

Magnetic Domains

Magnetic domains can be a difficult topic to understand, since magnetic domain structure takes place at a microscopic level, and is not common in everyday experience. While a thorough understanding of magnetic domains is not required to use and design with magnetic materials, some understanding of magnetic domains is useful for understanding the effects of different processes, alloying, and impurities in magnetic materials. This application notes provides a brief summary.

What Are Magnetic Domains?

Magnetic domains are regions in a magnetic material where the magnetization vector points in a single direction. The total magnetization of a material is the some total of the magnetic domain vectors. For a demagnetized material, the sum total of these vectors is zero. However, the material is full of regions magnetized in a single direction. The boundary between adjacent magnetic domains is a called a domain wall. As the material becomes magnetized, the domain walls move and the regions aligned with magnetic field grow larger, while others get smaller. In some instances, new domains are created or destroyed during a change in magnetization. It is also possible for the magnetization vector of a domain to rotate in the direction of the applied field. Domain wall motion and the magnetization process can in fact be rather complex. The domain wall motion is very crucial to determining the response of a material to applied magnetic fields, and thus, very crucial to determining its performance in an electromagnetic device.

Domain wall motion can be further illustrated by the figure below.

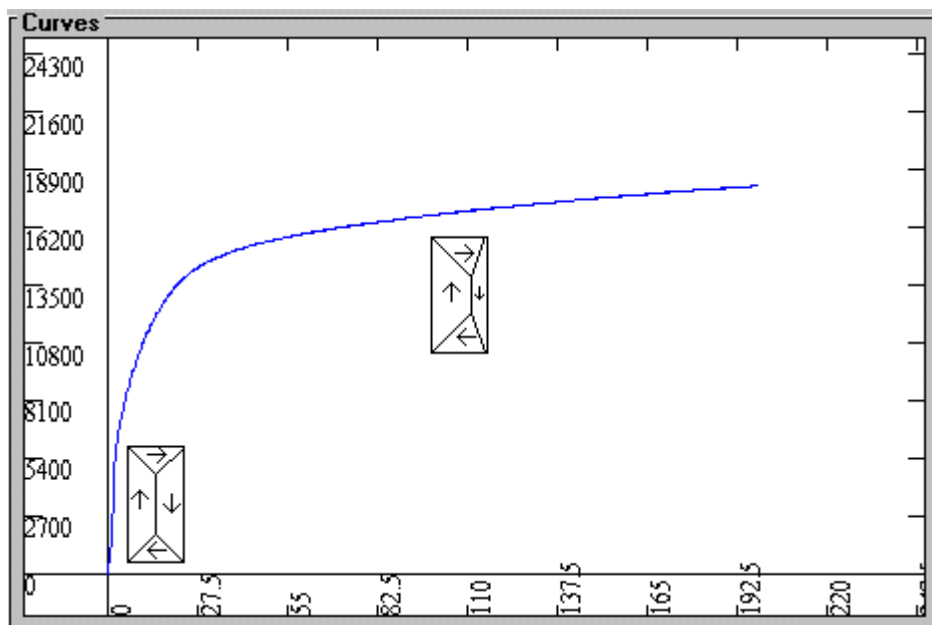


Figure 1: The initial BH-curve of 1010 steel with domain wall patterns reflective of the sample magnetization.

Figure 1 displays an initial BH-curve of 1010 steel. Near the origin where the sample is demagnetized, a domain pattern consistent with a demagnetized material is shown. The sum of the individual magnetic domain vectors is zero with this pattern. As the applied magnetic field is increased, the sample becomes magnetized and the domain walls move, with the magnetic domains changing sizes. As the domain walls shift, the net magnetization vector of all the domains is no longer zero and the material becomes

magnetized. When the magnetic field becomes strong enough, the material has a single domain, with that domain aligned with the magnetic field. When the material has a single domain aligned in the same direction as the magnetic field, the material is said to have reached magnetic saturation.

This domain wall motion and growth and decline of magnetic domains affect magnetic performance. For most soft magnetic materials, it is most desirable that the material be very responsive to magnetic fields. Therefore, anything impeding domain wall motion is undesirable, as it would limit the magnetic response of the material. For magnetically hard materials (permanent magnets), the goal is to remain magnetized even in the face of powerful magnetic fields, so domain walls resistant to motion are desired. Most manufacturing processes of both magnetically soft and hard include steps that either make the domain walls more mobile or more sluggish. While a comprehensive understanding of domain walls is not necessary to make effective use of these materials, it does give insights on how various manufacturing processes work, and how magnetic materials can be used more effectively.

Why Do Magnetic Domains Exist in the First Place?

If magnetic domains did not exist, even weakly magnetized materials would produce sizeable external magnetic fields. To produce magnetic fields requires energy, and materials, like many people, do not like exerting energy. To minimize the energy required to produce external magnetic fields, magnetic domains are created in the material, which greatly reduce the external magnetic fields, and the energy required to produce them.

Creating domains also requires energy, which limits the number of magnetic domains created. The domain structure of a material is an energy balance between the need to reduce the energy required to produce external magnetic field and the additional energy to produce magnetic domains.

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