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Paper Session II-D - Expanding Sensing Capabilities Using Fiber-Optic Technology

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Expanding Sensing Capabilities Using Fiber Optic Technology

Born through a ray of light, the communication industry of today has been revolutionized through the implementation of fiber optics. Fiber optics allow people to communicate at the speed of light to all corners of the globe. In the 21st century, fiber optic applications will inevitably expand into new fields and broaden our capabilities in countless areas, mainly due to their ability to be used simultaneously as communication devices and in the soon to be recognized area using them as intrinsic sensing devices. Everything from trains and airplanes, to smoke alarms and wrist watches will use fiber optics, because of their outstanding sensing capabilities. Fiber optics will be able to make our planes faster and our homes safer. Fiber optics revolutionized the communications industry in the 20th century, but in the 21st century, the utilization of fiber optics as sensors will expand our capabilities not only on earth, but also into outer space.

What I am researching is the possibility of expanding present day sensing capabilities through the implementation of fiber optic technology. Theoretically, in order to expand something's capabilities, you must reduce its limitations to the environment around it. An example of something that has limitations would be the conventional sensors of today because they work with electricity and are made from conductive materials, making them vulnerable to EMF, water, moisture, dust, static, and lightening types of interference. There are two main types of fiber optic sensors, intrinsic sensors where the fiber optic change its own light internally, and extrinsic sensors where something manipulates the light from an outside force.

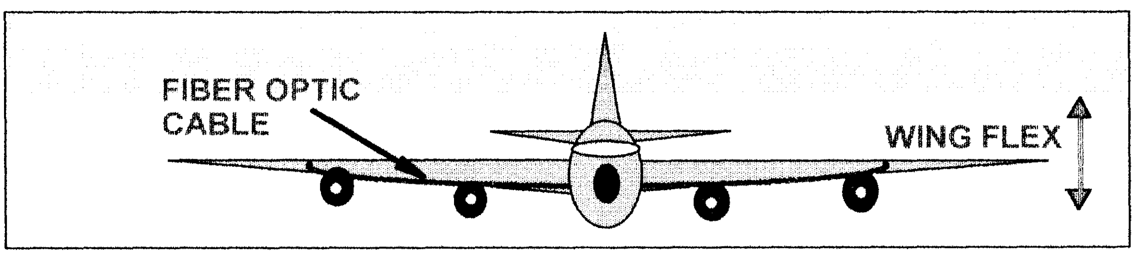
To better understand fiber optics future role as sensing devices, examine their consequences while functioning, and consider future breakthroughs, four major industries were selected (aeronautical, medical, industrial, and automotive) with which to simulate and evaluate fiber optics sensing capabilities. Each one of these industries exist in some sort of hazardous environment where the conventional sensors of today would inevitably fail due to their limitations. Fiber optic extrinsic sensors on the other hand would be immune to these types of interference that currently hender conventional sensors, because fiber optics are made from plastic and work with the transmission and usage of light as a signal. One fiber cable sensing many conditions would also be safer and more cost efficient than multiple copper wires and sensors . After I selected the industries to create simulations of fiber optics sensing capabilities, I chose specific examples within each application and narrowed my focuses on exactly what I was going to test, and how I was going to test it.

To test and evaluate the fiber optic extrinsic sensors, working prototypes were designed and built for each of the fiber optic applications. To house the prototypes, a test chamber was assembled with four computer outlets for each simulation. In order to properly test all of the prototypes, a data acquisition system was used to accumulate data from each application as they were tested. The acquisition system would be able to take many readings per second and effectively record large amounts of precision data over long periods of time. This system allowed me to accurately span and manipulate the data (because I was working with millivolts) and focus on constructing and developing the sensors, instead of wasting lots of time spent on data management (i.e.; recording, sensing, trial and error)

The concept behind using fiber optics as sensors, is when a fiber optic is bent, refraction instead of reflection starts to occur and light is lost inside the fiber optic core through the cladding due to the changing bend degree. A photoreceiver changes the light to a voltage, and as the light fluctuates, so does the voltage output from the receiver. For my project, the acquisition system was used to transfer this data into a computer to create visual and comprehensible graphs which were used to formulate conclusions and evaluations of the fiber optic sensors.

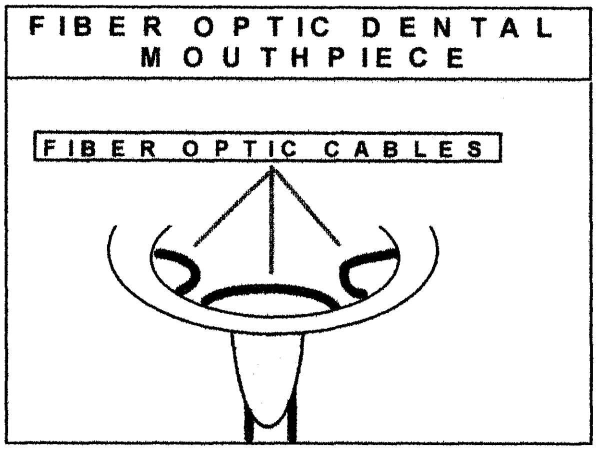
To begin with for the aeronautical application, I decided to use fiber optics to sense the flexing of aircraft wings (aeroelasticity) which causes microfractures within a wing, decreases its strength and durability, and reduces fuel efficiency. With the same fiber optic, I would also be able to sense the amount of fuel within the wings. In the future, aircraft will use fiber optic systems for many different applications, a fiber optic could be positioned from wing tip to wing tip, and as the wing flexes, the fiber optic bends, thus changing the light being detected by the receiver. This information could be used by ground mechanics to know how much stress the plane has experienced. The fiber optic used to sense wing flex could also be used to sense other conditions onboard such as measuring remaining fuel volume in the wing, by the more fuel in the wing, the lower the wing hangs, and the more the fiber optic bends. This information would be used by the airplanes pilots and ground mechanics to analyze how much stress the aircraft has gone through during flight, and confirm how much fuel is left in the wing.

For my test apparatus, I built a model E3A-AWAC, and positioned a fiber optic cable in an oval pattern underneath the wings. At the end of the fiber optic, I attached a light transmitter and a light receiver. This application works by as the wings flex up and down, the fiber optic underneath the wing is bent, which causes the light being received by the receiver to vary. The voltage from the receiver would then go to the computer acquisition system to be recorded for analysis.



Next, a dental application that uses fiber optics to aid in a process called aquisial equilibration, which is a time consuming, inefficient and uncomfortable process dentists use to fit bridges or crowns into a persons mouth. With this fiber optic application though, simplicity and patient comfort would greatly increase by using a mouthpiece specially fitted with fiber optics to sense differing pressures within a persons mouth and predetermine the dimensions needed for the bridge or crown.

As a simulation, a mouthpiece, obtained from a local dentist was fitted with fiber optics in three different areas of the mouth: the left, the center, and the right part of the mouthpiece. This application works by as the patient bites down on the mouthpiece, their teeth bend the fiber optics and cause them to loose light. With fiber optic sensors built into a dental bite plate all a dentist would have to do is place the mouthpiece in the patients mouth, push a button to record the fiber optics readings, and then adjust the bridge or crown according to the computer data.



The third application is the industrial application which uses fiber optics as a tank volume indicator and as a security sensing device.

With the tank application a sense-and-correct feedback loop was created to control the amount of liquid within a tank. A fiber optic attached to a floating arm that pivots as the liquid changes, senses the rising and falling of the tank volume. The acquisition system uses the fiber optics data to turn on or off a pump, and essentially regulating the tank level and keep it within certain thresholds. Using the fiber optics in this manner would allow industries to measure the volume of liquids in places like the future space station, where electricity would add unnecessary hazards.

The second simulation within the industrial application, a security system was created for the display cabinet by using two fiber optics to sense the opening and closing of the display cabinet doors. The fiber optics were positioned in a position where as the doors are closed they push against the fiber optics causing the fiber optic to bend and loose light. But as the doors are opened the fiber optics spring and deflect outward conforming to their natural shape of least resistance. The acquisition system senses this and knows that whenever the light being received increases this indicates the doors are open and to initiate an alarm.

Present day technology used magnetic strips as door sensors which can be faked out and bypassed by using another magnet to keep the magnetic field present while someone opens the door, and which also require electricity to the area where they are sensing. Fiber optic security sensors would make it very hard to be faked out because they work with the actual physical presence of the door and its movement, and are also very safe because they use light instead of electricity.

The final application is the automotive application which is broken down into three fiber optic sensor simulations: radiator fan sensor, an alignment sensor, and a shock depression sensor.

The radiator fan is one of the most important parts of a vehicle because it keeps the engine and its parts from over heating, but ironically there is no indication to the operator of how the fan is actually operating. As a test apparatus, a 12 volt computer cooling fan was used to represent an automobiles radiator fan. To sense the static pressure, I positioned a fiber optic cable onto a pivotal wind vein placed in front of the fan. The greater the wind velocity (or the greater the static pressure) from the fan, the more the fiber optic is pushed outward bending the fiber optic and causing it to loose light. This system would reduce the chances of a vehicle overheating by informing the operator of the vehicle whenever their fan is not working properly.

There is also no way to sense the alignment of a vehicles wheels without having to take it to the auto repair shop. With this simulation though, a fiber optic sensor, like this here, is placed around the alignment mechanism, and would be able to take the guess work out of maintenance by telling the operator exactly when the vehicles wheels needed to be realigned.

To test this application a fiber optic attached in the pivoting point of the alignment mechanism is able to sense the camber and castor alignment, and whenever the wheels become misaligned and bend the fiber optics past a certain point, the acquisition system initiates an alarm. This method would be able to reduce tire wear, increase safety by improving handling capability, and increasing fuel efficiency.

For the last automotive application, fiber optic sensors were used to detect the depression of a vehicle's shocks. As the shocks are weighted down and depressed, the distance between the chassis and frame decreases resulting in the lowering of the entire body of the car and increasing the risk of the vehicle being damaged by bottoming out when encountering rough road conditions. With this fiber optic sensor, as the shocks depress lower and lower, a fiber optic positioned around the shock looses light and would be able to sense the depression of the shocks. Present day sensors cannot detect shock depression directly because they would have to exist in an environment with lots of dirt and vibration. This information could then be relayed be to computer to add fluid to the struts, which would raise the vehicle, and decrease the chances of the vehicle bottoming out, increasing the safety and handling of the vehicle.

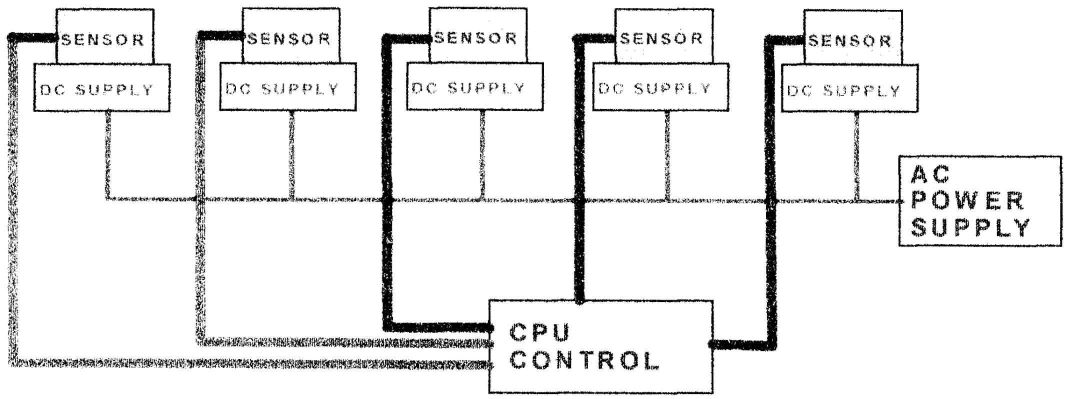
Few sensors are used today that allow the operator to know how their vehicle is functioning. Many different fiber optic sensors could be incorporated into vehicles to measure various conditions. Because of their durability, dexterity, and reliability, fiber optic sensor technology could be used to enhance the operator's understanding and performance of their vehicle.

After the completion of the tests, the fiber optics were evaluated and proved to be extremely successful and very reliable sensing devices, and when added to their durability and dexterity, they posses valuable characteristics over conventional sensors because they can be implemented into situations where the conventional sensors of today have great limitations.

This type of scientific research is pertinent, because the avenue of using fiber optics as intrinsic sensing devices has not come close in reaching its full potential. What I have done here is demonstrate just seven of thousands of potential applications for fiber optics as sensing devices, and with an acquisition system created feedback loops.

For my future years research, I propose to develop fiber optic extrinsic sensors. As seen in the diagram below, the sensor arrays of today require many wires and lines for power and for data transmission.

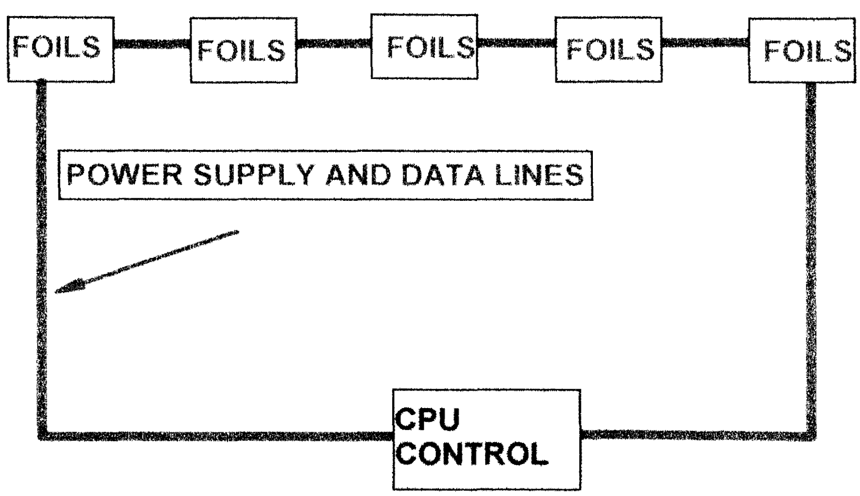
TYPICAL SENSORS OF TODAY



But what I am hoping to develop is a system that would eliminate the need for electricity and wires by using a single fiber optic to connect multiple sensors, and the sensors would use the light from the fiber optic to operate.

LASER SENSOR AND COMMUNUICATION SYSTEM

L. A. S. C. O.



In conclusion, I feel that fiber optic sensors will emerge to become the driving force to take us into new horizons of research and enhancing our understanding of the world and universe around us. I feel all of this will be made possible because of four reasons: 1) the dexterity of fiber optics to be used in hundreds of different applications, both in communications and sensing, 2) its durability to be able to be put into situations where ordinary sensors would surely fail, 3) fiber optics work mainly with simple beams of light instead of dangerous electricity, 4) and because a fiber optic can simultaneously be used for sensing and communication.

Bibliography

"Attenuation in Optical Fibers." Optical Communication Systems, Dec. 89, pp78-79.

Bogue, Adam. "Technology Bulletin; Smart Material Promises Safer Air Travel", Design News, p13, Feb. 6 1995

CD ClipArt Collection #2. Expert Software, Inc, Microsoft Corp. 1996.

"Diode Lasers." Lightwave, March 1992, pp. 47-57.

Dowell, Curtis."A Modern Course in Aeroelasticity."2nd Edition, Kluwer Academic Publishers,1989.

Dugundji, Professor John. MIT, Dept. of Aeronautics and Astronautics, Cambridge MA, letter, May 25, 1995.

"Electro-Optic Space Positioner Measures Precise Displacement of Aircraft Wing." Design News, April 7 1986, p 156.

"F-16XL Laminar Flow Research Aircraft." NASA, Dryden Flight Research Center, Bon-Meyer, Marta and Don Nolan, Oct 95

"FIBER." Lightwave, Mar 92, pp. 10-17.

"Intro to Fiber Optic Communications." Kennedy Space Center, Grumman, KSC Document #EL-115-GTS, 1991, June 3, 1991.

Grossman, Berry Dr. Florida Institute of Technology, Melbourne, Florida, interview 1995.

Hentschel, Christian."Fiber Optic Handbook."Boeblinger Instruments Div., Federal Republic of Germany, Hewlett Packard, Mar 89.

Howford, John, Douglas Aircraft, McDonnell Douglas Corp. Longbeach CA, letter 1993.

"Light Pulse Generator." Short Form Catalog, Jun 92.

Proctor, Paul, "Industry Outlook; Making Turbulance Obsolete." Aviation Week and Space Technology, Nov. 6 1995, p 13.

Watts, Harry, Fiber Optic Development Systems Inc., Santa Barbara CA, letter, 1996.

Wilkinson, Stephen. "Go With the Flow." Air and Space, June/July 1995, pp. 32-39.