Center for Nondestructive Evaluation (CNDE)

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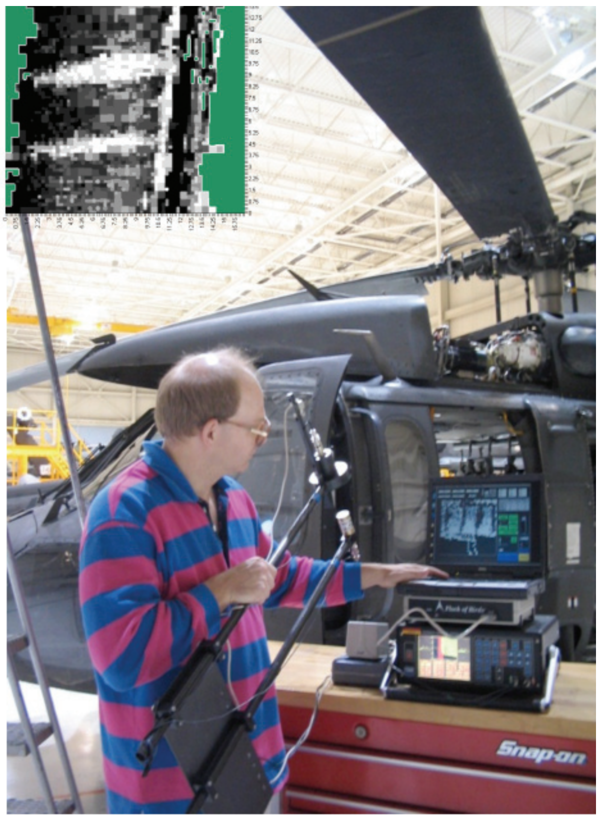
Generic Scanner to Image NDE Data



The Generic Scanner (GenScan) is employed to make manual scans for a number of nondestructive testing modalities in the field without a motorized scanning system. This photo shows the GenScan being used in mapping out tree strike damage (white stripes in inset figure) on the lower surface of a Black Hawk helicopter rotor blade using air-coupled through-transmission ultrasonic inspection.

The concept of the Generic Scanner or "GenScan" is to combine existing portable, manually-operated nondestructive testing (NDT) flaw detectors with off-the-shelf, relatively inexpensive position encoding devices. Combining these with specially developed interface software in a laptop or tablet PC generates inspection scan images in the field. The scan images so generated are saved in the computer and placed on the web for off-site analysis by structural engineers.

This technology breakthrough made by CNDE at Iowa State University was the result of research projects funded by the Federal Aviation Administration to develop improved methods for inspecting composite aircraft structures. The economical combination is characterized by the ingenious adaptation of position encoding devices contained in systems not related to inspection. For example, a "PC NotesTaker" for capturing handwriting and drawings on a page of paper was combined with ultrasonic or eddy current flaw detector to make small area inspection scan images. The "Mimio FlipChart" and DMA (digital meeting assistant) used in conference rooms for capturing writings and drawings on flip chart or whiteboard into a PC were adopted to make larger area scan images in ultrasonic inspection of composite structures on aircraft. In addition, a motion tracking system called the "Flock of Birds" used in virtual reality applications was combined with air-coupled ultrasonic flaw detector to inspect curved parts. The main advantage of the generic scanner is that it allows inspectors to create scan images manually in the field without using more cumbersome and expensive motorized scanning systems. The images it produces provide a more intuitive and thorough inspection of relatively large areas of commercial aircraft surfaces, e.g., composite control surfaces.

Some newer NDT modalities such as laser shearography and thermal wave imaging are intrinsically image based, but the two most widely used modalities, ultrasonics and eddy current, still rely on motorized scanners for making images. The motorized scanners are often bulky, heavy, and expensive. In addition, they often require considerable operator training. Motorized scanning systems typically cost $30K to $150K.

GenScan is a simple way of producing the type of quick scan images in the field using portable, manually operated NDT instruments with which most inspectors are already familiar. The position encoding that generates the images is provided by consumer electronics devices used for capturing handwritings and drawings. The simplicity and portability of the GenScan lends to easy deployment on aircraft and field applications.

Economic Impact: In commercial aviation, the term MRO (maintenance, repair, and overhaul) refers to all the services related to assuring aircraft safety and airworthiness. World-wide, the MRO market is of the order of $50B (according to IATA benchmark analysis of 2011) and the maintenance cost of an airliner accounts for approximately 10% of the total operating cost. The typical maintenance cost of a revenue-generating commercial aircraft is about $3M per year. In MRO operations, due to the large number of aircraft that require inspection, the same models of NDT instruments are usually bought in large numbers for the team of inspectors to use. For this reason, airline maintenance departments and MRO shops are more likely to purchase a large number of $5000 portable flaw detectors and much less likely to purchase one or two of $50K system such as motorized scanning systems. The GenScan approach makes use of existing portable flaw detectors and does not require the MRO facility to purchase additional hardware. The position encoding devices that make the imaging possible come from off-the-shelf consumer electronics and are relatively inexpensive. For example, a PC NotesTaker costs less than $100, the Mimio FlipChart and DMA are in the $600 to $1000 range. The magnetic “Flock of Birds” position tracker with 3-D capability is priced in the $3K range. The approach of making simple manually scanned images using existing portable instrument and modified position encoders, along with the help of interface software in a PC, often negates the need for the more costly motorized scanning systems (which tend to be much heavier and bulky; too much so for on-aircraft deployment) while economically providing the benefits of quality, quantitative, image-based inspection data.

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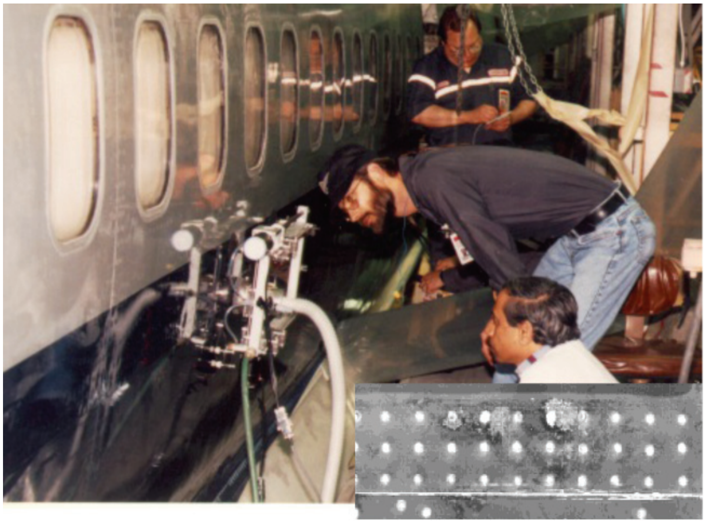
Dripless Bubbler: Portable Scanner for Aircraft Inspection



The Dripless Bubbler makes on-aircraft high-resolution images of flaws, damage, and corrosion with a focused ultrasonic beam. The figure here shows the Dripless Bubbler scanning Boeing 747 lap splices.

Researchers at the Center for Nondestructive Evaluation (CNDE) have developed an on-aircraft ultrasonic scanning system for imaging flaws, damage, and corrosion on aircraft structures. Developed by the center's Composite Group, the "Dripless Bubbler" ultrasonic scanner (DBS) is the first portable ultrasonic scanner with a closed-cycle water coupling system and uses high frequency focused ultrasonic beam. It is essentially a portable ultrasonic scanner designed and developed for on-aircraft inspection of both metallic and composite structures. It can be attached to the fuselage of an aircraft or to the upper or lower surfaces of aircraft wings to inspect for hidden corrosion in metals and in disbonds and delaminations in composites. It uses a unique closed-cycle pump/vacuum water handling system that makes possible the use of focused ultrasonic transducers.

In the past it has not been possible to apply focused ultrasonic beam for on-aircraft inspection in the field. The development of the DBS has made it possible to conduct focused beam ultrasonic inspection at relatively high frequencies. The focused ultrasonic beam leads to superior image resolution and can more accurately determine the depth of delamination or exfoliation corrosion and the amount of metal loss due to corrosion. The DBS has the unique capability to scan over protruding rivets on the skin of aircraft. The closed-cycle water-handling feature meets the safety requirement of not having wet surface on aircraft wings in maintenance hangars (a slip and fall hazard). The water recirculation system made it possible to perform high resolution ultrasonic scans in the field with image quality equivalent to that of a laboratory ultrasonic immersion tank. The high resolution afforded by the high frequency focused transducer makes it a useful tool for mapping out the depth profile of corrosion, such as exfoliation corrosion around fastener heads.

This technology received an R&D100 award and was extensively field-tested at commercial airlines (Northwest Airlines, United Airlines, and others), at the FAA Airworthiness Assurance Nondestructive Inspection Validation Center at Sandia National Laboratories, and at ARINC, Inc. The Dripless Bubbler scanner was patented and licensed exclusively to Sierra Matrix, Inc. of Fremont, California. The company supplied the system to the US Air Force for inspecting corrosion around fasteners on the wing skins of KC135 tankers. The center supported this activity by conducting training sessions for system inspectors at the Air Logistics Center at Tinker Air Force Base in Oklahoma City.

Economic Impact: The natural phenomenon of metal corrosion in aircraft has a major impact on the economy. The Dripless Bubbler ultrasonic scanner, with its superior resolution and sensitivity, is a powerful tool for early detection of corrosion. Interestingly, if caught early enough, incipient exfoliation corrosion around steel fasteners on aircraft wing skins can be eliminated by timely blending. Once corrosion becomes extensive, expensive repairs are required. Early detection of corrosion is particularly important for airworthiness and safety reasons for structures like lap splices of aluminum fuselage skin. The economic payoff for using the Dripless Bubbler can be substantial because the cost of making even major repairs is almost always lower than the cost of the aircraft component or the cost of the involved system. The direct cost of corrosion alone to the US economy is approximately $300 billion per year (2001 study by FHWA). The US military spends more than $20 billion per year battling the general problem of metal corrosion (GAO figures), out of which $3 billion per year is attributed to the cost of corrosion of military aircraft. The loss of revenue to commercial airlines when an aircraft is grounded for corrosion repair and maintenance is $100K per day. Finally, although composites are beginning to be used as fuselage, wing, and empennage material on aircraft, the great majority of aircraft today are still made of aluminum. Corrosion therefore remains a major concern in aircraft maintenance and safety. The economic impacts of the latter in particular are almost impossible to quantify.

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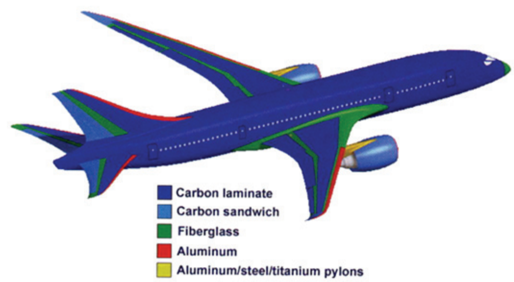
Aircraft Inspection: Time-Proven "Coin Tap" Automated

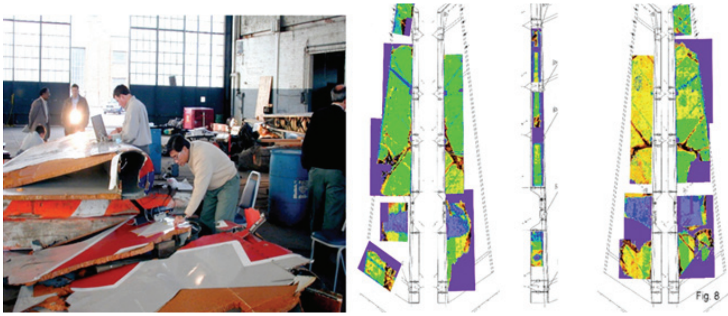
The use of composite materials in aerospace industry has increased dramatically since the 1970s. Carbon composites are quickly becoming the choice material for load-bearing primary structures on aircraft in recent years. The fraction of composites by weight has jumped from 12% on a Boeing 777 to 50% on the new Boeing 787. The Airbus A350XWB under development also has 50% composites. The stealth properties of composites and their ability to be molded into complex shapes are crucial to advanced bombers such as the B2.



Both commercial and military aircraft have in recent years greatly increased the amount of composite materials in their structures. For example, the figure here shows the new Boeing 787 with 50% composite by weight and much more by surface area (all blue and green areas are composites). Tap test is a time proven technique for inspecting composites, but is hampered by operator dependence (human factor) and being ruefully qualitative. The computer aided tap tester developed by CNDE specifically aims at providing quantitative image data for flaws and damage in composite structures.

Researchers at the Center for Non-Destructive Evaluation (CNDE) computerized and automated the hearing-based manual tap test, practiced widely by aircraft inspectors, to give it quantitative and imaging capabilities and to take the "human factor" variation out of the inspection procedure. The tapping action was automated with the invention of a magnetic cam scanning cart. Equally-spaced and uniform taps were made as the cart was pushed over the part's surface. The simple encoding method gave the tap test technique a previously unavailable imaging capability. Computer-Aided Tap Tester (CATT) has proven effective for the inspection of both composite structures and metal honeycomb structures on a wide variety of control surfaces on aircraft. It also provided the quantitative inspection results in image form that can be archived electronically.

The CATT developed by CNDE has been extensively tested in the field at commercial airlines, aircraft OEMs, MRO (maintenance, repair, and overhaul) facilities, and military bases. The design, operating software, and manufacturing process of the system have evolved over a number of years with input and feedback from the users in the field.



The Computer Aided Tap Tester (CATT) developed by CNDE of Iowa State University was used in the accident investigation of the Airbus A300 (American Airline flight 587) crash in Queens, New York in November 2001. The figures above show the mapping of the damaged rudder and the assembled image.

The Computer Aided Tap Tester (CATT) is better than previous technology in two important respects: first it provides quantitative engineering data on the local stiffness of the structure and second it provides an image of the inspected area using the measured stiffness data. The CATT is able to extract the local stiffness of the location it taps because it uses a high quality accelerometer with a steel tup that is much harder than the composite material it taps. As a result, the deformation is almost entirely in the less stiff composite material. Based on the known mass of the accelerometer and tup, the local stiffness can be calculated from the contact time between the part surface and the tapper based on a simple spring model. With the semi-automated magnetic cam inspection cart, the inspected area can be tapped in a grid pattern and a map is generated using the measured contact time or the computed local stiffness. The great advantage of the image data is that the inspector can intuitively distinguish between flaws or damage in the composite and the normal substructures based on the morphology. The system is exceedingly compact and can be easily used on aircraft components in the field.

Economic Impact: The primary benefits of using composites on aircraft are the reduced weight due to the superior specific stiffness (economic impacts due to enhanced fuel economy), the non-corrosive property of composites and assembly simplification. Composites cost about 35% more than comparable aluminum structure, but the higher cost is made up more than enough by the 65 to 85% lower manufacturing and maintenance costs.

The CATT represents a major improvement in terms of the quantitative and structural engineering nature of the inspection results and the scanning and imaging capability. With the low cost of the automated tap test system (approximately $5K for the system from ASI, Inc.), their use can be easily justified considering the replacement costs (often over $100K) of the flight control components on an aircraft. The CATT was patented by Iowa State University and licensed to Advanced Structural Imaging, Inc., a company founded by the inventors and colleagues. This new NDT instrument has been available on the market since 2001 and was purchased by many commercial companies, R&D organizations, military units, and universities here and abroad.

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