GAUSSMETER APPLICATIONS

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Abstract: The purpose of this paper is to discuss the method of measuring magnets, explicitly the Hall-effect Gaussmeter and the applications of this equipment. To ensure proper use of this magnetic measuring equipment, the engineer needs to understand the correct methods of applying the equipment.

I. INTRODUCTION

A Gaussmeter is an instrument that conditions and amplifies a Hall sensor output and provides its user with calibrated flux-density information. Benchtop versions come with IEEE-488 and RS-232 for interfacing with computer hardware. They also come with either analog or digital displays and can cover AC fields with frequencies up to 50kHz. The display can be seen in Gauss, Tesla or Amperes/meter. There are also units that display 2 or 3 axis simultaneously or a vector summation mode. Handheld units also cover a wide spectrum. With accuracies including probe to be less than 1%. These units also have a corrected analog output and an RS-232 interface that allows it to communicate to a PLC in a production environment

II. DISCUSSION

A. The Hall-effect Gaussmeter

A Hall-effect gaussmeter measuring system consists of two main components, a Hall probe and a gaussmeter. The gaussmeter is the stable source of the driving current and an adequate voltage indicator to detect the change in the Hall voltage. The probe is the external apparatus that contains the Hall generator. Each of these components has its own accuracy. When looking at the total accuracy of your system you must take in to consideration both of these components. Modern gaussmeters now can have an accuracy as low as 0.075%. Hall probes can have accuracies that range from 0.15% to 2%.

B. Hall Probes

The working part of the Hall probe is a semiconductor device called a Hall generator. Some of the semi-conductor materials used for Hall generators are indium antimonide (InSb), indium arsenide (InAs) and gallium arsenide (GaAs). Hall generators are rectangular in shape with the four leads connected to the outside edges. The leads attached on the longer edges and on opposite sides are connected to carry the output Hall voltage to the Gaussmeter while the other leads provide the current source through the Hall generator.

Because of the geometry of the Hall generator and the lack of the electron mobility along the fringes of this rectangle, the actual measuring region ("active area") of the hall generator is considered to be the size of the largest circle that can fit into the rectangle. For example a typical hall generator of 0.030" x 0.060" is said to have an active area of 0.030'diam. This active area is important because as a rule of thumb you want to have an active area that is approximately three times less than the area you want to measure. The overall construction of a magnet greatly effects the uniformity and shape of its magnetic field. Flux density can vary greatly across the surface of the magnet, which the Hall generator will detect. If the size of the active area were larger there would be less sensitivity or variations in flux density. If the Hall generator was larger than the magnet itself there would be even less.

This active area of the Hall generator measures the amount of flux lines passing through it. The Gaussmeter conditions this signal and provides its user with the calibrated flux density information, in Gauss. One Gauss equals one Maxwell per square centimeter. However, the Hall generator only gathers the magnetic induction that is at right angles to the active area. The more general equation for Hall voltage is $V_h=\gamma IB\cos\theta$, where θ is the angle between B and the normal to the Hall generator surface. An angle of 8° can bring an error of close to 1%. Maximum output is realized when the flux lines are perpendicular to the surface.

Flux lines emulating from one pole of a magnet must eventually return to the other side. The flux lines leave and enter the magnet at right angles. As the lift off distance from the magnet increases the flux density through the hall generator decreases along with angle of flux penetration approaches zero degrees. Doing a simple lift off test, with an exposed hall generator and a 9200 Gaussmeter you can see the how the Gaussmeter reading has varied by 20% at a distance of 0.025" from the surface of the magnet. Thus when measuring a group of magnets for quality control it is important to control the distance and the angle between the Hall generator in order to obtain consistent results. That is why building a proper fixture is important.

The Hall probes can come in a wide variety of sizes and shapes. For numerous applications, the Gaussmeter manufacturers are building special probes. Probes are built that can detect transverse, axial, high sensitivity, cryogenic, 2-axis and 3-axis fields. The transverse probes can have a thickness ranging from 0.010" to 0.060".

The thinnest probe is basically an exposed Hall generator while the thicker probes are protected with either a rigid plastic or aluminum housing. These probes are the most widely used. Their applications range from motor manufacturers checking for leakage flux, to speaker manufacturers measuring the magnetic flux in the gap.

Axial probes are normally used when the engineer wants to measure the magnetic field in cylindrical coil. Axial probes have diameters that range from 0.060" to 0.50". The stem length on all Hall probes varies depending on the customers' needs. Depending on the Gaussmeter used, an axial probe can be used to measure the magnetizing field generated by magnetizing fixture.

There are special applications where a cryogenic probe is needed. These probes can come in transverse or axial orientations. They can measure fields up to 100kG, with temperature extremes from -269°C to 75°C.

Special "high sensitivity" probes are called magnaprobes. These probes consist of two soft iron cores on either side of a hall generator. The soft iron acts as a collector and flux concentrator to direct the low magnetic fields through a Hall generator located between the two iron cores. This increases the sensitivity such that this probe can measure fields that are 100 times lower than the normal fields. The magnaprobe is very useful when detecting small changes from a magnetized package being shipped on an airplane. Because of FAA and IATA regulations you are not allowed to ship a package if it can create a field higher than 0.0005G at a distance of 15 feet away.

Two axis and three axis probes are similar to transverse and axial probes except they are mounted on a block. The active areas of each Hall generator obviously do not lie in the same plane. However, these probes are very closely located and provide the engineer with some very useful information on the x, y and z-axis simultaneously. Some of the latest versions of the 3axis probes have orthogonality between the three planes of less than 0.2 degrees.

There are now probes available that have a temperature monitor installed in the Hall sensor area. This is very big advantage to the engineer to see the gauss reading on the display as well as the temperature because the temperature has a big effect on the Hall generator. If the probe is not temperature compensated, there could be a severe offset when the unit is used above or below the temperature at which it was calibrated.

Hall probes do have a lot of standard configurations by most manufacturers. However all manufacturers can basically make the Hall probe to the customer needs. The working part of the Hall probe called the Hall generator can come in different variations. Some have linearity errors of less than 0.15% to 30kG. Other Hall generators have excellent temperature stability, (±0.0005%/°C)

III. CALIBRATION EQUIPMENT

Many devices are used to verify the calibration of magnetic measuring instruments. Hall-effect gaussmeters are checked using permanent reference magnets, solenoids and Helmholtz coils. These devices are also used to calibrate electronic integration fluxmeters.

A. Helmholtz Coils

The Helmholtz Coil assembly, named for the German physicist who developed it, has been a standard for low-level magnetic field measurements for over a century. It consists of two thin, round coils of square cross-section spaced apart from each other by one coil mean radius. The axes of the coil must be common.
It is imperative that both coils have the same number of turns and they must be connected in series

With a Helmholtz coil you can have access from more than one direction. Once a precise drive current is applied to the Helmholtz coils, the geometry of this apparatus creates a generated field that can be accurately defined from precise physical measurements. The generated magnetic field is homogenous in the central 30% of the volume between the coils. The formula for the field developed by the Helmholtz coil is

$$H = 0.8991(N)(I)/a \qquad (1)$$

Each coil has a square cross section, and should be as small as possible in relation to the overall size of the structure and field, which must be developed. In general, Helmholtz coils can generate magnetic fields from a few gamma up to 30 oersteds, depending on the size of the coils, the dimensions of the structure and the applied current. Either direct or alternating current may drive the coils.

B. Solenoidal Coils

Solenoidal coils have been used as magnetic reference standards for many years. They are easier to fabricate than a Helmholtz coil, but do not have the ease of access of the Helmholtz structure. However, the solenoid will generate a higher magnetic field for a given current. The solenoid should be made as long as possible in order to obtain a relatively large area of magnetic homogeneity.

In general, the field developed will be homogenous for about one third of the solenoid's length, with the homogenous area located at the center of the coil. In a radial direction from the coil's center axis, the homogeneity will be effective for about one-half of the solenoid diameter.

Prior to winding the solenoidal coil, a slot can be cut at the center of the tube to allow for transverse Hall probe measurements as well as axial probes. One should be careful of the angle between the generated magnetic field of the coil and the sensor being measured. Any deviation will bear an error in a direct relation to the cosine of the angle between the two axes. Make sure to place all measuring coils sufficiently away from any large ferrous objects, such as desks and filing cabinets. Also, be sure the test area is at least five feet away from motors, transformers, and other electrical devices.

C. Reference Magnets

Reference magnets are available for transverse as well as axial fields. Manufacturers have some standard values of gauss levels ranging from 100 Gauss to 20,000 Gauss. However, they can for an additional cost construct reference magnets to a certain value. This could be effective for a user who only measures a certain magnet assembly at the same value. For example, a speaker manufacturer always wants his speaker magnets to come in at 2kG ± 25G. He could then get a reference magnet at 2kG and check his gaussmeter accuracy at the range he works in constantly.

Reference magnets are usually made from AlNiCo magnets because of their long-term stability. There is a high-permeability shell, which surrounds the reference magnet. This shell serves two functions; it shields the reference magnet from external fields and also serves as the return flux path. Physical damage to the outer shell can cause a permanent change in the gap flux density. Reference magnets must avoid all the situations that can cause a magnet to de-magnetize. Vibrations or quick shock, such as dropping the magnet, will cause its value to change. Large opposing magnetic fields can cause the magnet to change its value.

Temperature can affect the reference magnet, however, only if it goes above the Curie point. Reference magnets are usually stabilized for use at ambient temperatures between 0°C and 50°C and have nominal temperature coefficients of about –0.02%/°C.
Since these reference magnets are temperatures cycled during manufacture, their change with temperature is predictable and retraceable; they will always return to a known value at any specific temperature.

D. Magnet Testing and Sorting

Gaussmeters are commonly used to test and sort magnets in quality control and manufacturing applications. The speed of these operations may be increased markedly by supplementing the meter with an audio alarm or a simple yes-no indicator.

This can be achieved by connecting a set point control relay to the gaussmeter analog output, 0 to 1 V dc. Connect the audio or visual alarm to the relay output, (bell, buzzer, etc.) Adjust the system with a test magnetic field. Observe the gaussmeter reading and adjust the relay to actuate at the desired field level.

D. FAA regulations on shipping Magnets

FAA regulation #173.1020 specifies that no package can be shipped via airfreight if it has a stray magnetic field greater than 0.00525G when measured from any surface of the package at a distance of 15 feet. This regulation further stipulates that any package with a magnetic field strength of 0.002 gauss or greater at a distance of 7 feet be classified as magnetized material and be labeled as such. The highly sensitive MOW64-2506 magnaprobe, which has a sensitivity of 0.01x, effectively magnifies the measured magnetic field by a factor of 100.

The shipper can test his packaging for stray magnetic fields by using the following procedure. Connect the MOW4-2506 probe to the 9550 Gaussmeter and zero the probe in the ambient magnetic field of the room. All other items in the area must be fixed and not moved during both the zeroing and measuring procedures. Keep in mind the magnetic fields to be measured are extremely small Stray magnetic fields which can be ignored under other circumstances may interfere with the accuracy of these measurements. Any items made of ferrous material such as metal tables; cabinets, etc. are potential sources of such a stray magnetic field.

The 0.002 gauss FAA specification can now be checked with the magnaprobe and gaussmeter. Bring the package into the test area. A thorough measurement is achieved by rotating the package at the appropriate distance and monitoring the gaussmeter for the peak reading.

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IV. CONCLUSION

When choosing a method to measures your magnets make sure you understand the limitations of each of the processes. The most important thing is for the magnetic assembly to work in the final application. Therefore the process must have reliability and repeatability.