2021 International Conference on Powder Metallurgy & Particulate Materials

Advances in Powder Metallurgy & Particulate Materials

Orlando, Florida, USA 20 - 23 June 2021

ISBN: 978-1-7138-8977-9

Printed from e-media with permission by:

Curran Associates, Inc. 57 Morehouse Lane Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2021) by Metal Powder Industries Federation All rights reserved.

Printed by Curran Associates, Inc. (2024)

For permission requests, please contact Metal Powder Industries Federation at the address below.

Metal Powder Industries Federation 105 College Road East Princeton, NJ 08540 USA

Phone: 609-452-7700 Fax: 609-987-8523

info@mpif.org

Additional copies of this publication are available from:

Curran Associates, Inc. 57 Morehouse Lane Red Hook, NY 12571 USA Phone: 845-758-0400

Fax: 845-758-2633

Email: curran@proceedings.com Web: www.proceedings.com

Advances in Powder Metallurgy & Particulate Materials—2021

CONTENTS

State of the North American PM Industry—2021 Dean Howard, PMT, President, Metal Powder Industries Federation	6
Part 1—Design & Modeling of PM Materials, Components & Processes	14
Part 2—Particulate Production	35
Part 3—Compaction & Forming Processes	71
Part 4—Powder Injection Molding (Metals & Ceramics)	108
Part 5—Pre-Sintering & Sintering	158
Part 6—Secondary Operations	230
Part 7—Materials	338
Part 8—Advanced Particulate Materials & Processes	383
Part 9—Material Properties	492
Part 10—Applications	576
Subject Index	607
Author Index	609

Category 1 — Design & Modeling of PM Materials, Components & Processes

A Combined Multi-Phase-Field/Discrete-Element Method for	
Sintering of Blended Elemental Powders	
Kazunari Shinagawa	15
Microstructural Evolution Simulation for Property Prediction	
in Cold Spray Processing	
Kyle Tsaknopoulos, Jack Grubbs, Bryer C. Sousa, Matthew Gleason,	
Christopher Massar, Matthew Siopis, and Danielle Cote	22

Category 2 — Particulate Production

Fowards the Development of Water-Atomized Tool Steel Powders for Utilization in Direct Energy Deposition (DED) and Laser Powder Bed (LPB)	
Denis Mutel and Carl Blais	36
Close-Coupled Transferred Arc Plasma-Wire Atomization Joseph Tunick Strauss and Chris Berghorn	52
Atomization for PM: Past, Present and Future	62

Category 3 — General Compaction & Forming Processes

Warm-Die Compaction of Low Alloy Steel Powder Mix – Compaction Mechanics and Densification Ilaria Cristofolini, Marco Zago, Alex Rambelli, and Federico Della Ricca	72
Comparative Evaluations of Powder Metallurgy Characteristics	12
of Commercial PM Lubricants in an Iron-Based Mixture using Advanced Characterization Methods	
Amir Shirani, Jean. V. Reid, Saba Mousavinasab, and Chantal Labrecque	82
High Performance Lubricant for High Density Applications	
and Warm Die Compaction	
Vincent Paris, Saba Mousavinasab, and Yannig Thomas	93

Category 4 — Powder Injection Molding (Metals & Ceramics)

V. Demers	109
Comparative Evaluation of Thermal Processing on the Microstructure of Metal Injection Molded 718 Rees Jones and Saul Encinia	131
Rapid Tooling Development with Freeform Injection Molding for MIM	
Uffe Bihlet, Kyriakos Didilis, Phil Grimmer, and Mathias Geisler	143
Compatibility of CIM Feedstock with 3D Printed Single-Use Polymer Molds	
Kyriakos Didilis, Uffe Bihlet, Amandine Lorriaux, and Aboubakry Agne	150

Category 5 — Pre-Sintering & Sintering

The Role of the Structural and Geometrical Activity Baselli, S	159
Ultra-High Temperature Sintering, the Benefits and Potential PM Opportunities Francis Hanejko, Jenifer Thorwart, Phil McDonald, and Kylan McQuaig	168
Critical Temperatures and Events in Nanophase Separation Sintering of W-15at%Cr Christian Oliver and Christopher A. Schuh	181
Optimizing Sintering Furnace Design and Operating Parameters for Best Results Ravi P. Malhotra	187
The Impact of Complete Lubricant Removal on the Mechanical Properties and Production of Powder Metal Components Containing Intralube HD Jacob P. Feldbauer, Scot E. Coble, Amber Tims, Craig Stringer, and Stephen L. Feldbauer.	201
The Impact of Complete Lubricant Removal on the Mechanical Properties and Production of Powder Metal Components Scot E. Coble, Jacob P. Feldbauer, Amber Tims, Craig Stringer, and Stephen L. Feldbauer.	212
The Effect of Elevated Sintering Temperature on the Microstructures and Mechanical Properties of a Low Alloy PM Steel Jordan Kramp, Yannic Praden, and Vince Williams	222

Category 6 — Secondary Operations

Evaluation of Consistency in Machining of Powder Metal Components Produced with Common Copper Steels Cody Kalinoski, Chris Myers, Bo Hu, Roland Warzel III, and Amber Tims	231
Increased Productivity and Longer Tool Life in Machining High Strength Powder-Forged Connecting Rods Bo Hu, Roland Warzel, Amber Tims, Edmond Ilia, and Doug Sinclair	240
New Machining Enhancer for High Strength Powder-Forged Connecting Rods Bo Hu, Roland Warzel, Amber Tims, Edmond Ilia, and Doug Sinclair	255
Enhancing the Machining Consistency of PM Components— A Look at a New Machining Additive Neal Kraus, Bruce Lindsley, and M. Kylan McQuaig	270
Evaluation of the Dimensional Change and Distortion After Heat Treatment of PM Components, being Subjected Post-Sinter Impregnation Processing by Inorganic Sealant Leonid Frayman, Stephen Quinn, Craig Stringer, Robert Powell, and Marty Timm	281
Dimensional Change of Heat Treated Components from PM Copper Steels Containing Various Carbon Content, and being Subjected to Post-Sinter Impregnation by Inorganic Sealant Leonid Frayman, Stephen Quinn, Craig Stringer, and Robert Powell	297
High Pressure Gas Quenching of PM Lean Alloy Powertrain Components Using Latest Generation of Compact Vacuum Equipment Vincent Lelong, Dennis Beauchesne, Michael Nemcko, Yannic Praden,	
Steam-Bluing Process of Sintered Parts Without Using Boilers – A Boon for PM Parts Manufacturing Ravi P Malhotra	
Nitriding Mechanisms of Ferrous Powder Metal Products in Gas, Salt and Plasma Methods Edward Rolinski, John Ludeman, Jake McCann, Vasko Popovski, and Mike Woods	

Category 7 — Materials

Properties of High Manganese Non-Magnetic Steel Chongxi Bao, Zeyu Sun, Weiwei Yan, and Weili Feng	339
Recent Developments and Trends in Aluminum Powder Metallurgy I.W. Donaldson and L.J.B. Smith	348
Material Preparation of High Temperature Solid Oxide Fuel Cell Interconnector Weiwei Yan , Chongxi Bao, and Weili Feng	365
New Environmentally Friendly Carbon Black and Tungsten Carbide Produced Therefrom	
Ned J. Hardman and Thomas J. Jewett	377

Category 8 — Advanced Particulate Materials & Processes

José M. Torralba, Paula Alvaredo, Mónica Campos, and Andrea García-Junceda	384
Variation of Double-Press Double Sinter (DPDS) to Produce High Density Low-Alloy Steel Parts Harb S Nayar, Gregory Carroll, and Vibhor Chaswal	423
Development of a New Cr-Based Hardmetal with Nanosized Tungsten Carbide Grain Size Through Liquid-Phase Sintering and Spark Plasma Sintering	
X.X. Deng, J.M. Torralba, and A. García-Junceda	443
Advancements in Continuous Processing of Soft Magnetic Composites Stephen L. Feldbauer	458
Research into Near Shape Processing of Magnesium and Magnesium Alloy Powders	
Steven C. Johnson and William A. Caron	463
Improvements to the Powder Processing of Near-Final Shape Alnico Magnets	
Emily Rinko, Eric Deaton, and Iver E. Anderson	475

Category 9—Material Properties

Improved Powder Compaction Through Use of Advanced Binders and Lubricants Kylan McQuaig, Lars Wimbert, and Bruce Lindsley
Toward the Improvement of Dimensional Control in FeCuC Steels
Elena Bernardo, Josep Pons, Jing Yang, and Jose Antonio Calero
Simon Gélinas, Gabrielle Laramée, and Carl Blais
I.W. Donaldson, B. D. Christensen, and M. Schneider
P.Beiss, K. Burkamp, and C. Broeckmann

Category 10—Applications

Lightweighting Material and Process Options for Automotive	
Applications—Focus on PM Aluminum	
Chaman Lall	575
The Allure of Stainless Steels Produced by Powder Metallurgy	
(PM) Technology	
Chaman Lall	588