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FYI

Demagnetization

by Roderic K. Stanley*

Magnetization is the orientation of crystal domains within magnetic materials, which themselves are always magnetized to magnetic saturation. Figure 1 shows a set of microscope photographs that show five domains in iron changing size as the applied magnetic field *H* is increased. Those with magnetization that is oriented in the direction of the external field will grow, while those with magnetization that is opposed to the external field will shrink. Thus the walls between the domains move (domain growth). As *H* increases to a point well up on the initial magnetization curve (curve plotted with magnetization *H* on horizontal axis and flux density *B* on the vertical axis when magnetizing a ferrous metal with zero residual magnetism — also known as *virgin curve*), those domains that are not oriented in the direction of the external field eventually rotate into the direction of the applied field (domain rotation). In Fig. 1, the domain that is shown to be vertical is seen to be getting smaller, and finally its direction will rotate. In the magnetization process, the domains, which are either crystallites that end at grain boundaries, or end at other discontinuities in the metal structure, are oriented by the externally applied magnetic field into the field direction, or grow at the expense of other domains. Thus toward saturation, the number of domains in a magnetized object also generally decrease as domain walls disappear. Demagnetization is the act of rescrambling these fully magnetized domains so that the net effect as viewed from outside the object is that there is no external field. But inside the material, these domains remain fully magnetized. Domain walls can actually be seen under the microscope using very fine magnetic particles, since they exhibit magnetic flux leakage (MFL).

* NDE Information Consultants; 5218 Sanford Road; Houston, TX 77035; (713) 728-3548; <rkstanley@ndeic.com>.

Some steels retain a large amount of magnetization, 1-1.5 T (10-15 kG), while others retain much less, 0.2-0.3 T (2-3 kG).[1] This is known as *remanence* (B_r), *retentivity*, or *residual magnetism*, and is a function of the chemistry of the steel, and its heat treatment and residual stresses. Checking ferromagnetic steel parts encountered in daily life with a tesla meter (gauss meter) will show that many of them are partially magnetized.

Reasons for Demagnetization

Demagnetization is often required by various manufacturing and inspection standards.[2] Demagnetization is discussed extensively in the *Nondestructive Testing Handbook* volume on magnetic testing.[3] Reasons for demagnetizing include (a) interference with subsequent machining operations, where magnetized chips may adhere to a cutter and scratch the cut surface, (b) interference with ionized plasma by deflecting it when welding, (c) interference with moving parts by having particles stick to materials, (d) difficulty in cleaning parts when magnetized particles are hard to remove from the corners of parts and thread roots, (e) effect during subsequent magnetization of parts, (f) small parts stick together when they go through wash cycle and (g) the potential effect on local instruments. Good examples of areas where demagnetization is needed include the ends of line pipe prior to welding, and threads on tubing after inspection by wet fluorescent magnetic particle inspection. However, there is often no need to demagnetize after performing magnetic testing if there is no effect on subsequent operations. Typically, plate in storage tank floors inspected by magnetic flux leakage is not demagnetized. In some cases, such as after inspecting oilfield tubulars by magnetic flux leakage, turning a longitudinal

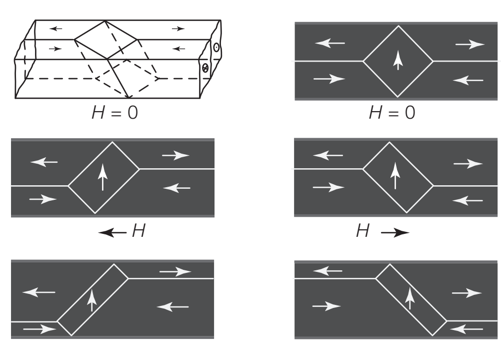

Figure 1. Domains in iron crystal changing as applied field strength *H* is increased. Vertical domain eventually disappears at higher applied field strength.

residual induction into a circular one by use of an internal conductor, so that there are very few poles outside the tube, is often considered sufficient.

Demagnetization Methods

Methods for demagnetization often depend on the size of the part, and in many cases, the part will not be fully demagnetized because it is virtually impossible to achieve this state. The only way to fully demagnetize is to heat the part above its curie point, which is about 770 °C (1420 °F) for steels, and allow it to cool with its major axis aligned east/west. Heating to lower temperatures will partially demagnetize the part. Elongated objects suspended roughly north/south will become partially magnetized in the earth's magnetic field, which may be about 0.02 mT (0.2 G). The amount of magnetism in the part will then depend upon the part's magnetic permeability. An early high school physics experiment is to place a demagnetized rod 2 mm (0.08 in.) in diameter in the earth's field and gently tap it with a mallet. Here sufficient energy is being added to the domain structure to assist in realigning or rotating them into the direction of the applied (earth's) field. The emerging magnetic field can then be measured with a hall effect tesla meter held at the ends of the rod. Demagnetization, or rescrambling of the domains, can then be achieved by placing the rod in a solenoidal coil excited by alternating current at 50-60 Hz and slowly withdrawing it to a point substantially away from the coil. In this process, the rod experiences a constantly reversing and decaying magnetic field as it emerges (Fig. 2).

Starting at B_r, the section is taken to saturation flux density ($-B_s$), then $+B_s$, and then to increasingly lower maximum values of B in time t until the value of B is very low. A problem here arises as the part gets thicker. From eddy current theory, the alternating current field penetrates roughly three "skin depths" (called *effective depth of penetration*) which for steel might be 1.5 to 3 mm (0.06 to 0.12 in.) for a standard power frequency of 50 or 60 Hz, so material deep inside the part will not experience any of the rapidly reversing alternating current field that causes domain scrambling.

Direct current methods, such as taking the part through a reversed field direct current coil, suffer from the problem that in many cases, where there is magnetism emerging from a part, (as can be seen by sprinkling the part with magnetic particles), poles have been created on the part. These poles create a demagnetization field within the part such that the magnetic flux inside the part is not constant. So the reverse field from the demagnetizing coil is encountering differing fields inside the part that are dependent upon the geometry of the part. One can adjust the field strength inside the demagnetization coil so as to obtain minimum externally measured field strength, but there then remains unknown (and geometry dependent) flux inside the part. The amount can be checked as shown later. Then, by any of several methods, some of this internal field can be made to reappear at the surface, where it can be measured. Typically, knocking or dropping the part may cause the inner magnetization to re-rotate the domains near to the surface and so create the effect of an external field.

Figure 3 shows the results of a test performed by the author on a 10 m (30 ft) length of steel pipe. In Fig. 3a, the longitudinal magnetization at the half way point is 1.14 T (11.4 kG), and at the two ends, where a meter

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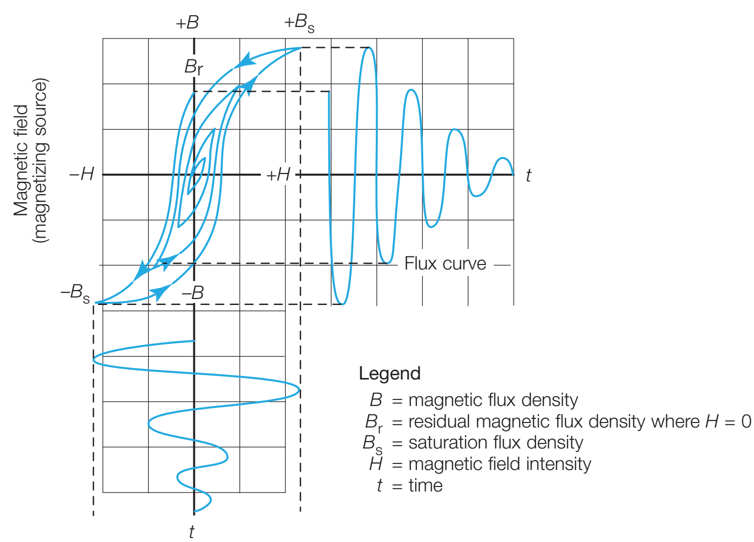

Figure 2. Changes in B and H with time (t) as part of material is taken through successive smaller swings in external field strength H.

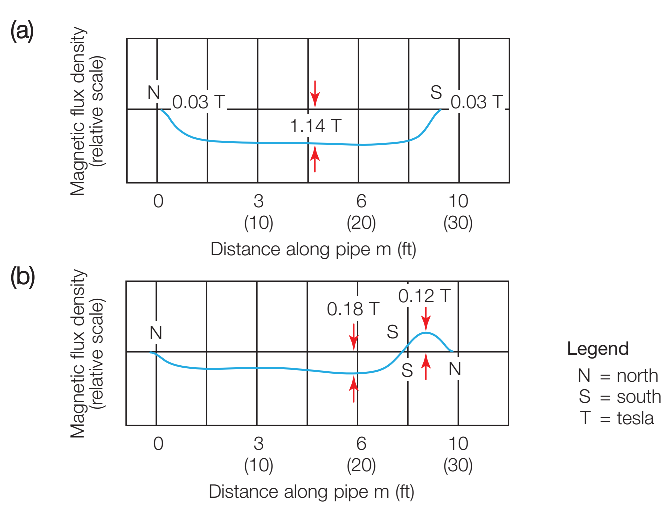

Figure 3. Measured longitudinal magnetic flux in 10 m (30 ft) pipe: (a) before and (b) after demagnetization with reversed field coil.

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would measure the external field strength, it is about 0.03 T (±300 G). Best attempts to demagnetize with a reverse direct current field (Fig. 3b) yielded a double dipole with maximum strengths 0.18 T (1.8 kG) and 0.12 T (1.2 kG).

In some cases, such as in tubular goods, it may only be necessary to remove a detrimental longitudinal field by rotating it into the circumferential direction. This involves placing an internal conductor through the material and firing one or more large current "shots" (central conductor technique). This is achieved using a direct current type of current source, such as a capacitor discharge unit. Of course, the part is now probably at B_r in the circular direction, and depending upon variations in the part's wall thickness, the magnetic flux external to the part will be small.

Checking Magnetization in Part

To check how well a part is demagnetized, it is passed through a sense coil (perhaps 100 to 500 turns) connected to a flux meter (Fig. 4).[4] Output of the flux meter versus length along the part shows the total magnetic flux (Φ) passing through the coil (Figs. 3 and 4). If the part is uniform, such as a rod or pipe, as shown in Fig. 4, $\Phi = \mathbf{B} \cdot \mathbf{A}$ where vector **B** is the flux density parallel to the coil axis, and vector **A** is the cross-sectional area of the part. Knowing **A**, then it is easy to deduce **B**. For full demagnetization, **B** should obviously be zero. However, as shown in Fig. 3b, if one tries to bring the external field down to zero, there will be some flux remaining in the part. Here, for this 10 m (30 ft) pipe sample, two dipole magnets N/S and S/N are formed by this particular reversed field demagnetization process. Figure 4 shows that by moving the part out of the coil, the flux through the coil has gone from Φ to zero, so we have a reference point for flux measurement.

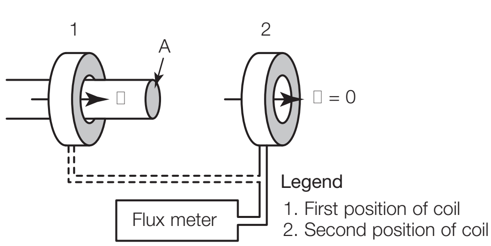

Figure 4. Measuring magnetic flux (Φ) with encircling coil.

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