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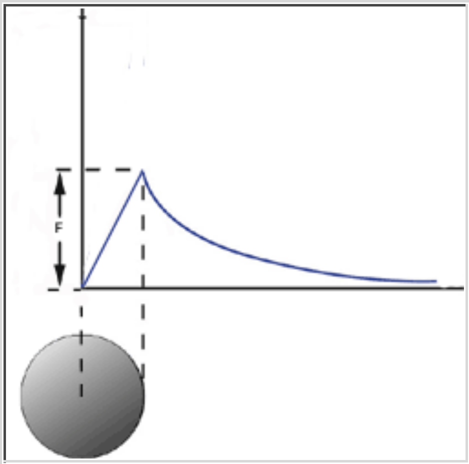
Circular Magnetic Fields
Distribution and Intensity

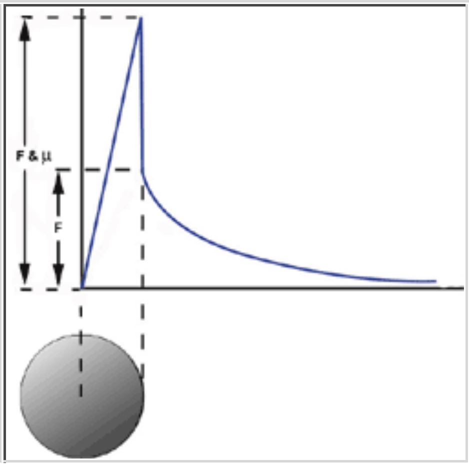
As discussed previously, when current is passed through a solid conductor, a magnetic field forms in and around the conductor. The following statements can be made about the distribution and intensity of the magnetic field.

- The field strength varies from zero at the center of the component to a maximum at the surface.
- The field strength at the surface of the conductor decreases as the radius of the conductor increases when the current strength is held constant. (However, a larger conductor is capable of carrying more current.)
- The field strength outside the conductor is directly proportional to the current strength. Inside the conductor, the field strength is dependent on the current strength, magnetic permeability of the material, and if magnetic, the location on the B-H curve.
- The field strength outside the conductor decreases with distance from the conductor.

In the images below, the magnetic field strength is graphed versus distance from the center of the conductor. It can be seen that in a nonmagnetic conductor carrying DC, the internal field strength rises from zero at the center to a maximum value at the surface of the conductor. The external field strength decrease with distance from the surface of the conductor. When the conductor is a magnetic material, the field strength within the conductor is much greater than it is in the nonmagnetic conductor. This is due to the permeability of the magnetic material. The external field is exactly the same for the two materials provided the current level and conductor radius are the same.

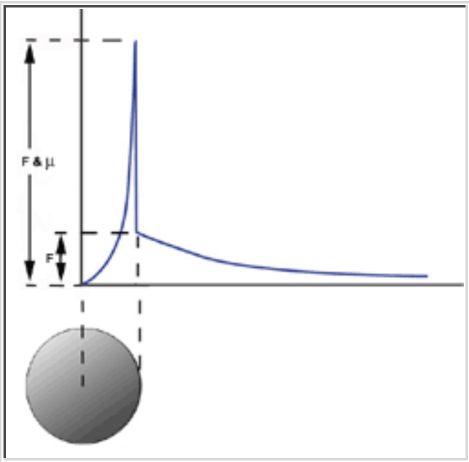


The magnetic field distribution in and around a solid conductor of a nonmagnetic material carrying direct current.



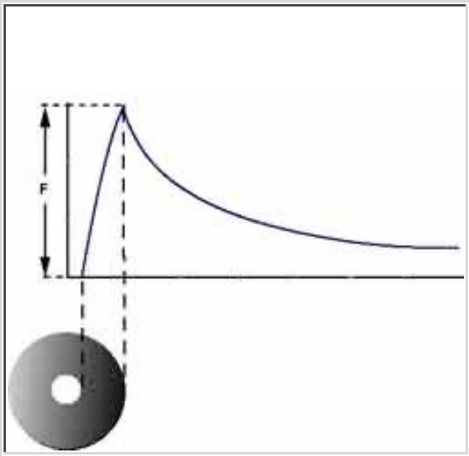
The magnetic field distribution in and around a solid conductor of a magnetic material carrying direct current.

When the conductor is carrying alternating current, the internal magnetic field strength rises from zero at the center to a maximum at the surface. However, the field is concentrated in a thin layer near the surface of the conductor. This is known as the "skin effect." The skin effect is evident in the field strength versus distance graph for a magnetic conductor shown to the right. The external field decreases with increasing distance from the surface as it does with DC. It should be remembered that with AC the field is constantly varying in strength and direction.

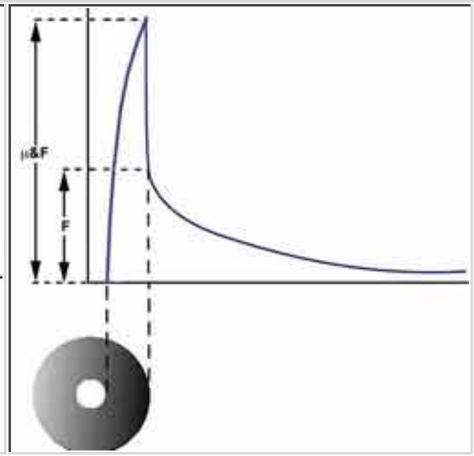


The magnetic field distribution in and around a solid conductor of a magnetic material carrying alternating current.

In a hollow circular conductor there is no magnetic field in the void area. The magnetic field is zero at the inside wall surface and rises until it reaches a maximum at the outside wall surface. As with a solid conductor, when the conductor is a magnetic material, the field strength within the conductor is much greater than it was in the nonmagnetic conductor due to the permeability of the magnetic material. The external field strength decreases with distance from the surface of the conductor. The external field is exactly the same for the two materials provided the current level and conductor radius are the same.

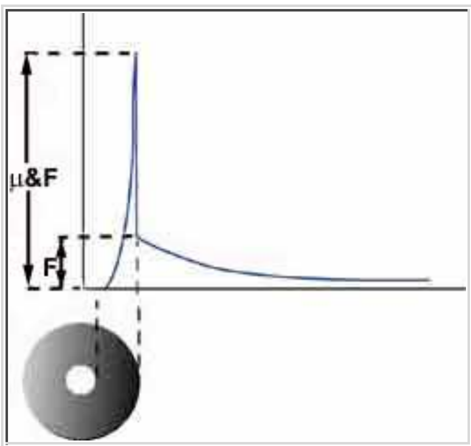


The magnetic field distribution in and around a hollow conductor of a nonmagnetic material carrying direct current.



The magnetic field distribution in and around a hollow conductor of a magnetic material carrying direct current.

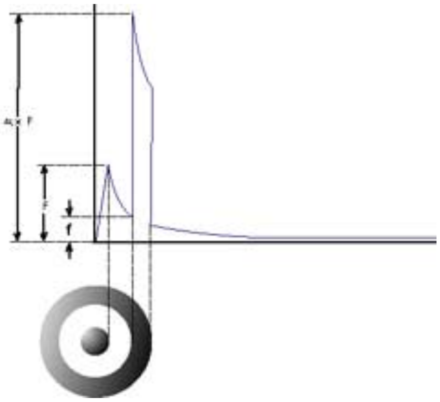
When AC is passed through a hollow circular conductor, the skin effect concentrates the magnetic field at the outside diameter of the component.



The magnetic field distribution in and around a hollow conductor of a magnetic material carrying alternating current.

As can be learned from these three field distribution images, the field strength at the inside surface of hollow conductor is very low when a circular magnetic field was established by direct magnetization. Therefore, the direct method of magnetization is not recommended when inspecting the inside diameter wall of a hollow component for shallow defects. The field strength increases rapidly as one moves out (into the material) from the ID, so if the defect has significant depth, it may be detectable.

However, a much better method of magnetizing hollow components for inspection of the ID and OD surfaces is with the use of a central conductor. As can be seen in the field distribution image to the right, when current is passed through a nonmagnetic central conductor (copper bar), the magnetic field produced on the inside diameter surface of a magnetic tube is much greater and the field is still strong enough for defect detection on the OD surface.



The magnetic field distribution in and around a nonmagnetic central conductor carrying DC inside a hollow conductor of a magnetic material .

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