Self-Tuning Process Monitoring System for Process-Based Product Validation

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This work will create a process monitoring system for milling machines that will autonomously correlate the physical characteristics of the product to the forces, torque, vibration, and acoustic emissions generated during a cutting cycle. The resulting force, torque, vibration, acoustic hyperpoints, and correlated physical characteristics will be overlaid on the product geometry model, which can be analyzed and visualized with extendible Virtual Reality Meta Language (VRML) or advanced virtual reality (VR) systems.

We will develop the autonomous correlation by statistically comparing the very detailed inspection records to the process hyperpoint values. Once deployed, the detailed inspection may be significantly reduced or eliminated. The work will deploy a feature-extraction routine, machine-calibration methodology, a stable sensor array, a sensor-calibration routine, a self-tuning sensor-inspection correlation routine, a hyperpoint overlay routine, and an advanced visualization interface.

The technology created in this project will help validate production of war reserve (WR) components by generating a process signature for products, processes, and lot runs. The signatures of all products can be compared across all products made within and across lot runs to determine if the processes that produced the product are consistently providing superior quality. Furthermore, the quality of the process and product will be quantified and visibly apparent.

Simply by monitoring the output from the sensor array displayed on the process monitoring computer screen, the machinist began to develop techniques to homogenize the machining process. Once they saw how the feeds, speeds, and toolpaths they chose were quantified against cutting force, vibration, and acoustic emissions, they began to think about incremental changes to make each cut more uniform. The researchers believe that once the cuts are consistent, the quality of the process can be better quantified and honed. This astounding result developed in the infancy of the project. Once we develop the full package, the results may be beyond initial expectations.

We accomplished the following in FY96:

(1) Installed existing sensor systems on Haas four-axis milling machine. We modified and used a Montronics tool-monitoring system as the process-monitoring system. The system has sensors for Spindle Power, three-axis force, vibration, and acoustic emissions. In addition, we monitored the position of the machine using a four-axis encoder interface card and also monitored the coolant pH with an Omega pH sensor. A PC with a National Instruments Data Acquisition Card reads all sensor signals. The entire system is very modular and is transferable to any machine tool.

(2) Developed a machine-calibration methodology. Machine calibration is critical to ensure that process monitoring will provide consistent indication of product quality across different machining platforms. Before sensor information could be useful, characteristics such as machine accuracy, natural frequencies, and spindle runout needed to be characterized. This information will help identify the sources of phenomenon that the sensors will measure.

(3) Developed a robust sensor-calibration routine. Calibrating the sensors is critical to ensuring that the information obtained is consistent and meaningful. Power is measured directly through current and voltage; therefore, no calibration is needed. We will calibrate the force sensors by applying forces through a previously calibrated portable dynamometer to the process-monitoring dynamometer, and by noting readings and adjusting discrepancies.

Solution Synthesis and Processing of PZT Materials for Neutron Generator Applications

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Neutron generator power supplies require two unique ferroelectric materials, specifically lead zirconate titanate with a Zr-to-Ti ratio of 95:5 (PZT 95/5) and PZT 95/5 with a partial substitution of tin for zirconia (PSZT). These PZT formulations are unique to neutron generators, and there are no current U.S. suppliers of the material. Based on our past experience in which we successfully developed and transferred to industry chemical preparation processes, we propose to develop an alternate process based on solution chemistry to prepare the PZT powders. We will develop the process such that the concerns of the previously used mixed-oxide process are satisfactorily addressed. We will emphasize the underlying fundamentals of system solution chemistry and how these fundamentals relate to the ceramic material properties that are critical to neutron generator applications.

A complete review of the literature on work related to the chemical synthesis of PZT and related materials revealed several synthesis techniques worthy of further evaluation for application to the PZT 95/5 material system. These processes included the Dosch alkoxide/lead lactate process, the Haertling/Land alkoxide/PbO process, and the British Zr/Pb nitrate process. We investigated the solution chemistry of each of these processes.

Since the British at AWE, Aldermaston, have been working on developing a chem-prep process specifically for PZT 95/5 for some time, we decided that an opportunity exists for possible collaboration. Through a visit to their facility at Aldermaston, we signed a nondisclosure agreement and obtained details about their process. We prepared several batches of powders using their process. As developed by the British, the aqueous-based process produces an excessive amount of liquid waste, a precipitate that is difficult to filter and requires spray drying, and a cation precursor solution that is unstable with respect to the source of niobium. We modified their process to reduce the problems associated with these issues and are currently evaluating the powders prepared by the modified processes.

Because of potential problems associated with the processes given above, we developed a new PZT 95/5 synthesis process. The route uses Zr, Nb, and Ti alkoxides mixed with a concentrated lead acetate solution as the cation solution. This solution is added to an alcoholic oxalic acid precipitant solution. Unlike previous processes, this method produces an easily filterable precipitate formed from true solutions. Chemical analysis of filtrates indicates that the process removes greater than 99.9% of all of the PZT constituent cations from solution, indicating an excellent ability to control stoichiometry. Finally, we designed the process such that the number of powder-handling steps and the amount of waste generated are minimized. We are currently evaluating the densification behavior of powders prepared by this process.

We will file a patent disclosure for the process as soon as we complete some of the initial electrical and physical characterization data on the ceramic material. We have already demonstrated the versatility of the process by modifying it to prepare lead magnesium niobate/lead titanate, PMN/PT, powders. To date, we have prepared powders with a stoichiometry appropriate for a high-energy-density capacitor DP application and are in the process of preparing a PMN/PT formulation suitable for lightning arrestor connector granules.

Effect of Composition and Processing Conditions on the Reliability of Cermet/Alumina Components

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Evidence of cracking in several cermet feedthroughs used in neutron tube subassemblies has raised questions regarding the suitability of cermet components in war reserve (WR) applications. Moreover, cracking is exacerbated in larger, more complex geometries such as the MC4277 tube frame. Preliminary failure and stress analysis indicate that the cracking is most likely associated with the considerable mismatch in thermal expansion between the cermet insert and the ceramic. Additional issues such as the strength of the cermet/alumina interface, and the control of relative sintering kinetics between cermet and alumina in the production of sintered cermet/alumina composite parts, need to be evaluated.

We accomplished the following in FY96:

(1) *Fabricated Mo-31V alloy.* The electrode was vacuum arc-remelted (VAR) three times at the Sandia melting facility. We are currently processing the ingot to permit fabrication of powder via the Plasma Rotating Electrode Process (PREP). Further milling and classification of powder will be needed to realize the powder size required for cermets.

(2) *Performed mechanical alloying of Mo-22V-3Fe alloy powder.* Under contract with UC–Irvine, we produced 100 gms of ternary alloy powder. We are in the process of characterizing this material, prior to trial hot-pressing of bars and cermet evaluation.

(3) *Developed reduced V-content ternary alloy.* We measured the coefficient of thermal expansion (CTE) and hydrogen compatibility of two new ternary alloys that appear promising for use in the cermets: Mo-22V-3Fe and Mo-22V-3Co alloys (composition in wt.%). We showed both alloys to be single-phase body-centered cubic-crystal structure (BCC) alloys and reduced hydrogen uptake relative to the Mo-31V alloy.

(4) *Documented suitable sintering conditions for cermet/alumina composites.* We observed shape distortions in composite parts because the alumina phase tends to shrink more than the cermet phase during sintering. Compaction experiments demonstrated that if the ceramic and cermet phases are prepressed to the same relative density prior to sintering, warpage in composite parts can be avoided. For the cermet/alumina system under consideration, prepressing the 94% alumina at 30 ksi prior to machining and backfilling with the cermet slurry will produce the proper relative density.

(5) *Acquired mechanical properties data for cermets.* As a baseline to compare with mechanical behavior of the new ternary alloy cermet, using ASTM C1161 we completed strength measurements on CND50, 94ND2, and composite cermet/alumina specimens. We developed a three-step process to fabricate composite test bars so that the microstructure at the cermet/alumina interface is truly representative of the manufacturing environment.

Publications

Other

Glass, J. S., S. L. Monroe, R. H. Moore, and G. A. Pressly. 1995. "Percolation Effects on the Structure and Properties of Alumina-Mo Cermets." Paper presented to the American Ceramic Society Basic Science Meeting, New Orleans, LA, 5–8 November.

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