolt, tungsten, nickel aluminium which are called ferromagnetic material. Easy to magnetize these substances when used for the cores of apparatus, make possible flux densities which are hundreds or even thousands of time greater than could be conveniently established with a practical coil with out the ferromagnetic core.

Engineering utilization of electrical devices containing ferromagnetic material necessitates quantitative description of circuit parameters representing the electric circuit beheavier of these devices. In the presence of ferromagnetic materials, an electric circuit element has a resistance parameter which depend not only upon the magnitude of the current in the circuit but also upon the way in which it varies. The inductance parameter is not only nonlinear but not even single valued function of the current. The major portion of this chapter is devoted to discussion of the properties of ferromagnetic materials of chief interest to electrical engineer.

Ferromagnetic substances are the materials which have positive magnetic susceptibilities and therefore, are attracted by the magnets, that is they tend to move into the densest parts of magnetic field.

The magnetic and electric properties of magnetic materials used in practical engineering work depend upon the uses for which they are required as follows:-

Electromagnet : High permeability low remanence small coersive force and high resistivity. A high permeability is desired so that the maximum amount of magnetic flux may be obtained for a given current strength; a low remanence permits the shortering of the air gaps and the lengthening the cores without sticky of armatures; a small coersive force permits the use of feeble alternating currents and reduces the hysteresis loss, which high resistivity reduces the secondary current loss. .. So that the ferromagnetic materials are characterized by one or more of the following attributes:

a. They can be magnetized much more easier than other materials. This characteristic is indicated by a large relative permeability μ/μ_0 when μ is permeability and μ_0 is permeability of free space.

b. They have a high maximumintrinsic flux density B max.

c. They are magnetized with widely different degrees of each for different value of magnetizing force.

d. They have in them the same flux different when we equally increase and decrease in magnetizing force. This artribute indicates that the relationships expressing the flux density and the permeability μ as function of magnetizing force are nonlinear and multivalued.

e. They have a good retentivity, that is they retain magnetization when the magnetizing force is removed.

f. They tend to oppose a reversal of magnetization after once being magnetized.

The material that available, iron is the most extensive use. Its permeability is large and its cost per unit weight is the least of all the ferromagnetic materials available. In commercially its production is in pure form, it is used frequently in the structure of numerous machines and also as the base element for practically all of the ferromagnetic alloys. Probably the alloy produced in the largest quantity is that composed of essentially pure iron and between 1 and 4 per cent of silicon depending upon the purpose of which the material is required. When this alloy is given a particular heat treatment, a material is obtained which, compared with iron, has better magnetic properties at low value of magnetizing force and larger resistivity. Both of these properties are desirable. By experiment the silicon content increases the core loss decreases with-in the preceeding range. The production of this alloy is rolled into sheets and strip, principally its thickness is between 0.014 and 0.025 inch, and annealed. The sheet form is convenient for punching into many shapes used in the construction of electromagnetic apparatus.

From the stand point of low core loss, silicon sheet steel is the best material now available for the cores of alternating current, electromagnets, or for quick-acting electromagnets in general. High silicon steel (about 3.5 per cent silicon) is brittle, but suitable for the cores of static transformers. Low silicon steel (up to 1 per cent silicon) is the silicon steel commonly used.

The silicon sheet steels are produced in many grades which are known amoung steel manufactures and electrical designers by certain descriptive names.*

Field grade. Sheets contain about one-fourth of 1 per cent silicon and have a resistivity of about 16 microhm-centimeter. This grade is used for small low-priced motor.

Armature grade. Sheets contain about one half of 1 per cent silicon and have a resistivity of approximately 19 microhm-centimeters. This grade is relatively soft so that it is easy to punch to the desired form. It is used in small motor and generator field poles, armatures, and other devices in which high flux densities are required but core losses are not great importance.

*From "magnetic circuits and transformers" by EE.Staff M.I.T.

Electrical grade. Sheets contain about 1 per cent of silicon and the resistivity is about 26 microhm-centimeters, and widely used in comercial motors and generators of small and moderate size and medium efficiencies and in transformers, relays, and other devices designed for intermittent operation.

Motor grade. Sheets contain about 2.5 per cent of silicon and its resistivity is about 42 microhm-centimeters, and used in medium size motors and generators of good efficiencies, in control apparatus, and in inexpensive radio transformer.

Dynamo grade. Sheets contain approximately 3.5 per cent silicon and have a resistivity about 50 microhm-centimeters. This grade is used in high efficiency motors and generators small power distribution transformer and radio transformer.

Transformer grades. There are several transformer grades available, the pricipal ones being designated 72 (Radio C) 65 (Radio B), 58 (Radio A) and 52. The numbers are the core losses of 29-gauge sheets in hundredth of watts per pound at 60 cps. The silicon content increases as the losses decrease. These sheets onse used primarily for power and radio transformers and for large high-efficiency alternators, motor and synchronous condensers.