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book reviews

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Orientations and rotations: computations in crystallographic textures. By Adam Morawiec. Pp. x + 200. Berlin: Springer-Verlag, 2004. Price hardback EURO 59.59. ISBN 3-540-40734-0.

The quantitative characterization and interpretation of crystallographic textures is the main object of a field in materials science known as texture analysis (TA), dealing with metals, rocks and other geological materials, ceramics or polymers.

After rotating a rigid body around the origin of a three-dimensional coordinate system, the axes in the final position of the body will commonly not be parallel to their position at the beginning. Therefore, after rotation the body has a certain orientation '*g*' relative to the starting situation. Since, after special rotations, the final position may be identical to the starting one, it is intuitively understandable that mathematically the 'space of all orientations' (*G*-, orientation- or rotation-space) is of finite character.

Considering the orientation of crystallites, belonging to the same phase in a polycrystalline sample, the resulting sample-specific orientation distribution of these crystallites with regard to a sample-fixed coordinate system is primarily termed crystallographic texture or simply texture. However, in TA many more characteristics are of interest, such as the orientation frequency between neighbouring grains (orientation correlation), directional characteristics of grain boundaries, relations between lattices of a grain undergoing a phase transition *etc*., all in the end connected with orientations and rotations.

The common literature on texture deals mainly with material-specific (*e.g.* f.c.c. metals) or 'technological' (*e.g.* deformation processes, recrystallization phenomena, phase transitions) aspects of the matter, interpreting and theoretically modelling the corresponding orientation distributions, their changes, and the influence of texture on macroscopic properties of polycrystalline materials. Obviously, this is a wide field.

From this point of view, the present book differs from typical monographs on TA, since it especially focuses on those basic elements of any activities in this field, *i.e.* just on orientations and rotations. They involve topics of direct practical interest, such as parametrization, the relations between different variants of parametrization, the determination of the result of successive rotations, the possibility to consider 'improper' (inversion-afflicted) rotations, the consequences of symmetries of crystal lattices for the reduction of the *G*-space to 'asymmetric domains' containing non-redundant information, *etc.*

Moreover, orientations and rotations are the subjects of several abstract mathematical fields, such as rotations in higher than three-dimensional spaces, group theory, topology and modern algebra. To give an insight into these demanding techniques and to demonstrate the application of the corresponding results to typical TA problems was one of the main intentions of the author of the present book.

From my point of view, he has resolved this non-trivial undertaking in an excellent way. Of course, this goal predetermined to a great extent the proportions and the structure of the text. So, in order to obtain a compact volume several techniques, such as the consideration of orientation distributions with the help of the 'harmonic' apparatus (using spherical functions), were completely omitted. Moreover, to meet his high demands on accuracy, the author restricts the demonstration of the influence of texture on properties of polycrystals to elastic phenomena only – a classic field, whereto he has made several substantial contributions. However, the author explained all these limitations explicitly and convincingly. In addition, using the given references, the reader is sufficiently well guided to competent monographs and publications on the missing or only scarcely considered subjects.

The text contains 11 chapters, about 150 references and an index with about 300 entries. The chapters are entitled 1. Preliminaries, 2. Parametrizations, 3. Geometry of the Rotation Space, 4. More on Small Orientation Changes, 5. Some Statistical Issues, 6. Symmetry, 7. Misorientation Angle and Axis Distributions, 8. Crystalline Interfaces and Symmetry, 9. Crystallographic Textures, 10. Diffraction Geometry, and 11. Effective Elastic Properties of Polycrystals.

The first two chapters deal with the definition, the parametrization and the computational properties of rotations (orientations). Connecting rotations with orthogonal transformations, there are relationships to matrix representations, eigenvalues and eigenvectors of orthogonal operators, and Clifford algebra. Terms such as 'Rodrigues parameters', 'Euler angles', 'axis and angle parameters', 'Caley–Klein parameters', 'quaternions' and 'Miller indices', all being considered in a broader sense than in the common TA literature, give an impression of the manifold of described parametrizations. The description of the rotation matrix in non-Cartesian coordinate systems is original.

The third chapter describes the group of proper rotations [SO(3)] as a Riemannian manifold or a Lie group, explaining connections to the resulting metric tensor, Christoffel symbols, geodesics and curvature with their relations to the practical problem of integrations in the orientation space. Small orientation changes (chapter 4) are of interest for rotational kinematics, especially considering texture evolution by models describing the deformation of polycrystals.

In chapter 5 some techniques to determine a 'mean orientation' in the framework of several parametrizations are described. For modelling of the so-called 'texture components' the most frequently used in TA distributions are given. Of practical importance are simple algorithms to generate individual orientations for the case of 'no texture' (random or 'uniform' orientation distribution) and for the statistical representation of non-uniform orientation distributions. Symmetries ('left-sided') of crystal lattices can be described by finite point groups. Certain statistical symmetries ('right-sided') of the constitution of a polycrystalline sample can also be described by point groups. Such symmetries permit reduced calculations, representations or interpretations of orientation distributions in the so-called 'asymmetric domains' of the *G*-space. In chapter 6 variants of asymmetric domains are given (using the parametrization by Euler angles or the Rodrigues space) for all typical crystallographic left- and right-sided pairs of symmetry. Misorientations are orientation characteristics between two crystallographic objects (*e.g* neighbouring grains) of the same or different phases. The distribution of such ‘correlations’ (again with left- and right-sided symmetries) are considered in chapter 7 and are of very special interest. The same concerns the simplification of the characterization of crystalline interfaces (chapter 8) due to the symmetry of the lattice pairs.

Contrary to possible expectations, chapter 9 (‘Crystallographic Textures’) describes (after referring to a more detailed monograph on TA) only some of the orientation- or symmetry-related subjects from this field. These are typical texture components or ‘fibre-like’ distributions for the cubic orthorhombic case, typical interphase relationships for metals, and coincident sublattices. Chapter 10 gives a brief description of how the orientation of individual crystallites in a polycrystalline sample can be determined by diffraction experiments, or how to reproduce the three-dimensional orientation distribution from pole-figure data. The latter are two-dimensional special projections of the distribution in question. Limitations, ambiguities and the so-called ‘ghost phenomena’ due to Friedel’s law (introduction of an artificial inversion centre into the crystal symmetry for the typical case of normal diffraction) are mentioned.

The final chapter demonstrates the complexity of describing effective physical properties of microinhomogeneous materials by dealing with the elastic properties of polycrystals. Starting with exact relations, it is shown that one may obtain some final closed expressions for special cases only (single phases, quasi-isotropic aggregates, cubic crystal symmetry, infinite samples) and when using quite rigorous approximations (*e.g.* neglecting any correlation characteristics of the grain ensemble). The apparatus of deterministic and perturbation methods (up to self-consistent schemes) is described as well.

In spite of the comprehensive and exact description of the state of the art of this classic topic (with a history of more than 100 years), there remains a feeling that something is missing. Intuitively, the reader would expect at least one example related to real experimental data, all the more if the reader interprets the term ‘computations’ from the subtitle as ‘to obtain numerical results’. Some comments about tendencies of the development, about real possibilities, actual problems, and the quality of finite element algorithms during the past decade, should also be included when preparing another edition.

I read the book with great pleasure. Sometimes the insight into more abstract mathematical generalizations, unexpected sides of a seemingly well known problem and examples beyond the main course of the text can give the reader a really aesthetic impression. From this point of view the book is less an introduction into the matter, but rather a valuable tool and compendium of useful expressions and references for those (including students) who have already some basic knowledge and experience with orientations and rotations, especially in connection with TA. Here, readers may find new tricks to optimize computer algorithms adapted to their problems, which are either orientation- or rotation-related, and may also be beyond the TA.

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