By Mark Robins

INNOVATIONS IN DENT DETECTION

NOT JUST COSMETIC, AIRCRAFT DENTS REQUIRE ATTENTION AND SOME INNOVATIVE SOLUTIONS CAN HELP.

8tree tools are calibrated under ISO17025 — the highest standard a metrology device can achieve. 8tree says as a result, dentCHECK measurement results are traceable to national standards and cannot be manipulated. 8tree images.

Aircraft dents happen. While some dents may have minimal effects, others can damage thin aircraft skin and compromise the aircraft's structural integrity and aerodynamic performance via the damaged area that is pushed in from its normal contour. Varying in size and severity, dents can range from minor indentations to more significant distortions of the aircraft's surface.

Dents on an aircraft's surface can disrupt the smooth flow of air over the wings' fuselage and other surfaces. These disruptions can increase air resistance, resulting in decreased lift, increased drag and reduced fuel efficiency. Dents can trap moisture and lead to corrosion. Furthermore, they can shorten fatigue life and contribute to the propagation of cracks. Failing to repair a dent in time can result in non-compliance with aviation regulations, leading to fines, aircraft grounding or other penalties.

Dents can result from old age and also impact with foreign object debris (FOD) like hailstorms, loose objects, small rocks, bird strikes and even accidental impact with service vehicles during loading operations. Regardless of their origin, Leonard Buck, marketing and business development manager at 8tree, Constance, Baden-Württemberg, Germany, says, "Dents are safety critical since they influence the structural integrity of the aircraft. Any dent has to be assessed prior to continuing aircraft operations." Airports, airlines and maintenance crews must be aware of dents and their origins, and take the necessary precautions to minimize them via proper training, procedures and maintenance programs.

Dent Detection Methods

There are procedures and equipment in place for MRO engineers to find, measure, evaluate, document and repair dents on aircraft skin, but it's not always easy. Dent detection via visual inspection is tedious, time-consuming and subject to human factors. They can be located in hard-to-reach areas of the aircraft with complex curved geometries or on leading edges, not always clearly distinguishable even by trained engineers. Also, inspection can occur at height and in challenging conditions, outdoors, where light and weather can interfere. Because dents can be smooth and without well-defined boundaries, with a depth often lower than 1 mm, they can be difficult to detect.

Buck explains that there are three distinct, different methods for dent assessment:

- **Traditional Tools (ruler, flashlight, depth-gauge and pen).** "This is the manual inspection method. Very time-consuming and error-prone. It's industry knowledge that 'you get 10 results if 10 people measure the same dent'."
- **General Purpose 3-D Scanners.** "3-D scanners require

Zeiss says they have products that offer scanning, probing, and tracking in a single system, a scalable field of view and high precision. Zeiss image.

significant surface preparation (stickers applied on the surface) and produce datasets and point clouds, which must be post-processed in specialized software and demands the expertise of highly trained metrology personnel."

- **1-Click 3-D Dent-Mapping Tools.** "Application-specific designed tools developed for the needs of mechanics and engineers. This tool contains a projector that displays the dent dimensions directly on the surface i.e., augmented reality."
- **AR-enabled 1-Click 3-D Dent-Mapping Tools.** "Application-specific designed tools developed for the needs of mechanics and engineers. Using Augmented Reality (AR), the tool projects the dent dimensions directly on the inspected surface. Mechanics will always receive instantly actionable results with the click of a button. That's what is needed on the line or in the hangar."

Despite these tools' dent-detection benefits, Buck believes that while "Dents are highly safety-critical and aviation (maintenance) is a highly regulated field … when we're looking at dent measurements, many airlines and MROs are still relying on guess work. Industry knowledge and studies show that traditional dent measuring is nothing but guesswork."

However, Buck adds that there are tools available today to solve this issue. All 8tree tools are calibrated under ISO17025 — the highest standard a metrology device can achieve. "The dentCHECK measurement results are therefore traceable to national standards and cannot be manipulated (thinking of compliance — big issue)," he says. "Any mechanic can operate the tool after a few minutes training. The AR-enabled dentCHECK tool was purposely designed for dent-mapping on aircraft. The projection of instantly actionable results on the aircraft surface is a giant leap for any airline/MRO/OEM operation and for passenger safety."

Levis, Canada-based Creaform's VXintegrity–Aerospace, is dedicated 3-D visualization software designed to assess and characterize dent damage on different aircraft components, sizes and surface finishes. Its guided workflow approach simplifies the measurement extraction of 3D scan data and obtains the exact dimensions required for the assessment. More accurate and faster than traditional methods, the software limits operators' impact on measurements and shortens the time needed to generate final reports, providing airlines with comprehensive data on issues that require further analysis.

Complex Geometries and Curved Surfaces

Complex geometries and curved surfaces have been known to be the bane of aircraft dent detection, but that's changing. Buck says it's becoming less difficult. "Inlet cowls, leading edges, acoustic panels etc., can be inspected with dentCHECK. Double-curved and highly curved surfaces are almost impossible to measure by hand (referring to the 'guesswork' statement again)." dentCheck has 1-Click 3D dent-mapping with real-time visual feedback providing go/no-go damage inspection through augmented reality. It can be used at the line, in the hangar, on the tarmac or in AOG situations.

Computer vision (CV) is an application of artificial intelligence (AI) that trains computers to identify, interpret and track objects in photos and videos. The technology is primarily driven by recognizing patterns that repeat themselves over a given set of data. For inspection purposes, AI can detect dents automatically on an aircraft, which could take a human worker up to hours to inspect, while trying not to lose focus on the task.

Jake Bauer, senior data scientist at Striveworks, Austin, Texas, says, "CV models are trained on 'ground truth' data: properly labeled examples of what the analyst expects to encounter in the real world. If an analyst is using AI to review complex geometries, then those same complex geometries need to be part of the model training. Striveworks pairs data scientists with customer subject matter experts to better understand the nuances and challenges in manual workflows. Together, they can create an optimal training dataset for a complex task like dent detection. A CV model optimized for complex geometries and curved surfaces will outperform general CV models at the same task."

AI and Dent Detection

AI has indeed provided real improvements in efficiency for aircraft dent detection. Striveworks worked with a leading Fortune 500 logistics company to create CV models — fine-tuned on imagery of aircraft dents — to help inspection teams identify dents and process vast amounts of imagery.

"Inspection teams using AI were able to find 27% more dents and work through images 50% faster than by doing the work manually," Bauer says. "These improvements allow teams to review vastly more aircraft surface in a shorter period of time, an obvious benefit when entire fleets are grounded following hailstorms. Because of the complicated challenge of teaching machines how to identify dents in photographs, advanced ensembling i.e., majority voting' and data preprocessing techniques are needed to add resilience."

When using AI to perform dent detection, Bauer believes specificity is key. "This starts with capturing data that is as similar as possible to what would be expected during an actual aircraft inspection. Using the exact same type of aircraft, lighting, paint color, camera sensor, camera angle, etc., for model training will improve a model's ability to correctly identify dents during a real inspection. There is no substitute for expertise when it comes to safety and inspection. While AI can recommend locations of possible dents with high accuracy and speed up the process, a trustworthy inspection should always have a human in the loop. Ultimately, the safe maintenance of aircraft requires a well-trained inspection crew."

Drones and Dent Detection

Improvements in drone technology have allowed analysts to capture dent imagery faster and at less expense. "Drone photography provides a critical AI input, both to tune CV models to perform optimally on the task of dent detection and during actual inspections," Bauer says. "Tuning models on the same

Donecle is a Toulouse-based aircraft manufacturer that has developed autonomous aircraft inspection UAVs. The company offers single UAVs and swarms of UAVs to visually inspect the exterior of airliners. Donecle image.

sensor data (drone altitude, camera angle, image sensor, etc.) that is used during actual inspections improves the performance of models. When any changes occur with the environment or sensors, the dent-detection models can quickly be retrained on the new, real-world imagery to improve performance."

Buck predicts drones used in dent detection represent the future. They will complement the handheld measurement capabilities. "The first IRIS dentCHECK dent-mapping drones are being delivered to the end customers. The IRIS dentCHECK is the 'flying version' of 8tree's handheld dentCHECK dent-mapping tool. It is the result of a partnership between Donecle and 8tree." AM