

5th International Conference

**HOT SHEET METAL FORMING
of HIGH-PERFORMANCE STEEL
CHS²**

May 31th until June 3rd, 2015, Toronto, Ont., Canada

Proceedings

5th International Conference

**HOT SHEET METAL FORMING
of HIGH-PERFORMANCE STEEL
CHS²**

May 31th until June 3rd, 2015, Toronto, Ont., Canada
Proceedings

Edited by

Prof. Kurt Steinhoff, University of Kassel, Germany

Prof. Mats Oldenburg, Luleå University of Technology, Sweden

Prof. Braham Prakash, Luleå University of Technology, Sweden

All rights reserved.

No part of this publication may be reproduced or transmitted
by any means, electronic, mechanical, photocopying or otherwise
without the prior permission of the publisher.

© 2015

Verlag Wissenschaftliche Scripten

Kaiserstrasse 32, 08209 Auerbach, Germany

info@verlag-wiss-scripten.de

www.verlag-wiss-scripten.de

ISBN: 978-3-95735-023-7

Editorial

Presently, we are facing the biggest paradigm change in metal forming technology since more than half a century. The driving force behind this remarkable change is a strong demand for safety: environmental safety, energy safety, resource safety, and individual safety. In the case of individual transportation, these safety aspects lead to a strong demand for new solutions to reduce the weight of vehicle structures, and to increase passenger safety. For current body-in-white designs, these requirements can only be met by utilizing hot-stamped/press-hardened, ultra-high strength steel components. They are the key to providing the requested superior crash performance and significant weight reduction.

Although the globalization of hot stamping technology began more than a decade ago, there are still extremely promising "blank spots" on the map concerning the remaining market and innovation potential. In order to identify chances, evaluate risks, and, finally, make proper decisions regarding whether to and how to occupy one or more of the aforementioned spots, comprehensive access to reliable information is crucial.

In the rapidly growing market of press hardening, the essentiality of the availability of comprehensive knowledge and operational skills for the exploration of the corporate economical potential of this technology, and to gain and sustain competitiveness is no secret.

To maintain this positive trend and harness the full potential of this technology, further innovation in press hardening steel technology is essential. Research and development, at both the academic and industrial levels, is one of the most important prerequisites for continuing innovation. This is what CHS² 2015 is aiming at in the 5th in the series of purely PHS-related international conferences.

Kurt Steinhoff
Mats Oldenburg
Braham Prakash

Table of Contents

Tailored Properties I (A1)

Partial Tempering of Press Hardened Steels by Direct Flame Impingement – the Review of an Alternative Approach for Tailored Properties	17
<i>Felix Zimmermann, Josef Spörer and Wolfram Volk</i>	
Laser Softening of Press Hardened Steel in High Volume Production Lines	25
<i>Marcel Schaefer, Dieter Schwoecker, Joachim Aichinger, Oliver Spitzer and Thomas Harrer</i>	
Hot Forming and Subsequent Cooling Outside the Press for Adjusted Tailored Properties of 22MnB5 Steel Sheets	35
<i>Bernd-Arno Behrens, Hans Jürgen Maier, Florian Nürnberger, Jens Schrödter, Jörn Moritz, Lars Wolf and Christoph Michael Gaebel</i>	

Hydrogen Embrittlement (B1)

Laboratory Experiments on Press Hardened Steels in Different Delivered States Exposed to Hydrogen	45
<i>S. Weczera, M. Rhode, C. Sunderkoetter, A. Plath and S. Juettner</i>	
Influence of Microstructures on Hydrogen Embrittlement Susceptibility of Hot Stamped Ultrahigh Strength Components	55
<i>Masahiro Matsumoto, Yoshito Takemoto and Takehide Senuma</i>	
Impact of Nb Microalloying on the Hydrogen Embrittlement of Press Hardening Steel	65
<i>Jian Bian, Hardy Mohrbacher, Shiqi Zhan, Hongzhou Lu, Wenjun Wang, Yue Zhang and Li Wang</i>	

Coatings I (A2)

Effect of Depth of Crack on Fatigue Property in Zn-Ni Coated Press Hardened Steel	77
<i>Koichi Nakagawa, Tatsuya Nakagaito, Takeshi Yokota, Kazuhiro Seto and Akihide Yoshitake</i>	

Unlocking the Potential of Zinc Coated Steel for HotForming by Innovative Process Modifications	85
<i>Guido Hensen, Peter Beentjes, Michael Abspoel and Jenny Loiseaux</i>	
55 % Al-Zn Coating for Press Hardening Steel	93
<i>Chang Wook Lee, Yeol Rae Cho, Bruno C. De Cooman</i>	
Characteristics of Crack Evolution in Al-Si Coating under Different Deformation Conditions	101
<i>Kai Wang, Peixing Liu, Zijian Wang, Bin Zhu and Yisheng Zhang</i>	

Tribology (B2)

Parameters Influencing Adhesive Wear Behavior within Hot Stamping Operations	111
<i>Michael Wieland and Marion Merklein</i>	
Validation of Tool-Wear Simulations Based on a Fullscale Press Hardening Experiment	121
<i>Liang Deng, Sergej Mozgovoy, Jens Hardell , Braham Prakash and Mats Oldenburg</i>	
Analysis of the Tribological Performances of New Tool Steels in Hot Stamping Applications	129
<i>Francesco Medea, Andrea Ghiotti, Stefania Bruschi, Rachele Bertolini, Paolo F. Bariani and Anwar Hamasaid</i>	
Adhesion Behavior of Aluminum for Aluminum-Coated 22MnB5 Steel in Hot Stamping Under Dry and Lubricated Conditions	139
<i>Kosuke Uda and Akira Azushima</i>	

Modeling & Simulation I (A3)

Microstructure-Based Modelling of Ductile Failure	149
<i>Rickard Östlund and Mats Oldenburg</i>	
Implementation of a Failure Criterion for Axial Crush of Fully Hardened Boron Steel	157
<i>Luke ten Kortenaar, Kaab Omer, Cliff Butcher, Alexander Bardelcik, Michael Worswick, Duane Detwiler and Skye Malcolm</i>	
Simulative High Temperature Friction and Wear Studies for Press Hardening Applications	167
<i>Sergej Mozgovoy, Jens Hardell, Liang Deng, Mats Oldenburg and Braham Prakash</i>	

Process Design I (B3)

Mechanical Link Servo Press for Hotforming	179
<i>Trent Maki, Masaaki Amino, Katsutoshi Hirano and Hiroki Murai</i>	
Production Control and Optimization of Hot Stamping Line	189
<i>Liang Wang, Bin Zhu, Qiang Wang, Ju Meng and Yisheng Zhang</i>	
From First Draft to Serial Production: Hot Stamping Part Design and Feasibility Study with Respect to Functionality and Optimization of Production Costs	197
<i>Jens Aspacher, Dirk Haller and Paul Thom</i>	

Tailored Properties II (A4)

Study on Fracture in Heat Affect Zones in the Vicinity of Spot Welds in a Steel with Tailored Material Properties	211
<i>Stefan Golling, Rickard Östlund and Mats Oldenburg</i>	
Fracture Resistance of Tailor Tempered Microstructures Obtained by Different Press Hardening Conditions	221
<i>Daniel Casellas, Antoni Lara, Silvia Molas, Anna Gironès, Stefan Golling and Mats Oldenburg</i>	
Partial Hardening of New Press Hardenable Steels	231
<i>Thorsten Marten, Holger Block and Thomas Tröster</i>	

Non-Destructive Testing, Joining & Formability (B4)

Industrial Demands and Nondestructive Testing (NDT) Solutions for Process Monitoring and Quality Control in Hot and Cold Formed Steel Production	243
<i>Christian Conrad, Rolf Kern, Bernd Wolter, Tim Wicke and Jens Tonne</i>	
Magnetic Pulse Welding – A Review on the Joining of Aluminum and High-Performance Steel	251
<i>Anatoli Rebensdorf and Stefan Böhm</i>	
Effect of Scale Thickness on Formability in Hot Stamping of Boron Alloyed Steel	261
<i>Akira Yanagida, Eitaro Komatsu, Naoki Nakajima, Naito Toyoshima and Akira Azushima</i>	

Product Properties (A5)

Crevice Corrosion of Patch Reinforcements of Hot Stamping Steels 271

Martin Jönsson, Lisa Levander and Daniel Berglund

Side Impact Crash Behavior of Press-Hardened Steels-Correlation with Mechanical Properties 281

Patrick Larour, Junya Naito, Andreas Pichler, Thomas Kurz and Toshio Murakami

Multi-axial Material Testing at High Strain Rates in High Speed Cupping Tests 291

Nathalie Weiß, Thorsten Marten, Holger Block and Thomas Tröster

Effect of Shot Blasting on the Residual Stress of Hot Stamped Parts 299

Rui Ge, Huan Xue, Yunjie Bi and Shaoyun Zhou

Heating & Cooling I (B5)

Experimental Measurements of the Austenitization Process During Reheating of 22MnB5 Steel Blanks 307

Noel Chester, Jonathan Leung, Mary Wells and Kyle Daun

PACEFLAME™ – A Versatile Tool to Boost Efficiency in Hot Forming Processes 315

Matthias Bors

Full Hardening of Products in Hot Stamping Using Rapid Resistance Heating 323

Tomoyoshi Maeno, Ken-ichiro Mori, Masato Sakagami and Yoshitaka Nakao

New Developments in Furnaces for Press-Hardening 331

Harald Lehmann

Coatings II (A6)

Zinc Coated Press-Hardening Steel - Challenges and Solutions 345

Thomas Kurz, Harald Schwinghammer, Gerald Luckeneder, Thomas Manzenreiter, Andreas Sommer

Coating Evolution and Mechanical Behavior of Zn-Coated Press-Hardening Sheet Steel 355

Zahra N. Ghanbari, John G. Speer and Kip O. Findley

Microstructural and Phase Evolution of Galvannealed Coating during Hot Stamping Heating 363

Akihiro Sengoku, Hiroshi Takebayashi and Kenichiro Matsumura

The Development of the Coated Hot Forming Steels at WISCO	371
<i>Yunjie Bi, Guanwen Feng, Fang Fang, Rui Ge and Shaoyun Zhou</i>	

Press Hardening Steel I (B6)

Low Temperature Hot Forming of Medium-Mn Steel	381
<i>Qihang Han, Wenzhen Bi, Xinyan Jin, Weili XU, Li Wang, Xiaochuan Xiong, Jeff Wang and Paul Belanger</i>	

Hot Forming Response of Medium Manganese Transformation Induced Plasticity Steels	391
<i>Radhakanta Rana, C. Henry Carson and John G. Speer</i>	

Origin of Hematite Whiskers or ‘Red-Oxide’ on Bare Press Hardening Steels	401
<i>Luis G. Garza-Martinez, Robert J. Comstock Jr. and Jerry L. Arnold</i>	

Metallurgical Controlling Factors for the Ductility of Hot Stamped Parts	411
<i>Shigeo Otani, Masaya Kozuka, Toshio Murakami, Junya Naito, Andreas Pichler and Thomas Kurz</i>	

Process Design II (A7)

Intelligent Process Control for Press Hardening	419
<i>Dirk Landgrebe, Norbert Pierschel, Michael Alsmann, Julia Schönherr, Stefan Polster, Ulrich Priber, Frank Schieck and Sebastian Berndt</i>	

Deep Drawing Technique with Temperature Distribution Control for Hot Stamping Process	429
<i>Eiichi Ota, Yasuhiro Yogo and Noritoshi Iwata</i>	

Investigations on Aluminium Hot Forming in Comparison to other Aluminium Forming Technologies and the Press Hardening of Steel	437
<i>Martin Skrikerud, Christian Koroschetz and Lars-Olof Jönsson</i>	

Modeling & Simulation II (B7)

Artificial Neural Network (ANN) Based Microstructure Modelling of 22MnB5 Boron Steel During Tailored Quenching in Hot Stamping Process	453
<i>Prasun Chokshi, D. J. Hughes, D. Norman, I. McGregor and R. Dashwood</i>	

From Part Design to Part Production - Virtual Hot Forming Engineering Illustrated – Focus Material Modelling	463
<i>Eren Billur, Harald Porzner, D. Lorenz, Martin Holecek , M. Vrojlik, M. Hoss, B. Damenha, Johan Friberg, Christian Koroschetz and Martin Skrikerud</i>	

Development of an Experimental Friction Testing Platform and a Finite Element Simulation for Hot Stamping	471
<i>Chinghua Hung, Tzu-Hao Hung, Heng-Kuang Tsai, Fuh-Kuo Chen and Ping-Kun Lee</i>	

Heating & Cooling II (A8)

Influence of Short Austenitization Treatments on the Mechanical Properties of Low Alloy Boron Steel	481
<i>Martin Joachim Holzweißig, Anatolii Andreiev, Mirko Schaper, Jan Lackmann, Stefan Konrad, Christian Johannes Rüsing and Thomas Niendorf</i>	

Incomplete Austenitization of Patched Blanks in Hot Forming Die Quenching	489
<i>Kamalpreet S. Jhajj, Kyle J. Daun, Mary A. Wells and Stan R. Slezak</i>	

Bake Hardening Analysis of 22MnB5 PHS by the Impulse Internal-Friction	499
<i>Ho Jun Kwon, Won Seok Choi, Jewoong Lee and Bruno C. De Cooman</i>	

Tailored Properties III (B8)

Forming Tailored Material Properties through Direct Contact Heating	504
<i>Joshua N. Rasera, Natalie N. Field, Michael D`Souza and Kyle J. Daun</i>	

A New Hot Stamping Process to make Tailored Properties Based on Air Cooling	515
<i>Peixing Liu, Kai Wang, Zijian Wang, Bin Zhu and Yisheng Zhang</i>	

Prediction of Thermal Softening of Hardened High Strength Steel	529
<i>Zijian Wang, Kai Wang, Peixing Liu, Yilin Wang and Yisheng Zhang</i>	

Heating & Cooling III (A9)

Effects of Heating Time on Transformation during Cooling of Boron Steel Sheets	541
<i>Kazuo Hikida and Nobusato Kojima</i>	

Effect of High Cooling Rate on Shape Accuracy of Hot Stamped Parts 549

Naruhiko Nomura, Hiroshi Fukuchi and Atsushi Seto

**Characterization of the Interface Heat Transfer Properties
in the Hot Stamping Process 559**

*Fuh-Kuo Chen, Tzu-Hao Hung, Pei-Wu Tsai,
Cheng-Kuo Liu , Tyng-Bin Huang and Ping-Kun Lee*

Tailored Properties IV (B9)

**Hotformed Tailor Rolled Products, Tailored Lightweight
Design Solutions for the Vehicle Structure 571**

J. Brecht, S. Pohl, A. Schlender and H. Voswinckel

**Development and Testing of a Hot Stamped
Axial Crush Member with Tailored Properties 583**

*Kaab Omer, Alexander Bardelcik, Ryan George, Michael Worswick,
Duane Detwiler, Skye Malcolm and Nick Adam*

**The Crash Behaviour of Hot Stamped Components –
the Effect of Tailoring Conditions 591**

*Amir Abdollahpoor, Xiangjun Chen, Michael P. PereiraI,
Namin Xiao and Bernard F. Rolfe*

**Comparison of Several Mechanical Tests
to Demonstrate the Robustness of the
Hot-Stamped Laser Welded Blanks Solution 601**

S. Gaided, Y. Yin, L. Cretteur and M. I. Rotarescu

Cutting & Trimming (A10)

**Cost Effective Trimming in Hot Stamping through
the Combination of Accurate Blank Development,
Hot and Laser Cutting 617**

*Christian Koroschetz, Martin Skrikerud , Ronny Kristensson,
Lars-Olof Jönsson, David Lorenz, Harald Porzner and Matthias Hoss*

**Combined Cutting and Local Heat Treatment with Laser
Radiation of Ultrahigh Strength Press Hardened Steels 629**

*Sabrina Vogt, Frank Schneider,
Andreas Weisheit and Martin Flaischerowitz*

**Improvement in Hot Stamping Efficiency
Through Tooling Optimization 639**

*Xabier Agirretxe, José Miguel Martín, Mónica Carranza,
Lander Galdos, Joseba Mendiguren, Daniel Casellas,
Ricardo Hernández and M. Dolores Riera*

Tool Steel (B10)

Recent Developments in Tool Steels for Press Hardening Tools 651

Anwar Hamasaiid, Marine Grausem and Isaac Valls

**The Selection of Tool Steels for Hot-Stamping Tools
with Respect to Increased Loads 659**

Reinhard Rahn and Ingolf Schrupf

**Role of Tool Material in the Interfacial Problematics
of Tool/Blank in Press Hardening Process 669**

Anwar Hamasaiid, Casimir Casas and Isaac Valls

Coatings III (A11)

**Corrosion Resistance after Hot Stamping of 22MnB5 Steels
Aluminized with 80 g/m² c.w. and ZnO Coating 681**

*Soshi Fujita, Jun Maki, Shintaro Yamanaka,
Hideaki Irikawa and Masao Kurosaki*

Characteristic Comparison for Coated HPF Steels 691

*Il-ryoung Sohn, Heon-sok Hwang, Jong-won Choi,
Dong-jin Kim, Yeol-rae Cho and Jong-sang Kim*

Nanoparticle Coatings: Oxidation Protection during Press Hardening 699

Britta Tigges, S. Benfer, A. Tenié, M. Yekethaz, W. Bleck and W. Fürbeth

**Coating Preparation for Steel for Hot Stamping
by Pack Cementation Aluminizing 707**

*Yong Liu, Qin Zhan, Bin Zhu, Yisheng Zhang,
Hongguang Yang and Xiaoming Yuan*

Press Hardening Steel II (B11)

**Development of a 1.8 GPa Martensitic Stainless Steel
for Hot Stamping Application 715**

*Guillaume Badinier, Jean-Denis Mithieux,
Pierre-Olivier Santacreu and Jean-Marc Herbelin*

**A New Invention of Press-hardened Steel Achieving
1880 MPa Tensile Strength Combined with 16% Elongation
in Hot-Stamped Parts 725**

H. L. Yi, P. J. Du and B. G. Wang

**Challenges and Successes on Manufacturing
Hot Press Hardening Steels at CSP[®] Mills 735**

Weiping Sun, Jason Smiley, Neil Gao and Daniel Liu

Quenching and Partitioning (Q&P) Die Quenching Processing of 30MnSiCrB6 Press Hardening Steel	745
<i>Eun Jung Seo, Lawrence Cho and Bruno C. De Cooman</i>	

Tailored Properties V (A12)

Hot Stamping of Tailored Component – Experiments and Numerical Analysis	755
<i>Göran Lindkvist, Hans Åhlin and Mats Oldenburg</i>	

Press Hardening of a Martensitic Stainless Steel Sheet Alloy for Manufacturing a Side Sill Demonstrator with Tailored Properties	765
<i>Enrique Meza-García, Anja Rautenstrauch, Verena Kräusel and Dirk Landgrebe</i>	

Mechanical and Microstructural Properties of a Tailored Hot Stamping with In-Die Heating	775
<i>Alexander Bardelcik, Yonathan Prajogo, Michael Worswick, Duane Detwiler and Skye Malcolm</i>	

Modeling & Simulation III (B12)

Simulation of a Comprehensive Hot Forming Process and its Experimental Analysis	785
<i>Martin Stillger, Steffen Hölzemann, Stéphane Graff, Stefan Werner-Bielefeld and Thomas Brenne</i>	

Understanding Temperature and Contact Pressure in Hot Stamped Channels	793
<i>Bernard Rolfe, Peng Zhang, Amir Abdollahpoor, Chengyong Wang and Michael PereiraI</i>	

Optimization of Finite Element Simulation for Press Hardening Processes	801
<i>Ralf Helmholz, Christina Sunderkoetter, Armin Plath, Hans-Elias Marusch and Bernd-Arno Behrens</i>	