Quantum Design

Application Note 1500-010

Accuracy of the reported moment: axial and radial sample positioning error

This document addresses an important aspect of SQUID VSM sample measurements, namely the effects of sample location on the accuracy of the magnetic moment. Ideally a sample should be mounted so that it vibrates in the center of the gradiometer, axially as well as radially. Quantum Design took great care in designing the instrument to allow concentric sample location. However, in practice it is very challenging to mount the sample in the ideal position. We will explore the effects of axial and radial sample positioning errors with respect to the gradiometer center.

Axial positioning error:

The graph below shows the error in the reported measurement of a palladium reference sample as a function of axial shift for 2 mm vibration amplitude. This demonstrates how critical it is to reliably locate the sample. As a general note, we recommend keeping the sample length less than 5 mm to maintain the accuracy of the point source dipole approximation used for calculating the moment from the 2f lock-in signal (see manual Figure 4-3 in Section 4.2.4.1). Furthermore, the size of the error for a given axial shift is smaller for larger vibration amplitudes. Thus larger amplitudes yield better accuracy regarding sample positioning error. However, it should be pointed out that other factors should also be considered when choosing the vibration amplitude, as pointed out in Application Note 1500-011.

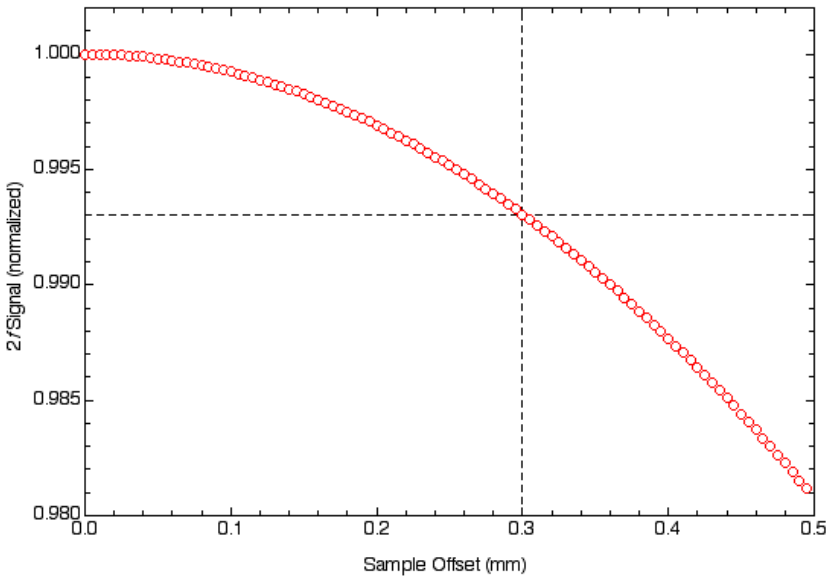

Fig. 1 Impact of axial shift on reported moment (2 mm vibration amplitude).

Using the locate scan

For samples having a magnetic signal, which is greater than $1x10^{-4}$ emu and produces a clean and symmetric centering scan, the position determined by the scan is typically precise to 0.04 mm. When the signal is weaker or produces an asymmetric scan, the curve fit's determination of the sample may be unreliable. In this case we recommend to perform repeated centering scans to verify the reproducibility and also to verify that the curve fit matches the real sample response.

Using the sample mounting station

Samples which have a weak magnetic signal at room temperature cannot be centered using the standard room temperature locate scan. In such situations, the sample mounting station provided with the SQUID VSM user kit allows to visually locate the sample and to enter the sample offset manually into the locate scan dialog. This procedure is accurate within about 0.5mm. An alternative way for achieving higher accuracy is to drive the sample to a temperature where it shows a strong enough magnetic signal to use the locate scan function. Enabling autotracking and selecting the proper sample holder will keep the sample centered at any other temperature within typically less than 0.1mm.

General practice

We recommend to always use the sample mounting station to install samples, even when a sample centering scan can be performed. It is also important to mount the sample as close as

possible to the longitudinal axis of the sample holder. The offset determined from the scan should be compared to the expected value based on the reading from the mounting station. This practice is to verify that the center position is based on the actual sample and not an impurity or end effect that might be present due to the sample holders.

Radial positioning error:

Figure 2 shows the normalized moment calculated for a point source dipole as a function of radial shift for 2 mm vibration amplitude. This result illustrates how important it is to radially locate the sample as close to the gradiometer axis as possible. As with axial shifts, the size of the moment errors due to radial shifts is smaller for larger vibration amplitudes.

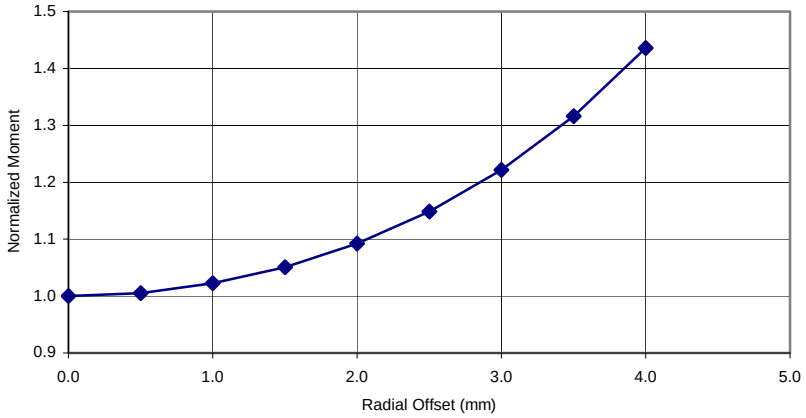

Fig. 2 Impact of radial shift on reported moment (2 mm vibration amplitude). ($R_{sample\ chamber}$ = 4.5 mm).

The magnitude of the moment will be overestimated as shown in the Figure 2. In practice, it is found that the moment depends on the orientation of the sample rod in the magnetic lock of the motor. Rotating the sample rod around the vibration axis will result in a moment reading with nominally periodic dependence on rotation angles. This occurs because: 1) the sample rod and holder are not perfectly straight and 2) the sample holder precesses about an axis that is not coaxial with the detection coils when the sample rod is rotated. To minimize this rotational dependence effect, we recommend locating the sample on the vertical axis of the gradiometer. This is best achieved by placing a thin sample on the face of the quartz paddle sample holder. Bulk samples should be placed in the middle of the brass sample holder tube. However, note that extensive usage of the brass sample holders can lead to a progressive degradation of the straightness of the holder itself. We recommend caution and periodic inspection of the holders as well as the sample rods.

As with any moment accuracy issue, the best way to verify the calibration is to produce a sample out of a standard material (such as pure nickel) in the same geometry as your research sample and measure it under identical sample mounting conditions. This will account for centering

issues discussed in this application notes, but also for sample shape and vibration amplitude dependence effects which are covered in other application notes.

The following reference examines sample size, position, and structure effects on magnetization measurements using a second-order gradiometer pickup coil. Although it is not based on the 2f detection technique used in the SQUID VSM, this paper and references therein are useful resources. The paper also investigates the effects of sample geometry which apply to any magnetic moment measurement system.

Contact apps@qdusa.com for any further questions.

REFERENCE:

P. Stamenov and J. M. D. Coey, Rev. Sci. Instrum. **77**, 015106 (2006).