



# Metal Foams: Fundamentals and Applications

By Nihad Dukhan

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Covers all phases of metal foam theory and technology Techniques linking pore structure to custom properties New applications in transportation, energy absorption, and orthopedic implants Foams from a variety of metals as well as special shapes and lotus-type

----- This book offers the first full-scale technical treatment of an important class of engineered porous materials: metal foams. Written by a team of metal foam experts from around the world, the volume offers new, as well as fundamental, information on all aspects of metal foams, including their theory, manufacture, structure-property relationships and applications. The book explains microscopy and modeling tools that enhance the prediction and determination of metal foam properties related to fluid flow, heat transfer, sound absorption and failure analysis. Attention is given to the many techniques for manufacturing and testing metal foams and to how their microstructure can be controlled to create custom properties for applications in acoustics, bone implants, heat sinks, lightweighting and crash protection. The text is sufficiently detailed to offer guidance to design and development engineers, and yet is basic enough to be used as a textbook or reference by students of materials science, mechanical, structural or chemical engineering requiring an introduction to the subject.

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## **Editorial Review**

### **Review**

A new volume has just appeared on metal foams or, to use more precise wording, on microcellular metals. It is an edited volume, comprising ten independently authored chapters that cover various aspects of these interesting materials. This publication is timely: the two main books on the subject [1, 2] are now a decade old and much has been accomplished since these were written, on the fabrication, understanding and exploitation of highly porous metallic materials. This new volume neatly covers what's new, with little overlap between chapters, good reference to the literature, and at a level that is appropriate for the book to have wide readership. The format of the various chapters is somewhat variable, in that the book comprises a blend of reviews of broad questions that are important to these materials (fluid flow, heat transfer, plastic deformation, acoustic properties and orthopedic applications notably) and chapters describing, by presentation of recent results, selected areas of recent progress, such as the use of tomographic imaging to view, analyse and model the structure and properties of microcellular metals. Coverage is not comprehensive (a book at least twice as thick would be needed). Rather, topics seem to have been selected to give the reader insight into key areas of progress accomplished over the decade since the appearance of the previous books on the topic (both of which remain valid and important references). Notably, it is increasingly clear that microcellular metals are finding application in situations where their function is not strictly structural: microcellular metals are used as electrodes, heat exchangers, catalysts and bone scaffolds, for example. Certain topics, such as fluid flow, heat transfer and biocompatibility have, as a result, grown in importance, and these subjects are well represented in this volume. In this context, the choice of editor, an expert on transport phenomena in these materials, was very appropriate. This is a nice addition to the literature on the subject and is bound to become a must-read reference on microcellular metals. --Andreas Mortensen, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Metal foams, and indeed foams in other materials, are interesting for a number of reasons. They can aid heat transfer and they can form effective structural members while undertaking this former role. They can be used as catalyst supports in chemical reactors, and in their non-metallic forms (e.g. activated carbon/ graphite) can be effective adsorbers in chemical heat pumps. .... . Heat sinks in electronics cooling, both single-and two-phase types, are also being developed using foams as enhanced heat transfer surfaces. One of the most prolific manufacturers of metal foams (and ceramic types) concentrates upon the foam as filter materials. It is therefore surprising to see foams being studied as extended surfaces in air-cooled heat exchangers in some scientific papers, where fouling may well be a problem. A foam heat exchanger in such uses is likely to be more difficult to clean than a conventionally-finned unit. This book, understood to be the first comprehensive treatment of metal foams for around a decade, has within its 432 pages and ten Chapters a substantial amount of data that thermal engineers will find directly or indirectly of use. Approximately 30% of the book deals with fluid flow and heat transfer in metal foams, although the applications chapter (Chapter 9) deals largely with aluminium foam and is strongly biased towards automotive nonthermal applications. Looking at the overall contents, Chapter 1, by authors from the Fraunhofer-Institute, examines the manufacturing process for metal foams. The Editor has contributed Chapter 2 on fluid flow through open-cell foams, stressing its position within the field of transport in porous media. Data on pressure drop are given, an important consideration in many potential applications. This is followed by a chapter on numerical simulation of the flow, and validation. This is written by authors from the Industrial Materials Institute, National Research Council in Canada. The data in this chapter will be of some interest to those modelling foams in PCMs, for example, although flow rather than heat transfer is the focus. The next two chapters address foam deformation and failure/ crashworthiness areas of less interest to the heat transfer engineer. Chapter 6 Heat Transfer in Metal Foams is detailed and includes a derivation of the macroscopic energy equations and

extensive data on thermal conductivity calculation. Reference is also made to ceramic foams in the context of interstitial heat transfer coefficient data. Written by Akira Nakayama of Shizuoka University, Japan, the topics in this chapter also include thermal dispersion the effect of the spreading of heat by fluid velocity variations from the mean and the solutions of problems such as steady heat conduction in a metal foam slab with internal heat generation, and convective heat transfer in a channel filled with a foam bounded by heated walls (as one might find in a heat sink). The chapter cites almost 60 references. Chapter 7, on acoustic properties, and Chapter 8, orthopaedic properties, are of less interest to the readers of Applied Thermal Engineering, but one topic discussed in Chapter 7, the measurement of foam porosity, is of universal interest and importance. Similarly, in Chapter 8 there is a discussion of corrosion in the context of titanium orthopaedic structures. Chapter 9 has been briefly discussed above. It does include wall panels made of aluminium foam, and one can readily envisage a heat storage medium being incorporated within these! The final chapter examines Lotus-type porous metals. This form of foam has straight pores, allowing a lower pressure drop, while also being characterised by very small diameter pores, down to 50 microns in some cases (Ogushi et al. [1]). Examples of their use as heat sinks are described in *Journal of Applied Thermal Engineering*, by David Reay, Editor, Aug. 2013

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