metis design

Seth S. Kessler, Ph.D. – President/CEO
205 Portland St, 4th Fl, Boston, MA 02114
617.447.2172 x203
skessler@metisdesign.com
www.MetisDesign.com

MD7-PRO DIGITAL SHM SYSTEM

Off-the-shelf in-service monitoring techniques utilize a dense web of analog sensors connected by individual wires routed to centralized acquisition and processing units. This traditional approach carries a significant weight penalty, can be complex to instrument and is susceptible to EMI. MDC has developed the MD7-Pro System, a digital Structural Health Monitoring (SHM) solution, where each element is networked on a serial data and power bus. Benefits of this distributed approach include higher fidelity data through digitizing at the measurement point, reduced computational burden through local signal processing and feature reduction, and overall minimal mass through the consolidation of cables and connectors.

ACCUMULATION NODE

The Accumulation Node serves as front-end interface to the SHM network. Measuring 55 x 40 x 5 mm with a mass of 20 g, it accepts 28VDC to distribute power for up to 100 daisy-chained Acquisition nodes, along with relaying commands, facilitating synchronization, and storage of the resulting data. It can be programmed to run autonomously, communicate over Ethernet, or accommodate flexible provisions for other wired and wireless protocol. In addition, the Accumulation Node offers 16 digital inputs and boasts 64-GB of static memory. A powerful FPGA with an ARM core processor can be programmed to execute embedded diagnostic algorithms or prognostic and health management (PHM) logic.

ACQUISITION NODE

The MD7-Pro system can be efficiently expanded by daisy-chaining Acquisition Nodes. Measuring 50 x 40 x 5 mm with a mass of 15 g, they are a direct replacement for traditional instrumentation such as oscilloscopes and function generators, enabling distributed data acquisition and signal processing. Each Acquisition Node provides a 20 Vpp 20 MSample/sec arbitrary function generator, 6 independent 12-bit channels of up to 50 MSamples/sec with programmable gain up to 250x, plus 8 multiplexed 16-bit channels at 1 MSamples/sec with 2 Gbit of DDR3 memory. A triaxial accelerometer and temperature sensor are also integrated into each device.

STRUCTURAL SONAR ARRAY

Traditional SHM methods require dense sensor meshes to precisely resolve damage position. Thus, MDC has patented the Structural Sonar Array, a PZT beamforming package to facilitate both passive acoustic emission and active guided wave scans. From a single node position, a probability of damage map can be generated in response stiffness changes detected by a guided wave scan, or due to the passively captured acoustic response from an impact event. Results from multiple nodes can be combined synchronously and/or asynchronously to enhance resolution.

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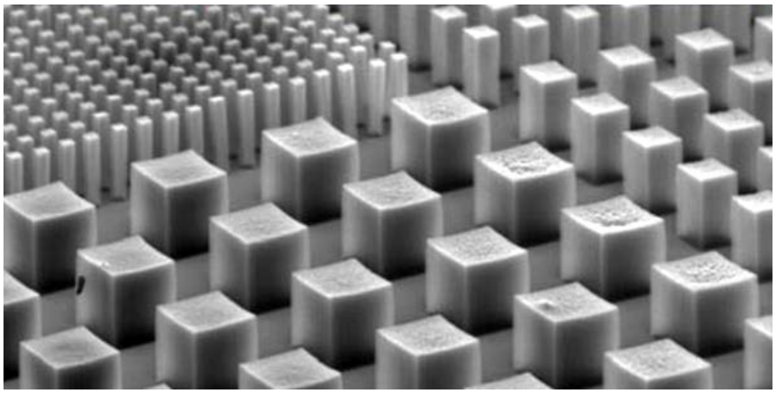
NANO-ENGINEERED FUNCTIONALITY

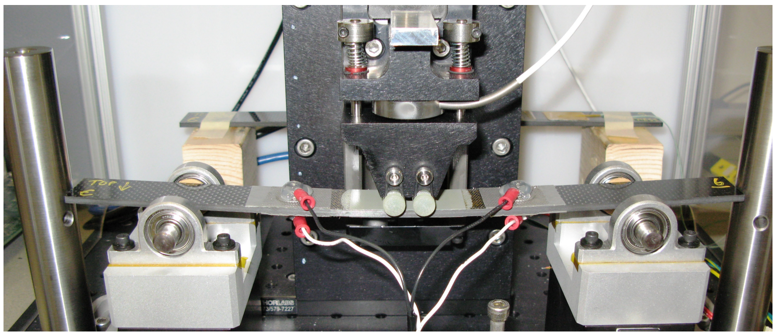


Carbon nanotubes (CNT) have demonstrated the ability to provide multi-functional capabilities to host materials due to their electrical and thermal properties, such as lightweight replacements for wire, ESD/EMI/lightning-strike protection and heat sinks. Most work at MDC has focused on tailoring optimized resistivity profiles. By varying sheet resistance between 1 and 100 Ohm/sq, they can provide an efficient means for generating heat. Similarly, they can be used as an embedded sensor network for monitoring structural health & usage. While MDC does not produce CNT, we have established reliable modeling and integration processes to incorporate COTS CNT into robust nano-engineered components.

ICE PROTECTION SYSTEMS

Ice Protection Systems (IPS) anti-ice to prevent the formation of ice and/or deice to remove ice build-up from aerosurfaces. Current thermo-electric methods suffer from durability issues and can cause manufacturing issues for composite parts. MDC has demonstrated that CNT can be integrated with both composite and metallic aerosurfaces as an effective means for ice protection. They can provide equivalent performance as metallic heaters at a fraction of weight (1%), and have the potential for significant power savings. MDC has performed many ice-tunnel tests across the FAA recommended icing envelope, and integrated their CNT-IPS design into a 3-meter full-scale UAV wing section.

HEALTH & USAGE MONITORING



Due to piezoresistivity, CNT provide an effective means for usage monitoring. Individual CNT represent sensing elements, exhibiting a resistance value that varies with strain state. Once integrated into a component and loaded, the CNT can be calibrated to match traditional foil strain gauge results, while sustaining higher strain (12,000 $\mu\varepsilon$) and temperature levels (550 ^{o}C). Furthermore, the dynamic response of CNT allow them to not only measure static strains, but capture stress waves due to an impact event. Finally, as damage can be represented as a permanence in local residual strain, the CNT network can be used to assess the health of a component.

OUT-OF-OVEN CONDUCTIVE CURING

Autoclaves heat convectively, meaning they heat air through a blower, which in-turn heats the surface of the composite. Since they contain a fixed volume of air, the cost to produce the heat remains fixed regardless of the size of part being cured, yielding much waste. MDC has demonstrated the use of CNT to conductively cure composites out-of-oven. Conductive curing costs scales with part surface area rather than autoclave volume, thus providing a path for reducing composite acquisition costs by up to 50%, while providing more uniform properties with degree-of-cure feedback.