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Eddy currents in the anisotropy of out-of-phase magnetic susceptibility measurement - A model study

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Analytical solutions of Maxwell equations for eddy currents caused by AC field in a conductive sphere, known from 1950s, provide a general formula for magnetic susceptibility. It contains the parameters describing the sphere (its size, conductivity and permeability), surrounding medium (permeability) and the applied field (frequency). The formula is complex and without numerical evaluation it is difficult to distinguish the real (in-phase) and imaginary (out-of-phase) part of susceptibility. Representing all the parameters by only two, relative permeability (sphere vs. medium) and skin ratio (summarizing the effect of sphere size, conductivity and permeability, and frequency of the field), we derive approximate formulas for both phases and the phase angle. These are valid for a reasonable range of parameters (from rock magnetism point of view) and enable us to study their influence. The in-phase susceptibility depends very weakly on the fourth power of the skin ratio while the out-of-phase susceptibility depends more strongly on its second power. The coefficients of the dependence are expressed by means of relative permeability. The approximations of in-phase and out-of-phase susceptibilities provide a possibility to assess possible effects of eddy currents in rocks in case of low content of conductive minerals and solve problems of the type by which size one piece of a mineral in the measured sample can produce a phase shift that is observed by measurement. Examples of magnetite and pyrrhotite are given.