

Magnetic Materials and Their Properties

Iron, cobalt, nickel and their alloys have atomic spacings in various crystalline or amorphous structures which produce an interchange of some spins of their 3-D shell electrons, so that these spins align in domain patterns and cause a strong magnetism called ferromagnetism. The magnetic material properties like saturation flux density, the ease of magnetization, permeability, the core loss, the changes of these properties with temperature are therefore influenced by the atomic structure, the anisotropies of this structure, its impurity levels and the stress patterns in the material. Improvements in the magnetic properties of materials can be made by controlling the purity or adding certain impurities for grain refinement, by adding alloying elements to increase the resistivity, by influencing grain size and grain orientation, by reducing the thickness of materials and influencing domain wall spacing through stress coatings, laser scratching and crystal orientation.

Figure 2 shows the hysteresis loop of a few commercial grade magnetic materials, low carbon steel, grain oriented 3% Si-Fe and 2V cobalt iron, which in 1984 cost in dollar per pound .30, .75 and .35. The area inside the loop is the core loss per cycle at the measured frequency. For motor and low cost transformer laminations, which are not continuously on-line, the low carbon steel is a suitable material. Low carbon steel has, however, a relatively high core loss (wider loop). For continuous on-line transformers grain oriented steel, with its narrower loop and higher flux density, is the optimum choice and for airborne application, where weight reduction is the main consideration, the 2V cobalt iron is the proper material, since it has the highest saturation flux density. Figure 3 gives the magnetization curves for these and some other alloys. Table 1 lists W/lb., VA/lb. and permeability at 1.5 Tesla (15,000 Gauss) for typical commercial steels.

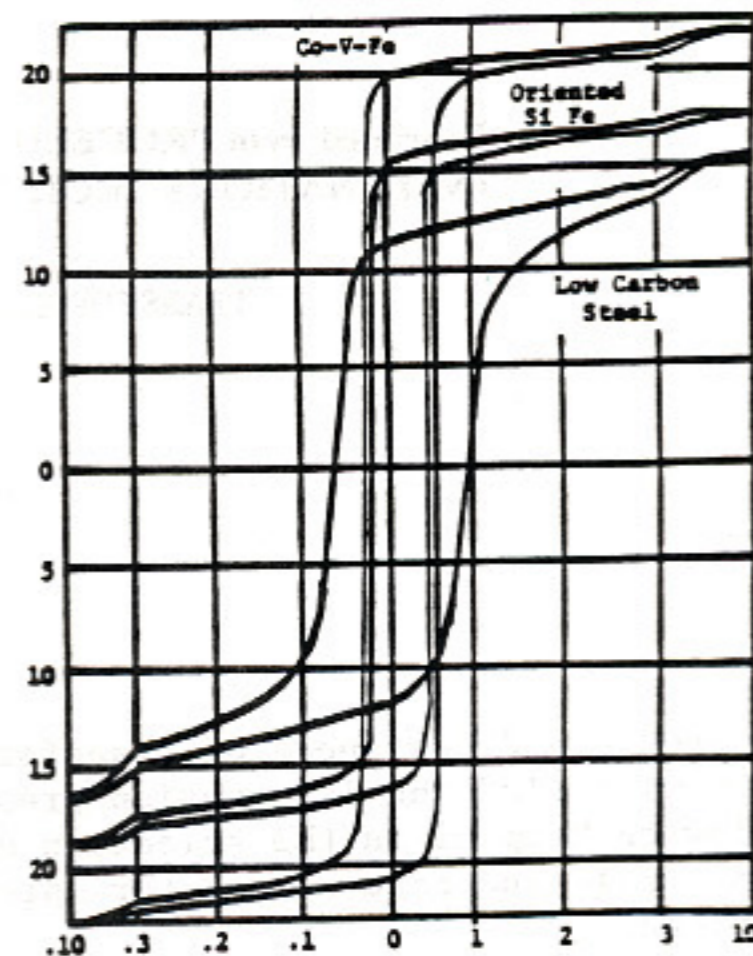


Fig. 2 Hysteresis loops of low carbon, 3% Si grain oriented and 2V cobalt iron steels.

We can expect further improvements of the various carbon and silicon steels in regard to core loss and permeability through improved melting techniques, improved processing and heat treatment. In addition, we can expect improvements in the cutting and stamping characteristics of such steels through better coating techniques and control of their mechanical properties like yield/tensile strength and elongation, which greatly influence the cutting and stamping.

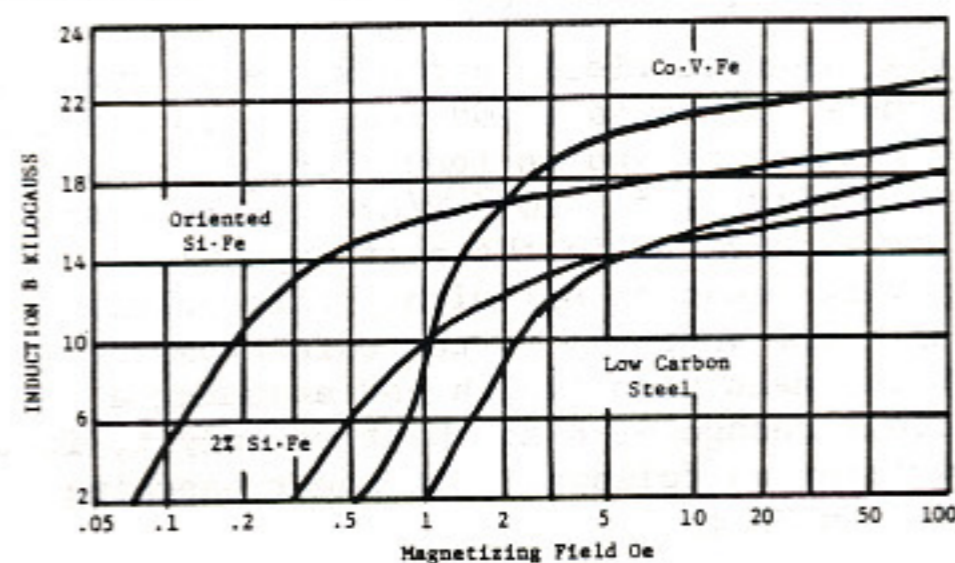


FIGURE 3 - Magnetization curves of cobalt-vanadium-iron, oriented, non-oriented silicon iron and low carbon steel.

Material	Thickness Inches	At 1.5 T, 60 Hz			At 1.0 T, 60 Hz	Comments
		W/#	VA/#	μ	μ	
L.C. Steel	.014, .018, .025	4	6	2,600	5,000	Low cost, moderate core loss
N.O. 5-1% Si Steel	.014, .018, .025	3	6	3,000	6,800	Low cost, improved core loss
N.O. 2-2.5% Si Steel	.014, .018, .025	2	7	2,000	8,000	Low core loss
G.O. 3.2% Si Steel	.014, .0185	.65	.80	30,000	35,900	Best buy for on-line trafo
G.O. 3.2% Si Steel	.008	.2	.60	40,000	42,000	Experimental

Table 1 W/#, VA/# and permeability of low carbon, non oriented and grain oriented Si-Fe steels. Data for underlined thickness.