

Book review

'Powder metallurgy – science, technology and materials' by A. Upadhyaya and G. S. Upadhyaya

2011, Hyderabad, India, Universities Press IIM/Boca Raton, FL, USA, CRC Press, 518 pp., ISBN 978 1 4398 5746 5, US\$169.95

This book is co-authored by the well known Indian 'PM family', G. S. Upadhyaya, Professor Emeritus, Indian Institute of Technology, Kanpur and his son, Anish, Professor at IIT Kanpur. It has been dedicated to Professor Günter Petzow, Max-Planck-Institut für Metallforschung, Stuttgart, in recognition of his successful bridging of science and technology in PM. This new book also combines logically PM fundamentals with industrial practice.

Since the book has been written by two experienced academic teachers, it is clearly and precisely written and thus also suitable for beginners in the field of PM, for example students of materials science, metallurgy, chemistry or physics who are starting to work on PM topics, or newcomers to the PM industry. Scientific-technical background is anticipated, therefore the book will be more useful for graduate students, but undergraduates will nevertheless find it interesting and helpful, although in part quite demanding. As is typical for textbooks, learning objectives are given at the beginning of each chapter and exercises for self-assessment at the end, as well as a list of literature for further reading. Within the chapters, examples are given that are basically exercises for which the solution is given and also explained; this must be regarded as a very useful introduction into the 'exercise' part.

The general structure of the book follows the classical lines, starting with a short introduction to PM and its main routes and steps and also some historical aspects; in view of the nationality of the authors, this includes of course the famous Delhi pillar manufactured about AD400. Then the various routes for powder manufacturing are given, chemical, electrochemical and atomisation techniques being described in detail and some typical powders being given as examples, but also advanced methods such as self-propagating high temperature synthesis. Powder characterisation methods are described together with powder treatments such as mixing, granulation and coating, as

well as pressing lubricants and mixing equipment. The next chapter contains the various compaction techniques such as cold and warm die compaction, but also cold isostatic compaction, extrusion and powder injection moulding. Pressureless shaping processes such as slip casting, tape casting and spray deposition are also described.

A major focus of the book is sintering, which is described from both the theoretical and the practical sides. In the former section, the various stages and mechanisms of solid state and liquid phase sintering are given, although the narrow definition of 'sintering equals densification' dominates, which holds for many but not for all sintered products. On the other hand, the microstructural aspects of sintering are considered as well as sintering in non-isothermal conditions. The authors also describe an approach to establish an electronic theory of sintering, relating the sintering behaviour to the bonding in the respective material. As a case study, sintering of refractory metals and their compounds is discussed. In the following chapter the industrial practice of sintering is described: the sintering furnaces used in practice but also 'exotic' techniques such as induction and microwave sintering. Regarding the high reactivity of powder compacts, the sintering atmospheres, their reactions with the compacts and also analysis and control of the atmospheres are thoroughly discussed. Finally, the main sintering parameters and the effects of sintering on dimensions and microstructure are described briefly, as is infiltration (which can be regarded as a 'hybrid' process between sintering and secondary operations).

Full density consolidation processes described in this book include well established techniques such as hot pressing, hot isostatic pressing, sinter-hipping, hot extrusion and powder forging, but also rapidly developing technologies such as spark plasma sintering and rarities such as dynamic compaction. Secondary operations such as sizing, machining, impregnation and joining, done mainly on sintered steel parts, are dealt with quite briefly, whereas surface engineering – and in particular heat treatment techniques – are described more thoroughly, although the peculiarities of sintered steels such as

open porosity might have been discussed in more detail in view of their strong impact on industrial practice.

In the following chapter, a wide range of characterisation techniques for PM products are described, from measuring the density to magnetic properties, thermoanalytical techniques and mechanical testing. This overview must be regarded as short but highly useful, leading to further, more detailed literature.

The chapter on metallic and ceramic PM materials is kept fairly short for the metallic part, describing selected materials such as unalloyed and low alloyed sintered steels, Fe-P, high speed steels and stainless steels, some Cu and Al alloys, as well as Ag, Ni and Ti alloys, refractory metals and intermetallics. Ceramic systems are discussed in more detail, from porcelain to ferrites, oxide superconductors to SiC. The section on 'Cermets' also covers cemented carbides, which must be regarded as an uncommon definition. Nano-crystalline metals and ceramics and functionally graded materials are mentioned, as is the MPIF materials coding and standards system. The wide variety of applications for PM products listed here ranges from standard structural parts and cutting tools to PM in power generation, fuel cells, electronics and implants. Finally, the economics of PM manufacturing is discussed; this is a particularly welcome feature, since the economics are frequently neglected in the PM literature. The authors give examples for the techno-economics of powder production as well as of secondary operations and discuss the energy saving potential of PM and recycling aspects.

Generally, the book must be regarded as a very welcome and useful addition to the library of any institute or company working in powder metallurgy. Although the depth of information must necessarily be limited – as is the case with any book giving a overview of powder metallurgy as a whole – it is an informative introduction to powder metallurgy, yet one in which experienced powder metallurgists will find new and relevant information. Its publication will, this reviewer hopes, help to attract many able young scientists to powder metallurgy.

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