BOOK REVIEW

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THERMAL CONDUCTIVITIES OF MIXTURES AND COMPOSITES*

Reviewed by A. G. Shashkov

The requirements of science and engineering can often be met only by composite materials, especially ones with preset physical properties. These materials may differ in structure (solid, granular, fibrous, liquid, gaseous, etc.). The creation of such material requires a theory that enables one to employ the physical and, particularly, thermal properties of individual components to calculate the thermophysical characteristics of the composite. A model for the material is necessary together with the basic laws of heat propagation.

This book deals with topics of this type.

The first chapter familiarizes the reader with the classification of structures and models for composites and gives relationships that allow one to calculate the effective thermal conductivity for a variety of structures and models. The second chapter deals with the effects of radiation, absorption, scattering, temperature steps, and accommodation as regards thermal conduction in porous heterogeneous media.

The third chapter gives a critical analysis of various models for granular systems, and a new model is presented for a granular material that allows one to calculate the effective thermal conductivity from the known porosity, the thermal conductivities of the components, the thermal conductivity of the material filling the pores, and the contacts in the framework.

Suitable assumptions are made regarding the model for a granular system with a random structure to derive relationships for calculating the effective thermal conductivity.

At the end of the chapter, recommendations are made on calculating the thermal conductivity of granular systems, and references are given to literature sources for the available data, with recommendations on the choice of a standard material; errors in the calculation of effective thermal conductivity are discussed, together with the effect of various factors on the effective thermal conductivity in a granular system.

The fourth chapter gives a theory of the effective thermal conductivity of a solid formed by sintering, and also of materials formed by partial melting and subsequent solidification. Relationships given in the previous chapter for granular systems are used with equations for the strain in particles in pressing and sintering to derive a formula for the effective thermal conductivity. Calculations made in this way are compared with the experiment for a large class of materials varying widely in porosity, density, and structure for a wide range of temperatures; characteristics are also given for many composites with various technical uses.

The fifth chapter deals with fibrous materials, and it is pointed out that these are used particularly in insulation. Standard relationships given in textbooks for the effective thermal conductivity of a fibrous material are accompanied by formulas for the purpose for various models of random fibrous structures. The effects of density and porosity are

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considered, together with the geometry and physical properties of the fibers, as well as the temperature and water content.

The sixth chapter deals with the properties of alloys. The thermal conductivity of an alloy may vary very widely, and alloys are of primary importance in many branches of engineering, which demonstrates the importance and value of a theory that provides detailed values for properties such as thermal conductivity and electrical conductivity, since at present there is no reliable analytical method of calculating these quantities from the values for the components. A formula is given for the effective thermal conductivity of a structure with interpenetrating components, which has been found satisfactory for practical design calculations. This formula gives results in agreement with experiment to within 10-15%.

The relation between the corpuscular theory and the continuum theory is discussed, which provides a means of calculating the effective thermal conductivity and electrical conductivity for various important continuous solid solutions in relation to temperature and concentration.

Similarly, the seventh chapter deals with the effective thermal conductivity of liquid solutions, binary melts of metals and salts, and liquefied gases.

In the case of a multicomponent liquid solution, the effective thermal conductivity is calculated by stepwise derivation from two-component systems. The effective thermal conductivities of electrolytes may be calculated from a formula that is similar to the formula for an ordered model with mutually interpenetrating components.

It is shown that the structure of a gas mixture may be represented as an isotropic random system with interpenetrating components. In the eighth chapter, it is suggested that the theory should be used to calculate the effective thermal conductivity of a gas mixture. Calculated values are compared with measured ones, the discrepancy being not more than 3% for mixtures of nonpolar gases.

This book is essentially the only universal textbook on analytical methods of calculating effective thermal conductivities for engineering purposes for a wider range of composites.

In most cases, the discrepancy between theory and experiment for the effective thermal conductivity does not exceed the error of experiment.

The book also contains a large volume of reference material on thermal conductivity and electrical conductivity for complex systems. Another good feature of the book is that examples are given of calculations on effective thermal conductivity for mixtures for a variety of composites in each chapter.

The book is to be recommended to scientific workers and engineering designers concerned with the thermophysical properties of materials.