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Case Study C-CAT - Kennedale

Prototyping Eliminates Tooling, Nets Millions in Savings

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Metrology-assisted assembly harnesses costs in building carbon-carbon aerospace components

By Belinda Jones

Building complex prototypes can often grind a budget and timeline into mincemeat. With declining funds for space programs and tight budgets in the aerospace industry, every dollar spent is vital…every dollar saved is survival. Serving those industries, Carbon-Carbon Advanced Technologies, INC, (C-CAT) has taken steps to drive new efficiencies into longstanding practices. And their resourcefulness has yielded big rewards and quality products.

C-CAT is a privately owned corporation and high-tech manufacturer specializing in the development of carbon-carbon structures for aerospace and commercial applications. The company was originally founded by Francis Schwind in June 1988. Schwind gained extensive experience working on thermal protection systems for the nose cap and leading edges on the Space Shuttle during the 1970s. This endeavor led to the carbon-carbon production environment that exists today. His fledgling company would go on to produce 2D prototype test liners for the Pratt & Whitney 119 engine.

In 2006, C-CAT expanded and relocated to a new headquarters in Kennedale, Texas near Forth Worth. Their state-of-the-art facility has oxidation protected carbon-carbon component manufacturing capabilities, including composite curing equipment, pyrolysis and densification equipment, a machine shop for tooling and components, coating furnaces, and a variety of ovens and test furnaces, and quality control inspection equipment. Current on-stream equipment is sized to process a 5 ft. x 10 ft. (1.5 x 3.1m) panel or 70 inch (1.8m) diameter nozzle through coating.

What is Carbon-Carbon?
Carbon-carbon or C/C is a composite material comprised of carbon fiber reinforcement in a matrix of graphite. C/C has gained a space-worthy reputation due to its high temperature resistance withstanding temperatures from 3,200 to 4,000 degrees Fahrenheit (1760 – 2204°C). And the material becomes stronger as it gets hotter. Components constructed from C/C will hold their shape and remain relatively sound under serious duress. Industry insiders say if the Space Shuttle was being built today, the lower half of the wing skins and panels would more than likely be constructed of carbon-carbon, as the structure would be substantially lighter and much less complex.

After early generations, C-CAT began to formulate an advanced grade of the material with the intent to use it for more complex structures than in the nose cap of the Shuttle. Now carbon-carbon is being used throughout an entire vehicle. For example, a quick glance at current generation reusable hot structure space- related programs reveals the flight controls are fully C/C instead of the outdated aluminum-and-tile shuttle structure.

Quality Moves
Raj Narayanan, quality assurance representative, arrived at C-CAT in 2003 to help move prototype programs toward flight qualifications and readiness. With a healthy background in both aviation safety engineering and quality engineering, Narayanan was ready to leverage his experience in the repair, overhaul and maintenance side of the aerospace business to deal with the new level of quality and certification requirements for C-CAT.

The evolution of small carbon-carbon components into much larger structures was unfolding at C-CAT. When the company began to work on hardware related to NASA/ DARPA/ U.S. Air Force projects and flight critical applications for space vehicle deployment, overall specifications for C-CAT became more stringent. Narayanan and his team focused on building quality system requirements, as well as inspection and certification capabilities into manufacturing and assembly processes.

Enter Laser Trackers and Metrology Assisted-Assembly
Narayanan was well aware of metrology-assisted assembly, and saw it in action at Lockheed Martin on the F-35 production line. For this operation, they employ laser trackers and a custom jacking system to align the large parts of the aircraft instead of having a complex jig to connect the main body with the wings and the nose section. He also had experience using portable metrology devices from past experience working for a nose radome manufacturer. Laser trackers were used for building tooling, taking aircraft measurements, measuring tight tolerances, part mating, assembly and reverse engineering applications.
C-CAT introduced a Leica LTD700 laser tracker to their program in 2004, and has added a Leica Absolute Tracker recently. Both portable CMMs are ideally suited for data acquisition and inspection applications within a large measurement volume. The Absolute tracker combines the measurement principles of the absolute distance meter and an interferometer. With multiple built-in redundancies, the Absolute Interferometer technology ensures high-accuracy measurements in all operating conditions throughout the measurement volume, which can reach a full 262 feet (80 m) when used with a corner cube, or 98 feet (30 m) when used with a wireless Leica T-Probe. Both trackers have fast measurement cycles for high point density at 3000 points per second, and deliver accuracies as good as 0.0015″ (0.04mm) over a 20 foot (6.1m) span (two sigma).

The company employs the use of laser tracking in several ways. First, the portable CMM is used as a true, traditional inspection tool to measure part width, thickness, features and more. But most importantly, during the build process of a significant complex structure such as a large scale aerostructure, the laser tracker is used in lieu of having expensive complex tooling.

"When building an aircraft or a component in the past, there were hundreds of jigs and fixtures used to hold components in place, as well as molds and tools to hold inside features, ribs and more. At that time, we were using standard metrology equipment such as height gauges, and fixtures to align those parts. During the early prototyping phases of a program, no one could calculate the number of on-the-fly changes that would be made during product development. Each change can impact how many fixtures or jigs that would be needed. And that would, of course, impact the bottom line," states Narayanan.

Today, C-CAT takes a much different approach to assembly using the laser tracker literally as a live alignment "fixture" tool. Aircraft parts and different sections of the aircraft are scanned, then assembled systematically using a laser tracking system. The 3D data acquired from the device is then compared to the 3D CAD model of part. The steps are straightforward. Take a set of data points, import them into the inspection software, build the assembly, import a CATIA model into the software, and compare the data.

When building a Carbon-Carbon aeroshell comprised of 40 or 50 pieces, C-CAT's in-house metrologists will take reference points off the internal parts and align the external components to them prior to the bonding process. Because it is a C/C composite structure, all parts will be bonded together. The portable CMM is used to precisely align where these parts should be in 3D space, as opposed to having a complex fixture.

Reality Check
For C-CAT, there are two realities of space vehicle development. One is the very low production realm of constructing prototypes and one or two flight critical vehicles. The cost to build multiple sets of tooling can be astronomical, especially during the early stages when design elements are constantly changing. The second reality is time. C-CAT is under the gun to rapid prototype these components and get them ready for flight launch within 16 months. Normal design cycles for space vehicles can extend into 3 or 4 years.

"The laser tracker provides a huge amount of time reduction capability for us, because we can eliminate or drastically reduce all of that tooling. On older programs like building Carbon-Carbon Scram/Ram Jet engines, we spent hundred's of thousands of dollars on tooling. If we had laser tracking then, we would have eliminated 50 to 60% of that cost. Compared to the newer Carbon-Carbon aeroshell project, when you add up all the fixtures that would have been required, plus the time delay without the laser tracker, the cost may have run similarly in the range of a half to three quarters of a million dollars in fixturing needed to do the alignment. And with metrology-assisted assembly, there are quality benefits you can't put a price on," concludes Narayanan.

Quality and Accuracy Fit the Bill
As expected, laser tracker usage at C-CAT has proliferated on several levels. On the current aeroshell, the 14 ft. (4.3m) structure and its internal heart structure of bulkheads and spars are all constructed of carbon-carbon. The laser tracker was used to acquire three-dimensional coordinate data for CAD model-to-part-compare, to establish baseline points and dimensions on all the sub-pieces, then align them in 3D space. Literally every part was aligned and oriented in the carbon-carbon aeroshell at some stage using the laser tracker.

Laser trackers meet the accuracy requirements of many aerospace programs that are mostly in the 0.005″ to 0.010″ (0.13 to 0.25mm) range. C-CAT is holding tight tolerances on critical dimensions over an entire surface of a 14 ft. (4.3m) aeroshell in the plus or minus 0.001″ (0.03mm) range, while subcomponents of internal structures are held to +/- 0.002″ or 0.003″ (0.05 or 0.08mm). For the X-37 programs, tolerance levels for the flight controls on piece components are nearly +/- .0001″ – .0002″ (0.003 – 0.005mm). To validate those numbers, C-CAT will occasionally contract unbiased third party metrologists to confirm key measurements. "Due to the criticality and application of some programs, we prefer to have a third-party inspection verification source. We have worked with Hexagon Metrology Services Inc. on several projects for that kind of professional support."

C-CAT has also used laser tracking technology for the Navy's hypersonic scram jet demonstration technology for building and alignment components in the later part of this system. For the carbon-carbon hot structure reuseability program, C-CAT rolled out the laser trackers for final inspection and provided coordinate data to its end customer, so they could align the C-CAT structure with their own structure and determine proximity to the target tolerances. Narayanan explains, "Everything boils down to interface control drawings. The laser trackers tell us whether we are in the ICD envelope or not, and where the deviations are. We use trackers for build at the start, and verification at the end."

Feeling the Potential
With C/C moving into the mainstream as a material for space vehicles and beyond, C-CAT has carved out a strategic niche for its expertise and capacity. Successfully driving out antiquated practices and introducing new efficiencies into their production model, the company has gained a unique insight into the benefits of metrology-assisted assembly, which arguably has made the biggest bang of all.

Whether building the fastest car, the biggest plane, or the most precise tooling, you need exact measurements to improve quality and productivity. So when it has to be right, professionals trust Leica Geosystems Metrology to help collect, analyze, and present 3-dimensional (3D) data for industrial measurement.

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