STOPPING POWER

A DISCUSSION OF THE STATE OF THE ART IN AIRCRAFT WHEELS AND BRAKES AND HOW THE U.S. AIR FORCE IS BRINGING ITS C-130S INTO THE TWENTY-FIRST CENTURY.

BY GARAN CHIVINSKI

Image courtesy of U.S. Air Force. Photo by Senior Airman Kenny Holston.

Airman 1st Class Benjamin Feldkamp works on the brakes on a B-2 Spirit at Whiteman Air Force Base, Mo.

Wheels and brakes are among the most vital yet abused parts of any aircraft. They are required to safely operate and stop the aircraft, often in less than ideal conditions, during both takeoffs and landings. Landing after landing, they are called upon to withstand, absorb, and safely dissipate the tremendous kinetic energy of the decelerating airplane and bring it to a safe stop.

As aircraft have become bigger, faster, and more advanced, the physical demands placed on wheels and brakes have increased accordingly, and traditional technologies and materials have been pushed to their limits. In order to meet the demands of modern-day aircraft, ensure safety in landings and takeoffs, and, at the same time, minimize maintenance costs to accommodate reduced budgets, wheel and brake manufacturers have been called upon to revolutionize their products.

Without doubt, the wheel and brake industry has risen to the challenge, and the sector has entered into an exciting new era of innovation. Sophisticated design processes, new materials, and

advanced electronic systems are changing the way that the biggest, most powerful aircraft take off and land. Smarter, longer lasting, more efficient wheel and brake components are being produced by such industry leaders as Crane Aerospace and Electronics, Goodrich, and Meggitt, and distributed by such top suppliers as Aero Precision.

As proof of a new dawn in this segment of the aftermarket, the U.S. Air Force recently opted to retrofit the wheel and brake systems of its fleet of C-130s with some cutting-edge technologies. Some of these same technologies already have been successfully tested in the private sector and on new-model military aircraft, but they are new to these transport aircraft.

CARBON BRAKES

Industry experts agree that the most important advances in wheels and brakes involve better controlling the heat and wear created by landings. Therefore, one of the most important innovations in aircraft brake technology has been the development of carbon heat sinks.

> This new equipment represents a significant leap forward, from a performance, maintainability, and safety standpoint, when compared to the current equipment.

Jeffrey Atkinson, Director of Military Programs for Goodrich, says that in recent years, "Brake heat sink wear material evolved from steel plates with sintered wear surfaces to multi-disk carbon composites, bringing with it the advantages of lighter weight, higher performance, better wear characteristics, and longer life - all of which translates to lowering cost of ownership for the operator on a lifecycle basis."

Carbon components can slow the aircraft well beyond the temperatures at which steel brakes will lose their efficiency and begin to fade. They also vibrate less, put less stress on wheels during braking, and wear up to eight times longer than steel.

Goodrich has fast become an industry leader in carbon brakes, marketing its product as DURACARB. Other manufacturers such as Meggitt, and Messier-Bugatti also are major suppliers and innovators in this area, with the latter having introduced their first carbon brakes in 1986 for the Airbus A310.

According to Atkinson, "This new equipment represents a significant leap forward, from a performance,

Senior Airman Michael Bruke and Airman 1st Class Britney Warner install a multi-disc brake on a C-130E Hercules in Southwest Asia.

maintainability, and safety standpoint, when compared to the current equipment. Our new carbon brake replaces the old steel brake and is capable of performing eight times the number of landings before wear-out when compared to the steel brake (2,000 versus 250 landings)."

{ One of the most important advances in commercial brake control technology is the amazing improvement in wet and icy runway braking performance. }

ANTISKID BRAKING CONTROL SYSTEMS

When an aircraft lands on substandard surfaces, such as gravel or ice, wheels can skid, potentially causing loss of directional control and substantial damage to the landing gear. The use of an antiskid braking control system (BCS) prevents destructive and dangerous skids by automatically adjusting the speed of the wheels to achieve the maximum achievable contact with the landing surface.

Crane Aerospace and Electronics has been making antiskid braking control systems since 1947, when the company introduced the Mark I antiskid BCS. In the latest version, the Mark IV, Crane has achieved their most sophisticated, efficient, and cost-effective BCS yet. The Mark IV features fully digital components, including a fault display unit (FDU) that facilitates troubleshooting and maintenance actions.

Aero Precision, a prominent provider of wheel and brake products, is the exclusive distributor of Honeywell F-15 and F-18 wheels and brakes, as well as Crane's C-130 Mark IV antiskid BCS. Noreen Kabra, International Business Development Manager for Aero Precision, says, "By reducing hard skids and improving troubleshooting and maintenance times, the Mark IV takes the BCS to a new level. The C-130 Mark IV BCS currently is in use on all C-130J models, and we offer the upgrade on the E models and H models to bring them to [the level of the] current enhanced J model."

Frank Cowle, President of Aero Precision, and a former C-130 technician explains, "One of the most important advances in commercial brake control technology is the amazing improvement in wet and icy runway braking performance. Early antiskid

Image courtesy of U.S. Air Force. Photo by Staff Sgt. Phillip Butterfield.

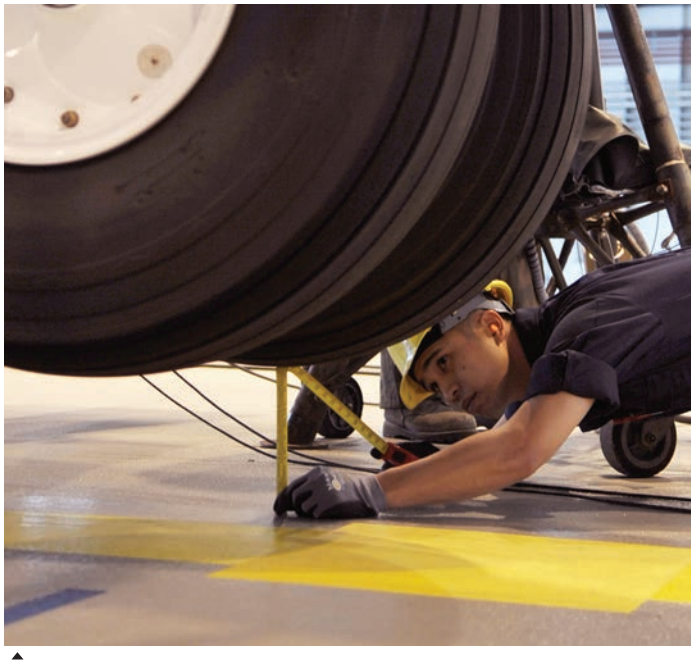

Image courtesy of U.S. Air Force. Photo by Airman 1st Class Caleb Pierce.

Airman 1st Class Joel Rivera measures the height off the ground of C-130J Super Hercules landing gear during an isochronal inspection at Ramstein Air Base, Germany.

Image courtesy of U.S. Air Force. Photo by Staff Sgt. Phillip Butterfield.

Senior Airman Joshua Arrington aligns a brake assembly on a C-130 Hercules after a brake change at Joint Base Balad, Iraq.

systems could operate at a relatively impressive 75 to 85 percent efficiency on a dry runway, but achieved a much less impressive 50 percent or lower efficiency on wet and/or icy surfaces. Using modern technology, Crane's Mark IV antiskid upgrade on the C-130 now achieves about 90 percent or greater efficiency on both dry and wet and/or icy surfaces.

"These performance improvements are important not only for safety, but also for operational flexibility and cost-effectiveness, since improved braking performance permits aircraft to carry more payload and operate on shorter fields." He concludes, "Those advantages, coupled with the lower maintenance costs due to improved materials and intelligent fault diagnostics capability, give the operator enhanced stopping power at a lower cost of ownership."

Other innovative solutions are contributing to improved safety and durability, while lowering maintenance costs. For example, to better monitor and control the build-up of damaging heat, electric brake fans have been added to blow cooling air across the wheel assembly. Meanwhile, brake temperature indicators (BTIs) are used to immediately alert pilots to excessive heat in the wheel wells. This reduces the chance of fires and tire failures, while also extending the life of the wheels and brakes.

ELECTRONIC ACTUATORS

One of the most revolutionary advances in wheels and brakes is electronic braking systems. For decades, most aircraft relied on hydraulic braking systems. These systems are often complex, heavy, and necessitate significant maintenance. Electrical braking systems replace hydraulic pistons with electric motor-actuators, resulting in much lighter, simpler, and more reliable braking systems.

Goodrich was an early leader in electrically actuated braking systems, having provided the advance to Northrop Grumman's Global Hawk RQ-4B unmanned aerial vehicle (UAV). Dispensing with heavy and complicated hydraulic braking systems was an obvious advantage for agile, long-endurance UAV such as the Global Hawk. As Atkinson points out, "Electrically actuated braking systems typically offer reduced system weight and installation time, improved reliability, and reduced installation, test, and maintenance effort."

He further explains, "Another significant advantage that electrically actuated braking systems offer is enhanced preventive and predictive maintenance capabilities. These systems utilize intelligent electronics that can tell the pilot, for example, how much life remains on each brake, or when a brake is worn to limits and needs to be replaced. If one of the brake actuators should fail, these systems not only inform the pilot, but also pinpoint for the maintenance crews exactly which actuator on which brake has failed, speeding repairs and a return to service."

Those benefits are equally attractive to civil aviation operators, and Goodrich quickly reached beyond the Pentagon to introduce the world's first commercial electric braking system for the Boeing 787 Dreamliner. More manufacturers and airlines are embracing the technology, and most industry experts believe that electric brakes will soon displace hydraulics for good.

BETTER WHEELS WITH RADIAL TIRES

To complement the new brake designs, the most important part of

Airman Andrew Boomershine relocates a serviceable C-17 Globemaster III tire to a staging area in a hangar at Joint Base Lewis-McChord, Wash.

the landing gear, wheels and tires, also have been improved. For example, Goodrich's new lock-ring main wheel replaces the old bolted wheel design.

According to Atkinson, the new wheel "has just five major parts and is rated six times the life of the current wheel (25,000 miles versus 4,200 miles). Because our new lock-ring wheel has no bolts, nuts, or washers holding the two wheel halves together, tire changes can be accomplished five times faster than when using the current wheel."

Over time, lighter, more heat-resistant - thus longer wearing - materials have been developed and adapted to tire designs. Goodyear, despite being in the airplane wheel business since 1909, was only able to bring the benefits of radial tires to the demanding world of aviation in the 1980s.

Early radial tires developed for automobiles were capable of surviving the much greater speed and weight demands of aviation operations. As a result, airplane tires have continued to be made of heavy steel, which added extra weight to aircraft and also wore out surprisingly quickly.

But with the development of lighter weight, higher strength aluminum alloys, tire designers at Goodyear have been able to produce more efficient, smaller cross-section tire designs with an aluminum core, instead of a steel core wrapped with strands of high-tensile wire. As a result, tires are now longer lasting and 3 pounds lighter compared to those with steel cores. Increased maintenance intervals translate into reduced costs for the operator, and a reduction in weight helps decrease fuel consumption, further reducing costs.

UPGRADING THE C-130 LEGACY FLEET

With these and related advances underway, the U.S. Air Force has recognized that now is the time to improve the performance and cost-effectiveness of their C-130 fleet by upgrading their antiquated wheel and brake systems. Officially dubbed the U.S. Air Force Wheel and Brake System Improvement (WBSI) and managed by the Landing Gear Program Office at Hill Air Force Base in Utah, the program will upgrade the C-130 fleets beginning this year, with completion scheduled for 2014.

The U.S. Air Force's C-130 legacy aircraft (E and H models) currently utilize a mix of Mark I and Mark II Crane Antiskid BCS, as well as steel brakes and obsolete analog control components. The upgrade will include Crane's Mark IV Antiskid BCS on the legacy models, and Goodrich's DURACARB brakes and lock-ring wheels on all their C-130 models, to include the newer J model.

In addition to efficiency, safety, and maintenance cost savings, the upgrades offer a tactical benefit. "Because of the significant increase in performance that our new equipment offers," Atkinson says, "the U.S. Air Force may consider reducing the currently recommended brake cooling time of 65 minutes after a heavy-weight, full anti-skid landing, to just 5 minutes. This would allow higher utilization of the aircraft and allow it to quickly depart contested areas after offloading cargo." This reduced downtime also is a

Image courtesy of U.S. Air Force. Photo by Tech. Sgt. Michael R. Holzworth.

Senior Airman Edwin Watkins looks over the landing gear of an A-10 Thunderbolt II before a training mission during the Green Flag West 11-2 exercise at Nellis Air Force Base, Nev.

Image courtesy of U.S. Air Force. Photo by Doug Spinks.

A C-130E from the 19th Airlift Wing at Little Rock Air Force Base, Ark., comes to a screeching halt during a Wheel Brake System Improvement test at Edwards Air Force Base, Calif.

Image courtesy of U.S. Air Force. Photo by Abner Guzman.

potentially useful performance improvement for civilian operators working out of increasingly congested airports.

Furthermore, since the latest C-130J already is equipped with these features, aircraft in the legacy fleet will be that much more interchangeable with the newest models in service. This efficiency will positively impact the U.S. Air Force's fleet operations and decrease crew training needs.

friendly. Therefore, from a lifecycle cost standpoint, carbon brakes generally are less expensive to operate than their steel brake counterparts.

Furthermore, when dealing with new materials, such as the carbon fiber used in DURACARB, it is not always easy to predict how such materials will react in the long run in the context of myriad conditions and various chemicals present in the

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HOW IS IT WORKING?

As with any innovation, these new technologies have some drawbacks, and there is always room for improvement. Though advances such as anti-skid and carbon brakes promise real savings over the life of the product, the initial cost of these new parts usually are much higher than the cost of traditional components. However, carbon brakes last longer than steel brakes and are lighter and much more maintenance-

environment and on the tarmac. Atkinson admits that the "increased use of new environmentally friendly runway de-icing compounds at airports is having an adverse impact on the life of some carbon heat sink materials. These chemicals are causing catalytic oxidation of the carbon brake discs, resulting in reduced performance efficiency and unscheduled removals."

According to Atkinson, the good news is that, in response, "Goodrich has developed and fielded improved carbon-oxidation inhibitor compounds that are capable of preventing or delaying the onset of catalytic degradation, allowing longer wear, increased life, better performance, and enhanced safety."

While ongoing improvements will continue to be made, such new wheel and brake technologies have proven extremely effective in the field and are quickly being adopted not only by the U.S. Air Force, but also across the industry. Steve Kelly, Director, Product Repair Services, for parts and maintenance provider Aviall, says that the new wheel and brakes technologies "are performing well and save customers money by increasing mean time between removals and providing significant weight reductions."

Not surprisingly, carbon brakes have become the industry standard and are now used on more than 23,000 military and commercial aircraft. In addition, the Mark IV Antiskid BCS from Crane has been applied with great success on major civilian aircraft such as Boeing's airliners.

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