Active Piezoelectric Sensing for Damage Identification in Honeycomb Composite Panels

Mentor: Gyuhae Park and R. Jason Hundhausen (LANL)

ABSTRACT

Structural health monitoring techniques based on the novel use of piezoelectric active materials will be explored. In particular, our goal is to develop damage identification methods that will provide an active, self-diagnostic damage detection system for the composite honeycomb panels that are typically used in unmanned aerial vehicles (UAV). Lamb wave propagation- and impedance-based methods will be used to identify typical panel failure modes, including cracking or buckling of the face sheets and damage incurred from foreign object impacts. This project will explore the feasibility of active-sensing damage detection techniques for UAVs, and outline several issues that can be used as a guideline for full-scale development of low-cost, active-sensing based diagnostic techniques suitable for UAV systems.

PROJECT OUTLINE

Unmanned aerial vehicles are increasingly being used in military and civil applications. The wing skin of UAVs is often made of composite honeycomb sandwich panels. The panels are made of two composite face sheets bonded to opposite sides of a honeycomb core, creating a very strong and light weight structure. Given the adverse nature of the environment in which UAVs may be used, these panels are subject to a wide variety of damage, including, for example, cracking of the face sheets due to excessive structural loading and fatigue, or cracking/delamination of the face sheets and/or honeycomb core due to foreign object impacts. In addition, poorly manufactured panels may exacerbate the ease with which damage may be initiated and propagated throughout the system. These defects originating during manufacturing or in service can lead to inefficient flight performance or even catastrophic failures. Currently, there are no reliable methods for assessing such failure modes in real-time.

This project will explore damage identification processes in UAVs based on the novel use of piezoelectric materials. Piezoelectric materials are very useful in structural health monitoring because they can perform both duties of sensing and actuation within a local area of the structure. Piezoelectrics are a class of materials in which there is a coupling between mechanical and electrical domains. Therefore, this type of material generates mechanical strain in response to an applied electric field. Conversely, the materials produce electric charges when stressed mechanically. This coupling property allows one to design and deploy an "*active*" and "*local*" sensing system whereby the structure in question is locally excited by a known and repeatable input, and the corresponding responses are measured by the same excitation source.

Two techniques, including Lamb wave propagation and impedance-based methods, will be integrated and used to interrogate the honeycomb panels in this project. In Lamb wave propagations, one piezoelectric acting as an actuator generates an elastic wave through the structure, and responses are measured by an array of piezoelectric sensors. The changes in both wave attenuation and reflection will be used to detect and locate damage. The impedance-based method monitors the variations in structural mechanical impedance, which is coupled with the electrical impedance of the piezoelectric. These techniques operate in the high frequency ranges (typically > 30 kHz) at which there are measurable changes in structural responses even for incipient damage such as small cracks, debonding, and loose connections.

In this project, two specific types of damage will be investigated: damage due to buckling of the face sheet(s), and damage due to foreign object impact. Both regular piezoceramic materials and newly developed Macro-fiber Composite (MFC) sensors will be used. The main focus of this project will be the capability of the diagnostic system to identify (detect and locate) incipient damage in real-time before serious damage has developed. Furthermore, the project will identify several issues for the full-scale development of low-cost, active-sensing based diagnostic techniques suitable for UAV systems.

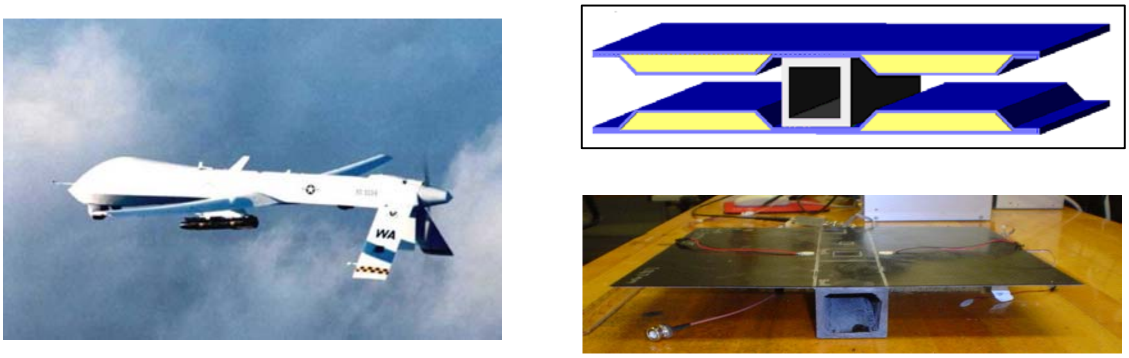
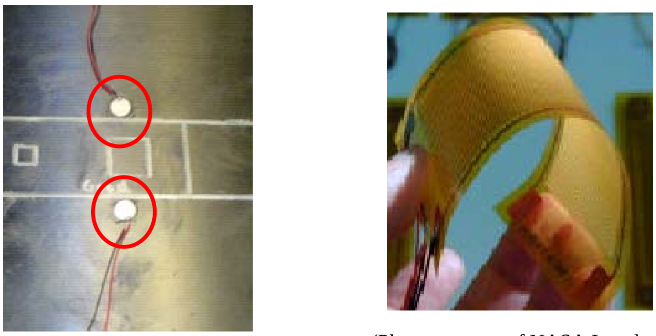


Figure 1. Schematic of a structure that will be used in the experiment.



(Photo courtesy of NASA Langley)

Figure 2. Piezoceramic and Macro-fiber Composite actuator/sensor

SCHEDULE

Weeks	Tasks
1	Orientation
2	Background research on the topics of piezoelectrics and papers listed below
3	Installation of PZT and MFC patches to honeycomb panels. Hardware use orientation.
4	Vibration testing/modal analysis of the structure with accelerometers and PZT sensors
5	Experimental investigation using Lamb wave propagation. Data analysis
6	Experimental investigation using impedance-based health monitoring. Data analysis
7	Begin write-up, reiterate tests, codes, etc as needed.
8	Writing up of results and presentation

HELPFUL REFERENCES

1. Inman, D.J., 2000. *Engineering Vibrations,* 2nd Edition, Prentice Hall, New Jersey, Chapters 5 and 6.
2. Park, G., Sohn, H., Farrar, C.R., Inman, D.J. 2003. "Overview of Piezoelectric Impedance-based Health Monitoring and Path Forward," *The Shock and Vibration Digest,* **35**(6), 451-463.
3. Sohn, H., Park, G., Wait, J.R., Limback, N.P., Farrar, C.R. 2004. "Wavelet-based Signal Processing for Detecting Delamination in Composite Plates," *Smart Materials and Structures*, **13**(1), 153-160.
4. Hay, T.R., Wei, L., Rose, J.L., 2003. "Rapid Inspection of Composite Skin-Honeycomb Core Structures with Ultrasonic Guided Waves," *Journal of Composite Materials*, **37**(10), 929-939.
5. Thien, A., Chiamori, H., Ching, J., Wait, J.R., Park, G., "Active Sensing for Damage Detection in Pipeline Structures," *Proceedings of 23rd International Modal Analysis Conference*, Jan 31-Feb 3 2005, Orlando, FL.
6. Park, G., Farrar, C.R., Rutherford, C.A., Robertson, A.N., 2005, "Piezoelectric Active Sensor Self-diagnostics using Electrical Admittance Measurements," *ASME Journal of Vibrations and Acoustics*, in review.
7. Sodano, H.A., Park, G.., Inman, D.J. 2004. "An Investigation into the Performance of Macro-Fiber composites for Sensing and Structural Vibration Applications," *Mechanical Systems and Signal Processing*, **18**(3), 683-697.
8. Burton, W.S. and Noor, A.K., 1997. "Assessment of Continuum Models for Sandwich Panel Honeycomb Cores," *Computer Methods in Applied Mechanics and Engineering*, **145**(3-4), 341-360.
9. Dickinson, S.M., 1978. "The Buckling and Frequency of Flexural Vibration of Rectangular Isotropic and Orthotropic Plates Using Rayleigh's Method," *Journal of Sound and Vibration*, **61**(1), 1-8.
10. Gorman, D.J., 1978. "Free Vibration Analysis of the Completely Free Rectangular Plate by the Method of Superposition," *Journal of Sound and Vibration*, **57**(3), 437-447.
11. Leissa, A. W., 1973. "The Free Vibration of Rectangular Plates," *Journal of Sound and Vibration*, **31**(3), pp. 257-293.
12. Lok, T-S. and Cheng, Q-H., 2001. "Free and Forced Vibration of Simply Supported, Orthotropic Sandwich Panel," *Computers and Structures*, **79**(3), 301-312.