Fall 2002

Center for Innovative Sintered Products

CISP

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Director's Note

Randall M. German-Center Director

During the past several months I have spoken to many in this industry and have been asked repeatedly what we are seeing at the academic end. We are seeing the fundamental changes that take place following a crisis. Harsher domestic conditions and international competition have made this industry tougher, more innovative, and better equipped to seize opportunities. Once again, we are seeing an upswing in visits to the Center and an interest in company-sponsored projects. Companies are contacting CISP in search of potential employees. Requests to perform testing and services are up. This is a healthy sign that industry is once again interested in research and development. Although the U.S. economy hasn't bounced back to full-scale growth, we are on a positive course.

The importance of research, development, and training are once again recognized by government officials and requests for proposals are surfacing almost daily. There are calls for proposals from all sectors, especially in areas to increase security or military applications. International cooperation and collaboration are emphasized; new calls are requiring joint research proposals with institutions throughout the world. We are in the process of preparing a proposal for Inter-American collaborations with two universities in Brazil, in addition to a second NSF proposal involving European Union partners. This is an ambitious effort, necessary to enhance our ability to continue on this path of progress.

Dimensional Producibility of High Tolerance Press and Sinter Components

This CISP sponsored project is beginning its third year. Past efforts focused on the collection of comprehensive dimensional capability data from P/M part producers. We have now shifted to the next critical phase of the effort - data analysis and model building. Our analysis database includes both process information and dimensional characteristics. We are assessing dimensional errors both from centering and from dimensional variability. Initial findings show large differences in the overall dimensional capabilities from producer to producer. Some companies have achieved low dimensional variability through effective process control while others excel at accurate dimensional centering both from the tool itself and from tool adjustments during production. However, for the various part producers studied, centering dimensional control does not always coincide with dimensional control through process control. Tight tolerances and small centering errors for Z-axis dimensions, indicate that good press setup and adjustment strategies are being employed. The large centering deviation on Z-axis by many producers suggests that process adjustment is a major component of overall dimension variation. The centering deviation on diameter measurements indicates that efficient dimensional feedback from tooling design to the final product has not yet been established.

Over the next months, further data analyses as well as continuing in-plant dimensional capability trials are planned. The broad support from participating companies is gratefully acknowledged. Contact: Bob Voigt (rcv2@psu.edu)

PENNSTATE
Center for Innovative Sintered Products

Upcoming Events

October 22-23, 2002
Powder Injection Molding Tutorial
State College, PA

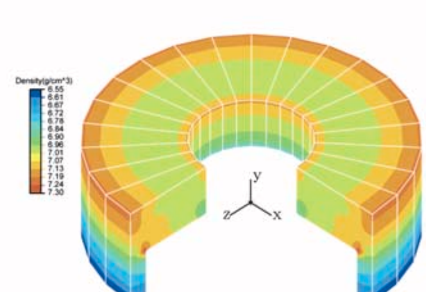
November 6, 2002
Sintering Concepts and Practices
Ridgway, PA

February 24-25, 2003
Industry Member Meeting
University Park, PA

March 17-19 2003
PIM 2003
State College, PA

March TBA 2003
Understanding Particle Characteristics in P/M and Ceramic Processing
University Park, PA

Numerical Simulation of the Die Compaction Process



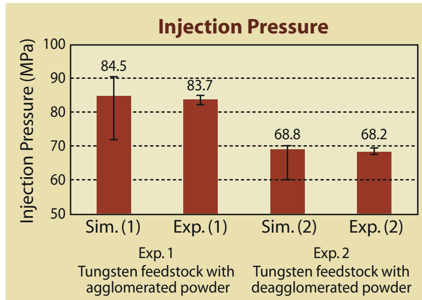
Distaloy AE powder
Density distribution after compaction

Crack generation during the die compaction process is a hot issue in the PM industry. CetaTech is working with CISP and the Center for Powder Metallurgy Technology to predict crack generation and densification behavior of the green part during the die compaction process. A new method to determine the material parameters for compaction modeling is proposed and verified with the experimental data of the die compaction process for a hub shaped part with complex loading condition. The proposed method using only a die compaction test for the simple cylindrical shape is simple, yet powerful without the need for the cold isostatic pressing (CIP) test, triaxial test or hot isostatic pressing (HIP) test. Even with this simple die compaction test, the simulation results from PIMsolver (FEA program to analyze and optimize the die compaction process) are excellent.

The new damage model is based on the Drucker-Prager failure surface to predict crack generation. The proposed damage model shows the accumulated damage in the green part by measuring the accumulated separation length from the Drucker-Prager failure surface. Additional research in this damage model is needed to verify and determine the parameters, but the proposed damage model is giving reasonable results. To date, 5 European research centers (CEA/Ceram in France, Fraunhofer IWM Frieburg in Germany, Lulea University of Technology in Sweden, University of Wales Swansea, UK, VTT in Finland) have already performed the simulation work for the same geometry and same loading conditions. Although many tests to determine the material parameters for the compaction modeling including triaxial test have been performed, the current results are superior in accuracy. Contact: Young Sam Kwon (yuk3@psu.edu)

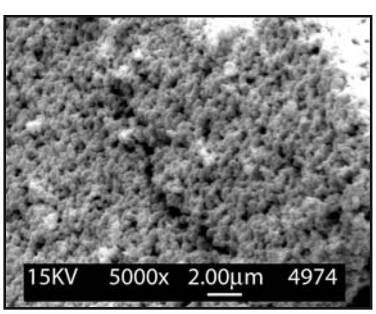
PIM Simulations

A 2.5D modeling of powder injection molding process is being conducted using the PIMsolver software to identify the effects of mixing and the rheology of the feedstock on the filling phase. This work was conducted at CISP in collaboration with Cetatech, Korea and UFGRS, Brazil. The simulations require that the feedstock be characterized for apparent slip phenomenon and temperature dependence of the viscosity. Results of the simulations considering the variability of viscosity with time for tungsten-based feedstocks are in close agreement with the experimentally observed injection pressures. Contact: Pavan Suri (pavans@psu.edu) or Song Jin Park (sup13@psu.edu).

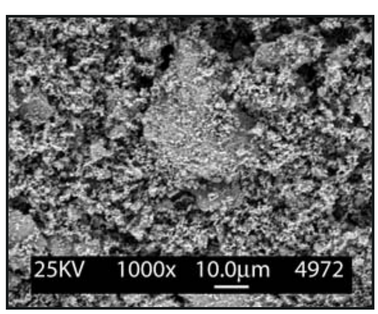


Research on W-Cu

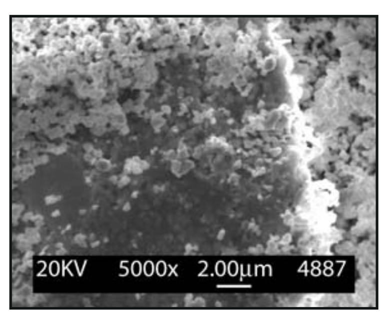
W-Cu composites, also called pseudo alloys, are an important class of material finding application as heat sinks for electronic application due to a combination of high thermal conductivity and low thermal expansion coefficient. While near-full dense (96-98 % of theoretical density) components are sintered, the role of impurities such as oxygen and transition metals picked up during processing is recognized but not quantified. Currently, fundamental research is being conducted using tungsten coated copper powders, ball milled W-Cu powders and mechanically alloyed powders to isolate the aforementioned effects on the sintering, properties, and microstructure of the W-Cu alloys. Contact :Pavan Suri (pavans@psu.edu).



As-received Tungsten-coated copper powder



Mechanically Alloyed W-Cu powder (1 hour in heptane)



W-Cu ball milled powder milled with WC-Co milling media for 24 hours

Furnace hits 2000°C

The Center for Innovative Sintered Products successfully launched the Kanto Yakin Kogyo (KYK) "Oxynon" furnace in late August. KYK Chairman Susumu Takahashi and President Shin-ichi Takahashi, along with other KYK delegates, industry personnel, and PSU researchers participated in this momentous occasion. This 225 mm wide (9 in) graphite belt furnace capable of 2000°C sintering is the first installation of this technology in the USA. It uses no flammable gases in its operation, yet creates reducing conditions during continuous sintering of strategic materials like titanium, tungsten-copper, Kovar, Invar, and Inconel. Samples of steel, titanium, and molydenum have been run with promising results. The final test concluded with a 48 hour run at 2000°C of molybdenum samples. The equipment is now available to companies for experimental purposes. Contact: Don Heaney (dfh100@psu.edu)

Top: First production run coming from the furance

Left: Rand German (Center Director) and Chairman Susumu Takahashi (Kanto Yakin Kogyo) examine first test samples.

Hard Metals

To avoid segregation and decomposition, the only way to make hard metals is via powder metallurgical green body preparation, and liquid phase sintering. After seven decades of production and use of hard metals the remaining issues for R&D are (a) the exploration of novel compositions and very fine powders for higher wear resistance/performance, e.g. for machining of miniature components, (b) novel consolidation techniques such as ultra-low-oxygen open furnaces and spark plasma sintering, free-form fabrication of complex shape parts, e.g. extrusion and sintering of functionally graded parts, but also (c) conceptual improvements such as lamination to optimize machining of common structural materials, as well as (d) particle coating for micro-tailoring of properties and performance. Technical capabilities are available at CISP, with several developments already underway. Contact: Ivi Smid (smid@psu.edu)

Refractory Alloys & Composites

For the very high melting temperatures of refractory alloys and composites, no crucible material is available for confinement of the melt. One way to make dense components is to pre-shape powders (cold compaction, selective laser sintering) and sinter in a reducing atmosphere; this is the conventional approach. Alternatives are (a) carbon crucibles, made of graphite or C/C composites, taking advantage of the presence of CO which reduces the partial pressure of oxygen (Oxynon furnace), or (b) applying direct heating, such as microwave heating and hot pressing. All essential pieces of equipment are available at PSU including the only "Oxynon" furnace installed in the USA. Contact: Ivi Smid (smid@psu.edu)

Sintering 316L Stainless Steel

As part of a larger study on the effects of chemistry variation on shrinkage in compacted 316L stainless steel, it was necessary to isolate the effect of particle size on shrinkage. Since small chemistry variations can affect shrinkage, one lot of 316L powder was sieved and re-blended to generate 5 different particle size distributions with the same chemistry, thus isolating the particle size variable. It is observed that relatively modest changes in particle size produce a significant difference in shrinkage. This data will be incorporated into a model to predict sintering shrinkage of 316L stainless steel, considering temperature, time, chemistry, and particle size. Contact Neal Myers (nsm104@psu.edu)

Modeling Two-material Injection Molding.

Two-material injection molding offers a unique opportunity in manufacturing functionally graded components. It is generally recognized that a successful processing of two-materials demands compatibility in the sintering behavior of the materials. Experimental results and theoretical considerations on the two-material injection molding of steels conducted at CISP indicate that such compatibility can be established via dilatometry. The extent of permissible deviation in the sintering behavior of the two materials is related to the *in situ* strength of the material during sintering. Contact: Don Heaney (dfh101@psu.edu) or Pavan Suri (pavans@psu.edu).

Student's Corner

Jobe Piemme

Jobe Piemme is a masters student in Materials at CISP. His thesis work investigates factors affecting dimensional variation for stainless steel powder injection molded components. Jobe has a B.S. in Plastics Engineering, with a major focus on injection molding. He has completed three internships at two metal injection molding companies. Jobe is graduating in December 2002 and will be seeking a full-time position in MIM.

Scholarships Awarded

Congratulations to Tony D'Amore and Shawn Keebaugh, this year's recipients of the AMETEK and Clayton Family Scholarships from the Center for Powder Metallurgy Technology. Tony is a senior in Electro-Mechanical Engineering and is looking forward to graduate school. He holds an associate degree in Materials and Mechanical Engineering Technology from Penn State DuBois and a certificate in Nano-Fabrication Manufacturing Technology. During the past summer he participated in our REU program on the research project "Producibility of High Precision Sintered Components". Shawn is a senior in Engineering Science and Mechanics.

Tony D'Amore

Shawn Keebaugh

He has been working at CISP for the past year on both the "Process Enhancements for Powder Injection Molding for Six Sigma Precision" and the "Multi-Axial *in situ* Monitoring (M.A.I.S.M.) Laser Dilatometer" research projects. Shawn's future goals are to continue his education at Penn State and work towards a PhD in Engineering Mechanics.

National Science Foundation Award Granted

The National Science Foundation has awarded a $500,000 grant for research to be conducted on "Protocol Development for Net Shape Powder Metal Part Production" to R. Engel, R. German, J. Rose, and S. Atre. The research team, involving 4 Ph.D. students, combines complementary skills in powder metallurgy, ultrasonic inspection, binder/lubricant technology, and computer-based design in manufacturing/processing. A set of protocols will be established to reduce the dimensional variability of die compacted 316L stainless steel components and will address material and processing issues to achieve distortion-free, full density components. For further information, please contact Sundar Atre (sva101@psu.edu)

Mr. Fox Returns from Japan

Kevin Fox, a graduate student working on the CISP funded project "Laminated Metal Carbide-Metal Binder Structures for High Performance Cutting Tools," recently returned from Japan where he participated in a summer research program sponsored by the National Science Foundation. While in Japan, Kevin worked with Spark Plasma Sintering, a technology recently developed and commercialized in Japan by Sumitomo Coal Mining Co. His study evaluated rapid densification of nano-grained, functionally graded WC-Co cutting tools below the eutectic temperature.

This NSF Summer Program provides U.S. graduate students in science and engineering first-hand experience in Japanese research environments, an introduction to the science and science policy infrastructure of Japan, and language training. The primary goals of the program are to introduce students to Japanese science and engineering in the context of a research laboratory and to initiate personal relationships that will better enable them to collaborate with foreign counterparts in the future. The Summer Institute supports up to sixty students each year.

The Industrial Ecology of Particulate Materials

sponsored by
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4-5 December 2002

http://www.mri.psu.edu/centers/cme.asp

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