The 9th International Conference on Semi-Solid Processing of Alloys and Composites — Busan, Korea, September 11-13, 2006

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Busan, a bustling city of approximately 3.7 million residents, is located on the Southeastern tip of the Korean peninsula. It is the second largest city in Korea. The natural environment of Busan is a perfect example of harmony between mountains, rivers and sea. Its geography includes a coastline with superb beaches and scenic cliffs, mountains which provide excellent hiking and extraordinary views, and hot springs scattered throughout the city.

The 9th International Conference on Semi-Solid Processing of Alloys and Composites was held Sept. 11-13, 2006 at Paradise Hotel, Busan. The five-star hotel offered a spectacular view of Haeundae Beach – Korea's most popular resort, which was the setting for the 9th S2P conference. The biannual international S2P conferences are dedicated to the science and technology of semi-solid metal processing and provide a grand forum for academia, scientists, engineers and manufacturers to share experiences and disseminate their latest understandings as the process continues to emerge and grow commercially. The first was held in 1990 in Sophia-Antipolis, France, and since has been held every other year at varied venues around the globe; Cambridge, MA (1992); Tokyo, Japan (1994); Sheffield, England (1996); Denver, CO (1998); Torino, Italy (2000); Tsukuba, Japan (2002); Limassol, Cyprus (2004); and Busan, Korea (2006). The next conference is already being planned for Aachen, Germany, in 2008.

***Figure 1** - A glance of Paradise Hotel.*

***Figure 2** - The setting for the 9th S2P Conference.*

Pusan National University, in conjunction with the Korea Institute of Industrial Technology, and the Korea Society for Technology of Plasticity hosted the 9th S2P conference. About 180 scientists and engineers coming from 23 countries attended the conference to present and discuss all aspects on semi-solid processing of alloys and composites. Eight distinct sessions contained 113 oral presentations and 61 posters. The eight sessions included: 1) alloy design, 2) industrial applications, 3) microstructure & properties, 4) novel processes, 5) rheocasting, 6) rheological behavior, modeling and simulation, 7) semi-solid processing of high melting point materials, and 8) semi-solid processing of wrought alloys.

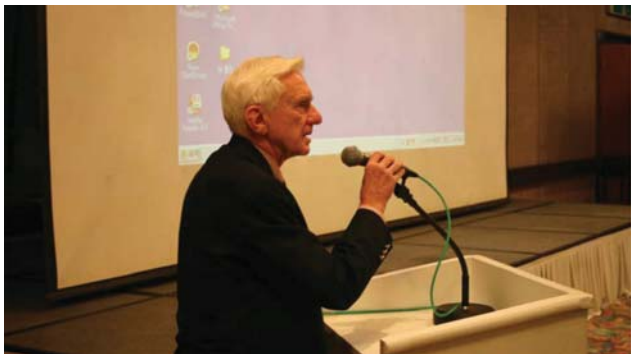

***FIGURE 3** - Professor Merton Flemings of MIT is giving a keynote presentation entitled "Principles of Microstructual Formation in Semi-Solid Metal Processing."*

The conference was opened with remarks by Professor C.G. Kang, the conference chairman. Keynote addresses were given by Drs. M.C. Flemings, M. Goka, H.V. Atkinson, Q.Y. Pan, G. Hirt and C.P. Hong. The keynote session provided an overview of microstructural formation principles, processing of high melting point materials, process development and optimization, as well as rheology and modeling, which set the theme for the sessions that followed.

The following sections give an overview of the eight sessions:

Alloy Design

Often newly developed manufacturing processes are evaluated with existing alloys rather than optimizing a special alloy that can take advantage of the attributes of the new process. Currently, conventional cast aluminum alloys are being used for SSM processing, which limits the full potential of this new technology. SSM alloy development/optimization remains a significant issue in SSM processing.

Several efforts have been dedicated to SSM alloy development and optimization. For example, Q.Y. Pan from WPI described the application of thermodynamic simulation to optimize a European die casting alloy-EN

AC 46000 for semi-solid processing. Similarly, J. Lecomte-Beckers and colleagues evaluated the thixoformability of several steels using both DSC analysis and thermodynamic simulations. A. Pola and co-workers developed new Al-Six-Mgy-Cuz alloys for semi-solid processing of structural components using thermodynamic simulations.

Industrial Applications

Twelve papers were presented in this session, which covered a broad spectrum of industrial applications. These included die coatings, casting simulations and designs, etc. For instance, S.Y. Lee from AnDong National University, Korea, spoke on the application of PVD coatings to improving die performance during SSM processing of copper alloys. They found that TiAlN/CrN multilayer coating gives the best protection. H.N. Chou and colleagues described the opportunities and challenges to fabricate aircraft components using semi-solid processing. They pointed out the main development area that needs to be addressed is to demonstrate that the technology can process high quality components within the tolerances specified by the aerospace industry and to establish a reliable database of mechanical and corrosion properties for SSM cast alloys.

Microstructure and Properties

The rheological properties of semi-solid metals are strongly dependent on their microstructure. A great deal of work was dedicated to understanding microstructural formation and evolution of various alloys under different processing conditions. In his keynote talk, professor M.C. Flemings addressed the role of cooling and convection in the formation of SSM structures, which set up a stage for this session.

W.D. Huang from Northwestern Polytechnic University, China, spoke on in-situ observation of SSM microstructure formation using a transparent alloy – NH_4Cl-H_2O – and a cooling slope under various variation conditions. J.P. Choi of Hanyang University in Korea described the effect of electromagnetic vibration frequency on the microstructure of hypoeutectic Al-Si alloys. They found that a low frequency (≤60hz) usually changes the morphology of the primary alpha phase, whereas, an extremely high frequency (≥500Hz) will change the morphology of eutectic Si phase.

Z.H. Wang and colleagues investigated SiC nanoparticle reinforced magnesium alloy-AM60 via semi-solid processing. They found that mechanical properties of the alloy can be improved considerably. M. Suery talked about in-situ 3D investigation of microstructural evolution during partial remelting of Al-Cu alloys using fast X-Ray microtomography. Essentially, this work is a continuation of their experiments reported at the 8th S2P conference. S.J. Luo from Harbin Institute of Technology gave an overview regarding the research progress of semi-solid processing in China. He reviewed the progress in six distinct research areas and described semi-solid processing as "a beautiful flower in the garden of metal processing in China."

Novel Processes

Eight papers were presented in this session, which highlighted several novel processes and applications. For instance, J. Wannasin from Prince of Songkla University, together with his colleagues R.A. Martinez and M.C. Flemings at MIT, introduced a novel process to make

SSM metal slurries. In this approach, gas bubbles are introduced into the melt during the initial stage of solidification to provide a certain amount of agitation, coupled with a controlled cooling. The approach can generate slurries with excellent SSM structures and shows a potential for rheocasting applications. F. Pahlevani and colleagues developed a simple cup-cast method, where the turbulence during pouring and heat distribution in the melt are controlled and optimized in order to generate SSM structures.

The cleanness of molten metal is critical for structural components. M. Fuchs from Buhler Druckguss AG, Switzerland, introduced an optimized molten metal feed system – Buhldos. Instead of using a channel, Buhldos utilizes a heated pipe to convey molten metal directly to the shot sleeve of a die casting machine with high feed accuracy and melt cleanness, which can have a significant impact on mechanical properties of structural components. Q.Y. Pan from WPI, demonstrated an important application of the Continuous Rheoconversion Process (CRP™) to low temperature high pressure die casting, where cycle time (process cost) can be reduced considerably by using an optimized CRP™ reactor.

Rheocasting

Twenty-two presentations focused on 1) development of new rheocasting processes and 2) optimization and refinement of rheocasting processes that have been developed recently. H.M. Guo of Nanchang University, China, introduced a process termed "Low Superheat Pouring with a Shear Field (LSPSF)," where the nucleation and growth of the primary phase are controlled by flowing low superheat melt through a rotational barrel. J.K. Lee from Korea Institute of Industrial Technology described an in-ladle direct thermal control (DTC) rheocasting process, in which the nucleation and growth of the primary phase are controlled through a strict thermal management of the melt in ladle. F. Knauf of RWTH Aachen University, Germany, demonstrated a concept of rheoforging of steel. Instead of reheating a steel ingot into the semi-solid state, the process involves pouring a low superheat melt over a slope into a holding cup, holding the melt for a certain amount of time and followed by inline forging.

J. Langlais of Alcan International gave an overview regarding the progress in commercializing the SEED process developed recently by Alcan, as well as their work to optimize processing parameters. M. Reisi from Isfahan University of Technology, Iran, spoke on the effect of secondary cooling rate upon morphology and size of the primary alpha phase of SSR processed Al-7Si alloy.

In his keynote address, Q.Y. Pan spoke on the effect of two key parameters-fraction solid and gate flow velocity on casting integrity and properties during rheocasting. In this study, systematic rheocasting (SLC™ process) and squeeze casting trials were conducted to investigate the interaction of the two parameters. Experimental results can provide valuable guidance for SSM process optimization.

Rheological Behavior, Modeling and Simulation

Semi-solid slurry differs significantly from molten melt during die filling in that semi-solid slurry can flow at a much higher velocity than liquid metal while still maintaining a stable flow front. Thus, semi-solid slurry is capable of rapidly filling thin sections without turbulence and air entrapment which is inevitable with fully liquid metal. One ongoing effort is to fully understand the rheology of semi-solid metals and to improve the capability to describe and predict SSM process. In her keynote address, H.V. Atkinson gave an overview regarding various experimental methods for rheological measurement. Specifically, she addressed the importance of transient rheological data in modeling SSM process.

Twenty-one presentations in this session concentrated on rheological behavior of semi-solid metals, and modeling of SSM process. A. Alexandrou from University of Cyprus gave a talk on "Parameter Estimation for Semi-Solid Aluminum Alloys Using Transient Experiments." M. Modigell of RWTH Aachen University, Germany, spoke on "Dynamic and Static Yield Stress of Metallic Suspensions." Also, he gave a second talk on "Rheology of Semi-Solid Steel Alloys at Temperature up to 1500°C." B. Ouriev of Buhler AG, Switzerland, presented a paper entitled "Rheology and Rheometry of Aluminum Alloys: Influence of Shear and Vibration on Aluminum Flow Properties," in which he found that vibration can change the rheological behavior of 226 alloy slurry from a shear-thinning to a Newtonian fluid. K. Solek and colleagues presented their work on the simulation of thixocasting process using ADINA simulation tool. S.S. Wu from Huazhong University of Science and Technology, China, spoke on their work on numerical simulations of rheo-diecasting process of Mg alloys using the computer program developed by the authors.

Semi-Solid Processing of High Melting Point Materials

Semi-solid processing of high melting point materials such as steel has gained more and more interest. As a fairly high temperature is involved during die casting process, one significant challenge is to develop/improve die materials that can stand such a high forming temperature. In fact, the development of die materials and die coatings was a prevailing theme of this session.

Thirteen papers were presented in this session. In his keynote talk, G. Hirt from Institute of Metal Forming, Germany, gave an overview regarding the progress in semi-solid casting and forging of steel, which set up the stage for this session. Specifically, he pointed out that tool life and part quality are two challenging issues that need to be well addressed.

R. Telle and co-workers studied the performance of silicon nitride (Si_3Ni) dies for steel thixoforming. They found that a proper die design and process conditions (cycle time, solidification time in the die) play an important role in the service life of these ceramic dies. Similarly, S. Muenstermann and colleagues introduced a self-heating oxide ceramic tool for thixoextrusion of high melting point alloys and found it is feasible for extruded steel parts with high shape accuracy and low extrusion forces. K. Bobzin and coworkers from RWTH Aachen University investigated the performance of PVD γ-Al_2O_3 thin film coating on a steel substrate as a tool protection. They found that PVD γ-Al_2O_3 coating shows an extraordinary stability for thixoforging of X210CrW12 and 100Cr6 steels. As a result, it can increase service life of tool considerably.

H.V. Atkison spoke on in-situ observation of semi-solid A201 samples using environmental scanning electron microscopy (ESEM). ESEM circumvents a limitation of conventional SEM in that samples can be examined in a gaseous atmosphere rather than a vacuum, which provides a useful means to understand microstructural evolution of semi-solid metals and thixotropic phenomena.

Semi-Solid Processing of Wrought Alloys

Seven papers presented in this session focused on thixoforging of 7000 series alloys. For example, Z. Azpilgain and colleagues studied thixoformability of 7000 series alloys using thermodynamic calculations and calorimetric experiments. G. Vaneetveld and co-workers investigated thixoforging of 7075 alloy at high solid fractions and found that a high solid fraction is beneficial for parts with thick sections. Y.O. Yoon of Sungkyunkan University, Korea, spoke on the development of thixoextrusion process for 7003 and 7075 alloys. K.H. Choe from Advanced Material R&D Center, KITECH, Korea, described thixoforging of high strength brass-KS CACIn304 (UNS C86300).

Concluding Remarks

Throughout the conference, a prevailing theme was rheocasting as it is commercially viable and attractive for the die casting industry. A great deal of effort has been devoted to: 1) the refinement of SoD processes that have been developed recently, and 2) the development of new, robust SoD processes. Several novel SoD processes have emerged and reported during this conference, which show a potential for commercial applications. It is envisioned that armed with our in-depth understanding on microstructural formation in the semi-solid state, simpler, robust, yet commercially viable SoD processes will be developed and commercialized. These developments will define the future of semi-solid processing.

In addition, semi-solid processing of high melting point materials such as steel has gained more and more interest in this community as it offers many benefits over conventional processes. Although much progress has been demonstrated during the conference, tool life and casting quality are still two challenging issues that need to be well addressed in the future.

All papers of the 9th S2P conference were collected in a special issue (Vols. 116-117, 2006) of the journal — "Solid State Phenomena." The journal is electronically available at www.scientific.net.

The 10th S2P, Aachen, Germany, 2008

Planning of the 10th S2P conference to be held in Aachen, Germany, in 2008 is already underway. Readers with interest in semi-solid processing are encouraged to keep watch for official call for papers and to offer presentation for this unique venue.

About the Author

Dr. Qingyue Pan is a research associate professor of the Metal Processing Institute (MPI) at Worcester Polytechnic Institute (WPI). He received his Ph.D. in materials science and engineering from Northwestern Polytechnic University in 1997. Dr. Pan joined MPI team in 1998 as a Postdoctoral Fellow and was appointed as a research associate professor in 2004. His research interests include alloy development, solidification processing, metal casting and semi-solid metal processing. He is a member of AFS, TMS and Sigma Xi. and has more than 40 scientific publications to his credit.