ABSTRACT. The application of magnetic susceptibility measurements to the study of time-dependent phenomena is reviewed. In particular, the measurements of the A.C. susceptibility, \( \chi(a.c.) = \frac{dM}{dH}(H \rightarrow 0) \) represents a powerful technique for dynamic studies. It gives a measure of the susceptibility at a given observation time \( t_m = \frac{1}{\omega} \), \( \omega \) being the angular frequency of the external oscillating magnetic field. The attention is focused on the study of magnetic relaxation in fine particles and spin-glass systems. Their main dynamic properties, are reviewed: the time dependence of the susceptibility, the time decay of the remanent magnetization and the frequency dependence of the blocking and freezing temperature.

1. INTRODUCTION

Susceptibility measurements are among the principal measurements carried out on magnetic systems to study their static and dynamic properties.

If a material containing magnetic ions is placed in a magnetic field \( H \), it acquires an induced magnetization \( M \) which is proportional to \( H \):

\[ M = \chi H \]  

(1.1)

The proportionality constant \( \chi \) is the susceptibility, which is a quantitative measure of the response of a material to an applied
Fig. 1 Definition of the susceptibility \( \chi = M/H \) and of the initial susceptibility \( \chi(i) = (dM/dH)(H \to 0) \)

magnetic field. \( \chi = M/H \) is usually called static susceptibility (d.c.) as it is measured in a static external magnetic field. For magnetically isotropic samples, where the \( H \) and \( M \) vectors are collinear, the susceptibility is a scalar quantity. For anisotropic materials \( \chi \) is a symmetric tensor. \( \chi \) is dimensionless, but is expressed as emu/cm\(^3\).

In some cases, when \( M \) varies linearly with the field (e.g. for paramagnets if \( H/T \ll 1 \)), \( \chi \) is field independent. In general \( \chi \) is a function of \( H \): \( \chi = f(H) \) (Fig. 1). Therefore the ordinary susceptibility \( M/H \) may be different from the initial susceptibility defined as:

\[
(1.2) \quad \chi_o(d.c.) = (M/H)(H \to 0) \quad \text{static initial susceptibility}
\]

\[
(1.3) \quad \chi(a.c.) = (dM/dH)(H \to 0) \quad \text{dynamic initial susceptibility}
\]

\( \chi(a.c.) \), called the dynamic or differential susceptibility, is measured by means of applying a very small oscillating magnetic field \( H(t) = h \cos \omega t \) which can also be written \( H(t) = \text{Re}[h \exp(i \omega t)] \) \( (\omega = 2\pi \nu \) is the angular frequency of the a.c. field). The magnetic field induces a magnetization varying in the time \( M(t) = m(\omega) \exp(i \omega t) \). The corresponding susceptibility is a complex quantity:

\[
(1.4) \quad \chi(a.c.) = \chi'(\omega) - i \chi''(\omega)
\]

The real part \( \chi' \) is called the dispersion, and \( \chi'' \) the absorption.

In the presence of magnetic relaxation the system can not be able to follow the changes of the external field immediately. In this case \( \chi(a.c.)(\omega) \) is different from the initial static susceptibility (d.c). The frequency dependence of \( \chi(a.c.) \) will depend on the value of the frequency \( \omega \) of the oscillating field with respect to the