Ultra High Temperature Micro-Electro-Mechanical (MEMS)-Based Smart Sensors for Monitoring Gas Turbines and other Similar Extreme Environments

UCF researchers have developed a novel and unique series of Micro-Electro-Mechanical System (MEMS)-based smart sensors for ultra-high temperature applications in gas turbines, space crafts and other similar environments. The uniqueness of the proposed sensors lies in the combination of a variety of sensors, novel heat resistant material and use of microfabrication. The unique material used to fabricate the MEMS smart sensors in the present invention is based on recent developments by UCF researchers in the field of Polymer-Derived Ceramics (PDCs). These materials are advanced ceramics with low density, and especially high thermal and chemical resistance, providing miniature sensors with overall dimensions that enable measurements of greater accuracy. Moreover, the MEMS smart sensors are capable of real-time environment by use of integrated sensors and actuators within their construction. Additionally these structures are able to forewarn about the onset of abnormalities and hence impending failures. The only drawback of this remarkable technology is that it is exceptionally challenging to develop smart materials and sensors for structures that operate at extreme conditions of temperatures, pressure, or fluid (air/gaseous mixture, air/fuel mixture) velocity, such as gas turbine engines, spacecraft and the like. Current state-of-the-art sensors cannot cope with the harsh combusting environment which can easily reach temperatures in excess of 1800o K, and chemical conditions that are quite hostile. As a result, current turbine design primarily relies on estimated or computed data obtained from Computational Fluid Dynamics’ (CFD) simulations, the very basis of which is questionable under present experimental conditions. Therefore, there is a need for smart sensors that can be integrated into smart structures capable of operating in extreme, harsh and hostile environments.

Technical Details

Materials technology has had a profound impact on the evolution of human civilization. One of the most important advances in material technology has been the focused development of smart materials. These materials have inherent sensing properties with self-adaptive capabilities to external stimuli; when such materials are integrated into larger configurations they are termed smart structures. A smart structure is a system containing multifunctional parts that can perform its own sensing, control, and actuation; such structures are a basically a primitive analogue of a biological body. Smart structures are designed to react to the surrounding environment by use of integrated sensors and actuators within their construction. Additionally these structures are able to forewarn about the onset of abnormalities and hence impending failures. The only drawback of this remarkable technology is that it is exceptionally challenging to develop smart materials and sensors for structures that operate at extreme conditions of temperatures, pressure, or fluid (air/gaseous mixture, air/fuel mixture) velocity, such as gas turbine engines, spacecraft and the like. Current state-of-the-art sensors cannot cope with the harsh combusting environment which can easily reach temperatures in excess of 1800o K, and chemical conditions that are quite hostile. As a result, current turbine design primarily relies on estimated or computed data obtained from Computational Fluid Dynamics’ (CFD) simulations, the very basis of which is questionable under present experimental conditions. Therefore, there is a need for smart sensors that can be integrated into smart structures capable of operating in extreme, harsh and hostile environments.


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condition monitoring, suppression of combustion oscillations and detailed measurements in an operating gas turbine engine. No existing sensor can match the high temperature performance of the proposed sensors without any external cooling, which can significantly increase the cost and size of the sensor. Thus implementation of the proposed sensors would be a tremendous leap forward in the gas turbine industry as well as for understanding of the complex science that governs the flow field between and inside combustor and turbine.

Benefits

- Able to withstand harsh, ultra-high temperature environments (up to 2000K) without the need for any external cooling
- Improves a systems safety, design optimization and reliability resulting in less down time and less frequent maintenance, significantly reducing overall costs *These small form factor sensors are inexpensive to produce and designed for large scale manufacture
- The use of materials such as polymer-derived ceramics provide miniature smart sensors with overall dimensions that enables measurements of greater accuracy

Applications

- Sensors:
  - Real-time condition monitoring
  - Suppression of combustion oscillations
  - Detailed measurements in operating gas turbines, space crafts, rockets and other similar systems
- Optical measurements under extreme heating conditions:
  - Monitoring flow
  - Turbulence (intensity and length scale)
  - Pressure
  - Temperature
  - Wall shear
  - Wall flow pulsation
  - Heat flux
  - Optical waveguides

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