

# **METAL FOAMS AND POROUS METAL STRUCTURES**

**Editors:**

**John Banhart, Michael F. Ashby, Norman A. Fleck**

**Verlag MIT Publishing**

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

**Metal foams and porous metal structures / [International Conference on Metal Foams and Porous Metal Structures, 14th - 16th June 1999, Bremen (Germany)]. Ed.: John Banhart ... - Bremen : Verl. MIT Publ., 1999**  
ISBN 3-9805748-7-3

International Conference on Metal Foams and Porous Metal Structures, 14<sup>th</sup> - 16<sup>th</sup> June 1999  
Bremen (Germany)

Editors: John Banhart, Michael F. Ashby, Norman A. Fleck

© Verlag Metall Innovation Technologie MIT  
Kiebitzbrink 79A, 28357 Bremen (Germany)

All rights reserved  
Alle Rechte vorbehalten

Printed in Germany

**ISBN 3-9805748-7-3**

Cover illustrations: Fraunhofer Bremen (foamed metals) and Karmann Osnabrück („Detroit Show Car 1998“)

## Contents

Preface .....	1
---------------	---

### **APPLICATIONS AND INDUSTRIAL USE**

#### **Automotive applications**

<i>Aluminium foam for automotive applications</i> .....	5
A. Fuganti, L. Lorenzi, A.G. Hanssen, M. Langseth	
<i>Derivation of materials energy absorption requirements from crash situations</i> .....	13
J.E. Siebels	
<i>Manufacturing and testing of aluminium foam structural parts for passenger cars demonstrated by example of a rear intermediate panel</i> .....	23
R. Kretz, E. Hombergsmeyer, K. Eipper	
<i>Application strategies for aluminium-foam-sandwich parts (AFS)</i> .....	29
H.-W. Seeliger	
<i>Aluminium foams for energy absorbing structures under axial loading</i> .....	37
C. Haberling, H.G. Haldenwanger, T. Bernard, J. Burzer, H.W. Bergmann	

#### **Application and cost studies**

<i>Multifunctionality of cellular metal systems</i> .....	45
A.G. Evans, J.W. Hutchinson	
<i>Cost modelling for the fabrication of aluminium foam via powder metallurgical route</i> .....	57
H. Kaufmann, B. Konrad, R. Kretz	
<i>Cost estimation and the viability of metal foams</i> .....	63
E. Maine, M.F. Ashby	

### **PRODUCTION AND PROCESSING**

#### **Powder compact method**

<i>Industrialisation of P/M foaming process</i> .....	73
F. Baumgärtner, H. Gers	
<i>Foamed aluminium cores for aluminium castings</i> .....	79
T. Höpler, F. Schörghuber, F. Simančík	

<i>A novel melt-based route to aluminium foam production.....</i>	83
V. Gergely, T.W. Clyne	
<i>Numerical simulation of foam formation and evolution with modified cellular automata.....</i>	91
C. Körner, R.F. Singer	
<i>Foaming kinetics of aluminium alloys .....</i>	97
I. Duarte, P. Weigand, J. Banhart	
<i>Effect of foaming parameters on the pore size .....</i>	105
F. Simančík, N. Mináriková, S. Čulák, J. Kováčik	
<i>Characteristics and handling of titanium hydride .....</i>	109
R. Kresse	
<i>Production technology for aluminium foam/steel sandwiches .....</i>	113
J. Baumeister	
<i>Tailored blanks based on foamable aluminium sandwich material .....</i>	119
R. Braune, A. Otto	
<b>Foaming of liquids and casting</b>	
<i>Aluminium foam „Alporas“: the production process, properties and applications .....</i>	125
T. Miyoshi, M. Itoh, S. Akiyama, A. Kitahara	
<i>Aluminium foam produced by the melt foaming route - process, properties and applications .....</i>	133
P. Åsholt	
<i>Interfacial criteria for ceramic particle stabilised metallic foams .....</i>	141
G. Kaptay	
<i>Processing of cellular magnesium materials .....</i>	147
Y. Yamada, K. Shimojima, Y. Sakaguchi, M. Mabuchi, M. Nakamura, T. Asahina, T. Mukai, H. Kanahashi, K. Higashi	
<i>Investment cast near-net shape components based on cellular metal materials.....</i>	153
C. Hintz, I. Wagner, P.R. Sahm, P. Stoyanov	
<i>Properties and applications of cast aluminium sponges .....</i>	159
J. Banhart	
<i>Preparation, structure control and acoustic properties of porous aluminium with open cells .....</i>	163
F. Chen, D.P. He	
<b>Sintering methods</b>	
<i>Porous metal structures made by sintering: processes and applications .....</i>	167
P. Neumann	

<i>Stainless steel hollow sphere foams - fabrication, carburization, and properties .....</i>	171
J.L. Clark, K.M. Hurysz, K.J. Lee , J.K. Cochran, T.H. Sanders	
<i>Fabrication and microstructure of metal-metal syntactic foams .....</i>	179
J.H. Nadler, K.M. Hurysz, J.L. Clark, J.K. Cochran, K.J. Lee, T.H. Sanders	
<i>Novel metallic hollow sphere structures: processing and properties .....</i>	183
O. Andersen, U. Waag, L. Schneider, G. Stephan, B. Kieback	
<i>Novel process for cellular materials with oriented structure .....</i>	189
L. Tuchinskiy, R. Loutfy	
<i>Preparation and characterisation of high porosity titanium-, stainless steel- and superalloy parts .....</i>	197
M. Bram, C. Stiller, H.P. Buchkremer, D. Stöver, H. Bauer	
<i>Pore formation during reactive sintering of iron-aluminium powder mixtures .....</i>	203
M. Knüwer	

## CHARACTERISATION AND PROPERTIES

### Structure

<i>On the non-destructive testing of metal foams .....</i>	213
H.P. Degischer, A. Kottar	
<i>Deformation heterogeneity in cellular Al alloys revealed by surface deformation analysis.....</i>	221
A.-F. Bastawros, A.G. Evans	
<i>Characterisation of cast and compressed foam structures by combined 2D-3D analysis .....</i>	227
F. Grote, A.Schievenbusch	
<i>Desktop X-ray microtomography for studies of metal foams .....</i>	233
E. Cornelis, A. Kottar, A. Sasov , D. Van Dyck	

### Static Deformation

<i>Reproducibility of aluminium foam properties .....</i>	235
F. Simančík	
<i>Deformation behaviour of aluminium foam under uniaxial compression (a case study) .....</i>	241
B. Kriszt, B. Foroughi, K. Faure, H.P. Degischer	
<i>Multi-axial yield of aluminium alloy foams .....</i>	247
V. Deshpande, N.A. Fleck	

<i>On the behaviour of aluminium foams under uniaxial and multiaxial loading .....</i>	255
W. Ehlers, H. Müllerschön, O. Klar	
<i>Mechanical behaviour of aluminium foams for various deformation paths. Experiment and modelling .....</i>	263
Y. Chastel, E. Hudry, S. Forest, C. Peytour	
<i>Failure mechanisms of aluminium foams under compressive loads .....</i>	269
E. Saenz, A. Villate, I. Garuz, A.M. Irisarri, G. Rausch, M. Weber	
<i>Modelling of the mechanical properties of metallic foams based on X-ray analysis .....</i>	277
J. Burzer, T. Bernard, H.W. Bergmann, O. Damm	
<i>Influence of micro - and meso-topological properties on the crash-worthiness of aluminium foams .....</i>	283
T. Daxner, H.J. Boehm, F.G. Ramerstorfer	
<i>On the mechanical properties of steel foams .....</i>	289
C.-J. Yu, T.D. Claar, H.H. Eifert, M. Knüwer, M. Weber, J.C. Runkle	
<i>Elastic properties of cellular metals processed by sintering mats of fibres .....</i>	293
F. Delannay, T.W. Clyne	
<i>FE simulation of metal foams based on the macroscopic approach of the theory of porous media.....</i>	299
W. Ehlers, A. Droste	
<i>Modelling of the aluminium foam properties according to percolation theory .....</i>	303
J. Kováčik, F. Simančík	
<b>Behaviour of composite structures</b>	
<i>Sandwich panel design using aluminium alloy foam .....</i>	307
A.-M. Harte, N.A. Fleck, M.F. Ashby	
<i>Aluminium foam filled steel tubes as composite shock absorbers .....</i>	313
R. Gradinger, M. Seitzberger, F.G. Ramerstorfer, H.P. Degischer, M. Blaimschein, C. Walch	
<i>Bending and bulging tests on steel sheet / aluminium foam sandwiches .....</i>	317
H. von Hagen, W. Bleck	
<i>Optimum design of metal foam in sandwich structures using genetic algorithm .....</i>	325
J. Deocon, L. Salvo, P. Lemoine, D. Landru , Y. Bréchet, R. Leriche	
<i>Microstructure and mechanical properties of cellular magnesium matrix composites .....</i>	331
M. Hartmann, I. Crößmann, K. Reindel, R.F. Singer	
<i>Bending crush behaviour of foam-filled sections .....</i>	337
S. Santosa, J. Banhart, T. Wierzbicki	

**Dynamic loading, fatigue and fracture**

<i>Deformation energy absorption of metal foams at high strain rates</i> .....	347
C.-J. Yu, T.D. Claar, H.H. Eifert, I.W. Hall, R.E. Franz, K.T. Leighton, D.F. Hasson	
<i>Energy absorption of light-weight metallic foams under dynamic loading</i> .....	353
T. Mukai, H. Kanahashi, K. Higashi, Y. Yamada, K. Shimojima, M. Mabuchi, T. Miyoshi, T.G. Nieh,	
<i>The effect of impact velocity on the deformation of layered metal foam/ceramic composites</i> .....	359
A.E. Markaki, T.W. Clyne	
<i>Fatigue of an aluminium alloy foam</i> .....	365
O.B. Olurin, N.A. Fleck, M.F. Ashby	
<i>Fatigue of aluminium foams at ultrasonic frequencies</i> .....	373
B. Zettel, S. Stanzl-Tschegg	
<i>Fatigue behaviour, strength and failure of aluminium foam</i> .....	379
O. Schultz, A. des Ligneris, O. Haider, P. Starke	
<i>Fracture toughness of honeycombs</i> .....	387
I. Schmidt, N.A. Fleck	
<b>Thermal, acoustic and damping properties</b>	
<i>Thermal transport and fire retardance properties of cellular metals</i> .....	391
T.J. Lu, C. Chen	
<i>A finite element model updating approach intended to simulate vibro-acoustic behaviour of Al-foam structure</i> .....	397
A. Zopp, F.G. Kollmann	
<i>Noise attenuation using aluminium foams</i> .....	405
J. Kováčik, P. Tobolka, F. Simančík	
<i>Acoustical investigation of sintered highly porous metal fibre structures as sound absorbers</i> .....	409
F. Albracht, G. Lotze	
<i>The damping performance of porous aluminium (PA) and porous aluminium-polymer composites (PAPCs)</i> .....	413
D.P. He, F. Chen, L.Q. Ma	
<b>Author index</b> .....	417