The Invariant Strain Scaling Function for the Strain Dependence of Composite Nb_3Sn Superconductors

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Introduction

It has long been known that the critical properties of Nb_3Sn are sensitive to strain in a very generally way, with dependence on hydrostatic strain and on deformation strain induced in a variety of forms. The strain dependence data for the effective upper critical field is often presented in normalized form, being normalized by the maximum value obtained in a uniaxial tensile test. This normalized strain dependence is here called the strain function. The general invariant analysis gives a physical explanation for the origin of the strain dependence of Nb_3Sn, and suggests a form of invariant strain function. In order to compare the invariant strain function with measured strain dependence, the invariant strain function is compared to empirical strain functions that have been used to fit the experimental data.

Discussion

The physical basis for the strain dependence of Nb_3Sn was treated in the general invariant strain analysis [1]. The critical superconducting properties of Nb_3Sn are related to the phonon frequency spectrum in the Nb_3Sn crystal lattice. The phonon frequency spectrum is in turn reflected in the electron-phonon spectral function, and further in the critical superconducting properties. With the assumption of a strain energy density, the elastic stiffness of the Nb_3Sn crystal lattice is changed by the application of strain, and with it the phonon frequency spectrum is changed in characteristic patterns. The corresponding changes in the critical superconducting properties are observed to have characteristics seen in the measured strain dependence. The form of the invariant analysis suggested an analytic form of strain function called the invariant strain function. From the origin of the invariant strain function, it is expected to provide a unified analytical form to fit the various measurements of strain dependence. In order to test this expectation, the invariant strain function has been compared to a wide range of data, indirectly, by comparison with the various empirical strain functions used previously to correlate that data [2,3]. A comparison was made between the invariant strain function and the power law, the polynomial form, the deviatoric description, and the deviatoric power law. The combined data for longitudinal strain on both wire and tape is shown to be fit well by the invariant strain function [4]. None of the strain functions so far has provided a satisfactory explanation of transverse strain properties. Such an explanation may require a more detailed mechanical analysis of the composite conductor under the application of the transverse mechanical load.

References

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