Spring 2004

Center for Innovative Sintered Products

CISP

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PIM 2004: A Quick Update

Global Powder Injection Molding Industry

Rand German – Director

The PIM industry had its annual update meeting in Orlando, Florida, in March. This series of annual meetings started in 1990 and is set to continue with next year's program planned for San Francisco in March 2005. The meeting is organized by the Center for Innovative Sintered Products and managed by Innovative Material Solutions. The meeting was attended by CISP member firms, trade organizations, publishers, universities, and various industry segments, with a surprising participation by the cemented carbide segment. This year the participant gift was provided by AMT. Co-chairs were Kay Leong Lim from Advanced Materials Technologies (Singapore) and Christian Kukla of Battenfeld Kunststoffmaschinen (Austria).

As characteristic of prior PIM meetings, there was broad support, including passive participation (looking on but not saying much) from more than 35 PIM producers, good participation by the supplier and equipment vendors, and an excellent university presence. PIM 2004 consisted of

- 110 registrants
- 40 oral presentations
- 19 tabletop displays
- participants from 17 countries.

An interesting trend was the strong presence of companies wanting to buy into the industry. Further, representatives from large-scale users attended the meeting to review vendors. Clearly, the PIM meetings have an important undertone of networking, with significant business discussion going on in the hallways.

From a technical viewpoint, highlights included discussions on how master alloys are becoming a major means to fabricate ferrous alloys. The atomized master alloy is mixed with carbonyl iron and during sintering the mixture homogenizes to form the alloy. Progress was documented on large PIM parts with a few examples presented from stainless steel and tungsten alloys. At the other end of the spectrum, microminiature PIM is now common. Computer modeling was present in many areas, with some impressive demonstrations on mold filling, sintering shrinkage, and powder-binder separation. Various functional gradient materials including simple bimetallic (two-layer) materials were demonstrated, including the novel combination of dense and porous materials. Material properties, rheological data, sintering models, and new furnace control concepts were documented. A surprising presentation on alumina injection molding demonstrated the importance of powder moisture control for repeatable parts production. Overall, the meeting was upbeat and filled with positive news and optimistic participants. Fostering this dialog is one of our important roles and the effort will continue on the west coast next year. Although the CISP researchers enjoy the opportunity to show off our lab, a trip to Orlando this March, and San Francisco next year, are attractive alternatives.

Crack Detection in Green Parts

Identifying cracked green parts before sintering and removing them from a sintering batch reduces the cost of producing P/M parts by eliminating added procedures on defective parts. Inspection using the surface wave mediator technique provides an indication of a green part's structural integrity for quality control during the manufacturing process.

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Upcoming Events

May 10-11, 2004
Industry Member Meeting
University Park, PA

June 13-17, 2004
PM²TEC
Chicago, IL

October 4-5, 2004
Industry Member Meeting
University Park, PA

October 17-21, 2004
PM2004 World Congress
Vienna, Austria

KYK Inspection/Upgrade

KYK, the manufacturer of the Oxynon furnace, visited CISP in February for inspection, upgrading, and training. The furnace is functioning well, although a few adjustments were needed to lower the oxygen partial pressure. The Oxynon furnace can process metals and ceramics at temperatures of up to 2000°C. It allows the sintering and brazing of metals and alloys at a reduced oxygen partial pressure without the use of vacuum or hydrogen. This is particularly desirable for sintering and brazing of materials with high vapor pressure elements such as chromium and manganese. CISP has been doing trial runs for industrial clients on sintering and brazing of metals and alloys such as stainless steel, tungsten, tungsten carbide, niobium, molybdenum, titanium, manganese containing brazes, alumina, etc. The Oxynon furnace works by reducing the partial pressure of oxygen within the furnace by oxidation of the graphite in the furnace. The graphite essentially acts as a "getter" for any residual oxygen that is present in the process gas. Some highlights: titanium has successfully been sintered continuously with an elongation of 15%; superalloys have successfully been brazed; and manganese containing braze has successfully been used to sinter braze P/M components with good bond strength. Many other materials have been evaluated in the furnace and are under development. For more information contact Tracy Potter (tjp4@psu.edu) or Donald Heaney (dfh100@psu.edu).

Crack Detection in Green Parts

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This technique is unique because it allows for the inspection of green parts through minimal contact without the potential for contamination of the part surface before sintering.

Research completed on this project to date has been tremendously successful in a laboratory environment. The development of a versatile fixture for proper alignment of the surface wave mediators allows for the inspection of a variety of different part geometries with repeatable results. The surface wave mediator technique has a high sensitivity for determining the presence of cracks in green compacts.

Recent testing performed at a CISP member company has shown the versatility of the surface wave mediator for testing parts with complex geometries and has provided us with feedback for improvement on the testing technique, fixture, ultrasonic data acquisition hardware and software, and crack determination algorithms. These improvements will make the system easier for press operators to use when setting up presses and easier to implement in an inline inspection system.

To generate interest in the technique from the automotive industry and the powder metal industry, the following papers are being presented: "A Novel Couplant Free Mediator Ultrasonic Rayleigh Wave Technique for Detecting Surface Cracks in Green Parts" presented at the SAE 2004 World Congress, March 8-11, 2004, Detroit, MI and "Green Part Crack Detection Using Ultrasonic Surface Waves" to be presented at PM^{2}TEC 2004: International Conference on Powder Metallurgy & Particulate Materials, June 13-17, 2004, Chicago, IL.

Green parts with crack formation problems during pressing and handling are requested so that we can further develop our testing technique, as well as solve problems that are important to industry. We are also interested in discussing implementation considerations at industry. Eric Hauck (eth116@psu.edu).

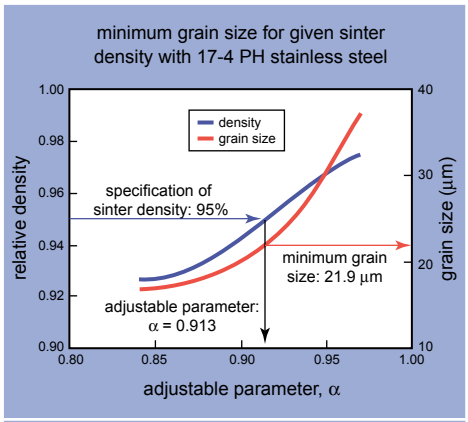
Integration of MSCs and Optimization of Sinter Cycle

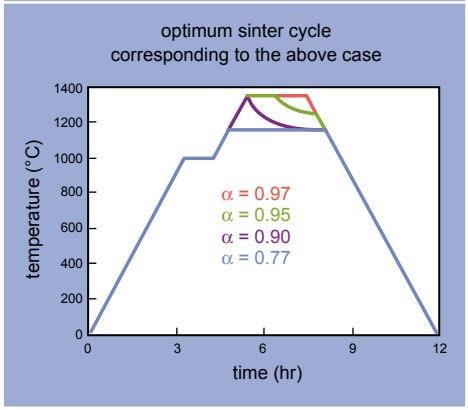
CISP has developed a novel software to construct master sintering curves (MSCs) for densification and grain growth of materials during sintering. The MSCs can be integrated and optimum sintering cycles can be designed to obtain better final properties.

The software

- enables the process designer to better understand the sintering behavior for a given material system
- helps the process designer to design the initial sintering cycle with relatively few experiments
- helps the process designer optimize the sinter cycle to minimize grain size for a given specification of density

Contact Seong Jin Park (sup13@psu.edu) or Ravi Bollina (rxb901@psu.edu).





The Sub-Sieve Sizer – Still Useful

With the prevalence of advanced particle size measurement techniques such as laser scattering, dynamic light scattering, zone sensing, optical counting and others, the Fisher sub-sieve sizer (FSSS) is sometimes considered an obsolete instrument. The technique itself is over 60 years old; possibly the only older way of measuring small particles is the sieve.

The sub-sieve technique measures particle size by measuring the pressure drop across a packed powder bed using a water-based manometer. The pressure drop is related to the permeability of the packed bed, which is related to the surface area of the particles, which is reduced to an effective spherical average particle size on the instrument using a pre-calculated paper chart. The instrument itself has a charming old-fashioned look, with a wood finish, glass plumbing, calculator chart reminiscent of an oversized slide rule, and no attached computer. When the unit is seen next to modern computerized instruments in our lab, a common question heard from people is, "Do you still use that?" *(Pictured: Kevin Razawich operating the FSSS)*

A major disadvantage of the technique is that it does not give any information on the distribution of particle sizes within the powder, only a surface-area based average size. If a maximum particle size specification must be met, the Fisher test by itself cannot determine that a given powder is all below a given size. However, this does not prevent the instrument from being used extensively.

In commercial powder production, the FSSS is used in generating particle size data for lot analysis specification sheets, including cobalt, graphite, nickel, molybdenum, tungsten carbide, and tungsten. It's also used in powder lot analysis for precursor chemicals in metal and ceramic powder production, and for powders used in drying tubes for gas chromatography.

Beyond industrial use, FSSS can be used for biological powder testing. The FSSS is used to qualify several pharmaceutical products including an antifungal drug used to treat ringworm. Recently, CISP participated in a study on the use of commercial iron powders for nutritional fortification. This effort is coordinated by Sustain (www.sustaintech.org), a non-profit organization dedicated to improving nutrition in developing countries by sharing technology. CISP's effort in support of this study was to measure physical properties of the powder in an attempt to develop a screening test to determine whether a commercially available iron powder was suitable for use as a nutritional supplement in areas where iron-deficiency anemia is a problem, especially for children.

In the course of the Sustain study, laser scattering particle size, BET surface area, FSSS size, and acidic solution solubility of several iron powders made by different methods were measured by multiple labs in a double-blind round-robin study. It was found that the FSSS size correlated best with the observed solubility (–0.93 correlation coefficient [r]), slightly better than BET surface area (r=+0.90) and much better than D50 laser scattering particle size (r=–0.70). Sub-sieve data from the round robin also had less variation between labs than BET data.

A study on dimensional control of press and sinter 316L stainless steel is under way at CISP, examining the effects of many powder parameters on the dimensional reproducibility of sintered parts. It was found that the sub-sieve particle size number showed a strong linear correlation (r~–0.91) at both high and low sintering temperatures, while no linear correlation was observed (r~–0.1) for laser scattering D50 at either temperature.

The high correlations between Fisher sub-sieve particle size data and chemical or sintering behavior indicate that this is still a very useful tool in evaluating powders for use in industrial, medical, or biological applications. The easy use of the instrument and its low cost to buy (under $5000) and to own (under $100 per year if running 10 tests a day) are all attractive qualities. The Fisher sub-sieve can still hold its own in a lab full of modern equipment. Lou Campbell (lgc102@psu.edu).

Job Network

Over the life of the Center, I have found our short- and long-term value shift to better serve the members. In the past several weeks, we have averaged one request per week from employers seeking prospective employees. This shows that companies are looking to the next leg of growth. If companies focus on continuous improvement with customers and employees and have a drive for innovations they can be positioned to capitalize on upcoming opportunities. We intend to keep the momentum going as we are now exploring the best method of informing you of job opportunities. Comments or suggestions are welcome. Sharon Elder (cisp@psu.edu).

Students' Corner

Cody Greene

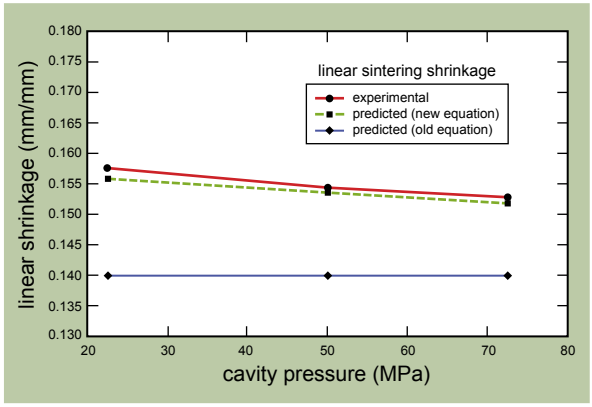
Cody Greene is a master's student at CISP. He received his B.S. in Plastics Engineering Technology from Penn State Erie, The Behrend College. He has developed a new equation for predicting the linear shrinkage of metal injection molded components, which incorporates the shrinkage induced from the injection molding process. His interests include a hands-on approach to PIM feedstock formulation, design, and processing. He will be graduating this May and is seeking a job opportunity in the industry. Cody Greene (cdg132@psu.edu).

Eric Hauck

Eric Hauck, from Tamaqua, PA, is a Ph.D. student in the Engineering Science and Mechanics Department. Eric received his B.S. in Mechanical Engineering from Lafayette College in Easton, PA. His research interests include applications of ultrasonic nondestructive inspection techniques using guided waves for structural heat monitoring and process control. He is currently developing a method for crack detection in green compacts using ultrasonic Rayleigh waves induced through couplant free mediators. Eric Hauck (eth116@psu.edu).

Predicting Linear Shrinkage

A new equation for predicting the linear shrinkage used for the mold scale-up of metal injection molded components has been developed, incorporating the shrinkage induced from the injection molding process. The molding shrinkage is directly related to the pressure-volume-temperature (PVT) characteristics of the feedstock. Experiments determined that increasing the hold pressure during the packing stage of the injection molding process decreased the linear shrinkage in the green components and the final sintered components. The new equation predicts the sintered linear shrinkage within 0.002 mm/mm, when compared to the experimental results. Cody Greene (cdg132@psu.edu) or Don Heaney (dfh100@psu.edu).



Honorary Doctorate

Photo: l. to r. Gregorio Peces-Barba, Randall German, Jose Manuel Torralba

Randall M. German, Director of the Center for Innovative Sintered Products was awarded an honorary doctorate at the Universidad Carlos III de Madrid in Spain in February 2004 for his seminal contribution in sintering. Nomination for this honor originated from the Department of Chemistry, Engineering Materials, and Chemical Engineering, chaired by Prof. Belen Levenfeld Laredo. Dr. Jose Manuel Torralba, Vice Rector of the university and Professor of Materials Science and Engineering, offered the qualifications and nomination. University Rector Dr. Gregorio Peces-Barba accepted the nomination and presented Dr. German with five symbolic items - a hat, ring, white gloves, diploma, and medal - to culminate the honor. Dr. German was the only honorary doctorate recipient for this event, which was held in conjunction with graduation activities. The university has awarded several honorary doctorates; past recipients include the President of Costa Rica (in 2000), past Secretary General of the United Nations, Boutros Boutros-Ghali, and an economics professor from the University of London.

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CISP Newsletter
Published four times per year

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