

Aircraft & Composite Recycling

(2007 Boeing Commitment Update)

The Boeing Company is committed to improving the environmental performance of the airplanes it designs and manufactures, including the pursuit of aircraft life cycle improvements. Several years ago Boeing conducted a field survey of approximately 50 companies involved in older fleet management and aircraft scrapping. A realization from that process was that a group of companies quickly distinguished themselves in terms of experience, capabilities and technologies, and Boeing began to focus its attention in that direction. For the past several years, Boeing has helped facilitate discussions amongst those companies, sharing its industry commitment to the environment and safety [1].

Since that time 19 companies, including Boeing, have come together to establish a common industry working group, AFRA (Aircraft Fleet Recycling Association.), [2] with a mutually shared commitment to improving older fleet asset management and fostering the recovery and the safe and environmentally progressive reuse of aerospace materials.



Fig. 1 - Bill Carberry (right), Project Manager, Commercial Airplanes Airplane and Composite Recycling, being interviewed by French TV about Boeing's support of AFRA airplane-recycling initiatives. (Pauline Bucaille photo)

AFRA was officially announced on April 17, 2006. It formalized its charter and elected a board of directors and executive director in June 2006 in Châteauroux, France. Bill Carberry, Boeing Commercial Airplanes Project Manager, Airplane & Composite Recycling, (Fig. 1) was elected Deputy Director. Charter European and North American member companies included the following:

- Adherent Technologies (Albuquerque NM)
- Air Salvage International (Alton UK)
- Bartin Recycling Group (Châteauroux, France)
- Châteauroux Air Center (Châteauroux, France)
- Evergreen Air Center, (Marana AZ)
- Europe Aviation (Châteauroux, France)

- Huron Valley Fritz West (Tucson, AZ)
- Milled Carbon Ltd (Warwickshire, UK)
- Rolls-Royce (Derby, UK)
- The Boeing Company – (Chicago, IL)
- WINGNet – (Oxford, UK)

The AFRA charter contains the following goals and objectives for the organization:

- *Develop a code of conduct for retired aircraft management.*
- *Establish next-generation standards and industry best practices for aircraft recycling and reclaimed materials management.*
- *Work to promulgate these practices through broader industry associations.*
- *Continue cooperation between all AFRA members in technical and commercial matters.*

In its first year of operation AFRA has incorporated as a non-profit industry association with offices located in Washington, DC and its membership has risen to over 30 companies from eight countries on three continents. In addition, AFRA has established a strategic relationship with the Aviation Suppliers Association which is providing valuable guidance and administrative support as AFRA works to develop and disseminate voluntary best practices for aircraft recycling and older fleet management.

Boeing, as a founding member of AFRA, recognizes the benefit of working on these issues with a wide array of experienced companies in addition to aircraft manufacturers. This includes companies with expertise in older aircraft management, and others that have developed highly innovative methods for recycling and reclaiming materials from retired aircraft, including some of the more exotic new materials used to manufacture today's aircraft. AFRA's growing membership roster illustrates the benefits of a cooperative approach to developing guidelines for responsible aircraft life cycle management.

Regarding Aircraft



Source: The Boeing Co.

Fig. 2 - Scrap airplane parts from a retired cargo plane being loaded into a container for shipping to a recycling facility

The Boeing objectives for aircraft recycling are as follows:

- Promote Boeing's industry leadership and endorsement of AFRA's recycling initiatives,
- Demonstrate through its participation in AFRA that the organization has a long-term commitment to build and expand its offering to industry,
- Offer airline customers end-of-life and maintenance options that will:
 - Re-sell planes that are fit to return to service
 - Offer safe parts recovery, scrapping and recycling of planes that are not fit for service,
 - Greatly improve materials recovery from retired planes and manufacturing scrap. [1]

Boeing believes that AFRA members, as established companies in the aircraft recycling field, have the necessary expertise and capability to provide leadership. AFRA membership is open to all interested companies in the aviation industry who are prepared to sign onto the AFRA charter and meet the other criteria for AFRA membership listed on the AFRA web site.

AFRA is an independent entity. Members are independent entities wholly responsible for their own actions. AFRA exercises no control over its members beyond the maintenance of a members list, and inclusion on that list is a function of the commitment of the member to this charter and is a function of the honesty and integrity of the member. AFRA accepts no responsibility or liability for the activities of any other legal entity.

AFRA's members are taking the lead in promoting voluntary best practices with respect to older fleet management and aircraft recycling. There are two types of members in AFRA; those that are directly involved in processing materials and those that provide strategic support to the first group. Boeing is part of the second group.

Boeing anticipates that as many as 7,200 commercial aircraft will be retired from active service in the next 20 years and all should be available for recycling (Fig. 2). Recycling, rather than land-filling, is better for both business and the environment. Boeing supports efforts to develop commercially feasible and environmentally sound guidance and best practices for aircraft recycling.

One of AFRA's primary objectives is the development of a voluntary industry code of conduct and industry-recommended best practices for efficient, safe and environmentally-sound management of retiring airframes and their components and scrap from the new manufacturing technologies employed on next-generation planes. The purpose of these standards is to set out reasonable service levels expected by the industry.

AFRA's first guidance subject, *Management of Used Aircraft Parts & Assemblies*, contains voluntary best practices for the removal of parts from an end-of-life aircraft, covering parts management prior to their entering the distribution network (which is covered by FAA Advisory Circular 00-56A).

AFRA members from US, UK and France participated in the development of this first guidance document, which was done exclusively by teleconference (no travel costs). The trial draft [3] was reviewed by FAA and EASA (European Aviation Safety Agency), and field tested in trial audits at two companies in the US and two in Europe. The findings and feedback were then reviewed and incorporated into a final version approved at the AFRA July 2007 annual meeting. AFRA has now completed the revisions of its guidance, *Management of Used Aircraft Parts and Assemblies*, and is now in the process of developing a protocol by which interested companies may seek, on a voluntary basis, to be certified to that best practice (expected in early 2008).

Beyond the newer challenge to reclaim carbon fiber from composite scrap, recycling considerations include: aluminum sorting by alloy, aircraft electronics recycling, effective disposal of other aircraft components such as hazardous waste, solid waste, airplane fluids, and the conservative use of labor and energy to accomplish the overall objective of reducing the impact of a retired aircraft on the environment. AFRA's approach is to integrate such new and emerging technologies into older aircraft management and new materials recycling industries. Various current members are improving the technologies that address composite recycling, aluminum separation by alloy type, and electronics recycling. (AFRA does not endorse or recommend any specific technologies or companies.)

AFRA, including its member companies from three continents, represents the first time that this combination of best practice guidance development and integrated application of cutting edge technologies to improve airplane life cycle value has been attempted.

Regarding Composites

Boeing is actively working with its global partners to find applicable best practice guidelines for the 787 program. As the newest member of the Boeing family of airliners, it is an all-new, mid-sized airplane with long range capabilities. The 787 is being made primarily of carbon



Source: Milled Carbon Ltd.

Fig. 3 - Scrap carbon fiber composite ready for shredding and fiber reclamation processing

fiber composite material comprising 50% of the 787's structural weight. This represents a breakthrough from today's airliners that are primarily composed of aluminum. Looking forward, Boeing is working with companies around the world towards a goal of maximizing the use of recyclable materials on the 787. Although the first retirements of the 787 are likely 30-40 years away, it is important that the foundation of that recycling activity begin today to support 777 retirements (20% by weight composites) as well as other aerospace products.

Boeing is continuing to work with a number of companies, including AFRA-affiliated companies, towards a goal of being able to recycle all composite manufacturing scrap from its plants in Frederickson, Washington and Seattle, Washington, as well as from its other commercial, military and space programs. This is an important part of the Boeing commitment to continually improve environmental performance and find solutions for its global partners and customers.

The recycling of composites is normally a two-step procedure that involves; first, a mechanical process that separates composites from other aircraft materials during an aircraft's retirement (Fig. 3) and second, a recycling process that recovers fibers of sufficient quality that they can be re-introduced as a materials source in aerospace manufacturing.

For the past three years Boeing has worked 1) with Huron Valley Fritz West (AZ)[4] on optimizing aircraft composite scrapping techniques; 2) with both Milled Carbon Ltd. (UK)[5] and Adherent Technologies (NM)[6] to optimize their recycling technologies, and 3) with

researchers at N. Carolina State Univ. and Nottingham Univ. (UK) on fiber evaluation and characterization.

Milled Carbon uses a pyrolytic (incineration that chemically decomposes materials by heating them in a near oxygen-free atmosphere) continuous flow process to burn off all the resin and additives, freeing the fiber reinforcement. It does not need to pretreat the material before pyrolyzing and has the ability to process the recycle further by chopping or milling for various applications. Adherent Technologies uses a low-temperature catalytic conversion batch process to recycle complex mixtures of thermoplastic and crosslinked thermoset polymers. It reclaims not only fibers but also thermoplastic and thermoset polymeric waste in the form of reusable hydrocarbon fractions (chemical building blocks). The various materials are separated by designated support unit operations during the process. Both processes are proprietary and owned by their respective developers.

Shredded composite scrap from damaged F/A-18 horizontal stabilizers (end-of-service, scrapped aircraft parts) was sent to both Milled Carbon and Adherent. The reclaimed AS-4 fibers (Fig. 4) were sent back to Boeing and subsequently forwarded blind to N. Carolina State Univ. for testing. The control was virgin AS-4 (35 msi modulus / 3501-6 graphite epoxy, Fig. 4). Spectroscopic analysis showed that both processes left a metals residue on the fibers. Both processes were "optimized", which removed this residue from a second run of the scrap.

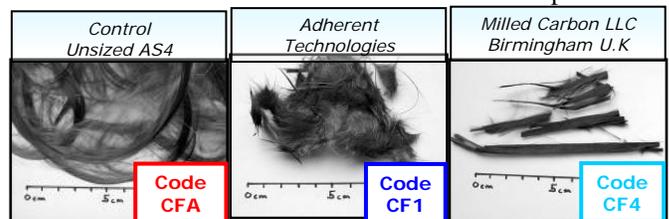


Fig. 4 – Control & Reclaimed Fibers for Testing[7]

Single fiber tests included visual assessment (X-ray), plus surface and mechanical properties (Fig. 5).

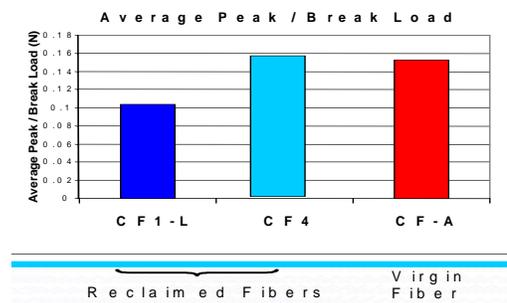
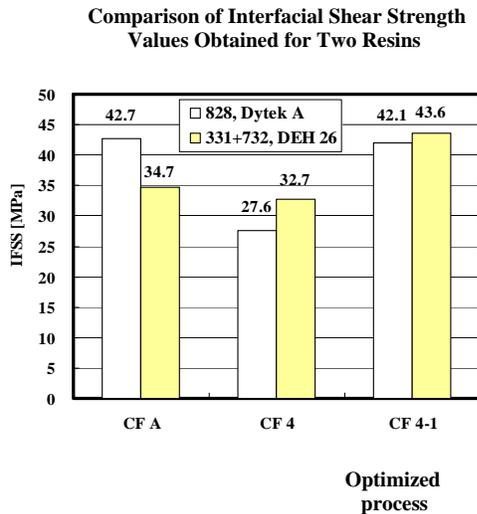


Fig. 5 – Example: Single Fiber Property Retention [7]

Composite system level work was mostly resin/fiber adhesion assays (Fig. 6).

Fiber from both Adherent and Milled Carbon has been successfully compounded into injection molding and bulk

molding compounds for evaluation. Performance characteristics exceeded those of glass reinforced materials and in the case of injection molding were competitive with off the shelf virgin carbon fiber filled compounds [8].



Excellent Resin to Fiber Adhesion after Process Optimization

Fig. 6 – Example: Resin to Fiber Adhesion [7]

Recycled F18 carbon fiber has also been directly incorporated into fiber preforms for a compression molding demonstration. Materials Innovation Technologies of Fletcher North Carolina was able to successfully fabricate preforms directly from as provided fiber after chopping and had them molded into a production configuration automotive component. This Corvette C6 fender well component (Fig. 7) fabricated from recycled carbon fiber is approximately 20% lighter than the production fiberglass component even without engineering for improved stiffness [8].



Fig. 7 – Corvette C6 Fender Well Component Molded from Recycled F18 Carbon Fiber [8]

The first commercial U.S. composite recycling facility, which will be designed, built, owned and operated by Milled Carbon’s U.S. entity, Recycled Carbon Fibers, Inc., is expected to be up and running by mid 2008. The site is yet to be determined, however a priority will be its ability to also service facilities like the Aerospace Maintenance And Regeneration Group’s (AMARG) Center [9]. The Tucson, AZ, Center is the prime USAF site involved in military aircraft recycling and disposal.

In Conclusion

AFRA is proof positive that there is a strong, healthy segment of companies with a desire to perform reclamation services conscientiously and responsibly, and to work in a cooperative fashion to provide guidelines for the responsible management of the full aircraft life cycle. Through the AFRA network, tools for aircraft owners to deal with the end-of-life of their equipment can and will be provided – now and in the future. Materials reclamation is being extended to carbon fiber composites by AFRA members in a proactive effort to accommodate industry changes in commercial airframe structural materials. The key messages are:

- *Environmental considerations are part of Boeing’s lifecycle management approach to aircraft design, manufacturing and recycling*
- *AFRA member companies seek to provide a comprehensive set of tools for aircraft owners to deal with the end-of-life of their equipment – now and in the future*
- *AFRA members are developing technologically advanced end-of-life composite recycling processes for the Boeing 787 and composite parts on any other aircraft models.*

[1] Backgrounder – Aircraft & Composite Recycling, Apr. ’07, <http://www.boeing.com/commercial/environment/pdf/recycling.pdf>

[2] AFRA website <http://www.afraassociation.org/>

[3] AFRA Guidance <http://www.afraassociation.org/documents.cfm>

[4] Huron Valley Fritz West website <http://www.hvfwest.com/about.htm>

[5] Milled Carbon Ltd. website <http://www.milledcarbon.com/>

[6] Adherent Technologies Inc.; Recycling Technologies website http://www.adherenttech.com/recycling_technologies.htm

[7] Carberry ppt.presentation “Aircraft & Composite Recycling” at Feb. ’07 CSI M&P Workshop , available from Carberry.

[8] George, P.E, Carberry W.L., “Recycled Carbon Fiber Performance in Epoxy and Polycarbonate Matrices”; Proceedings from Oct.’07 Composites Innovation 2007 Conference, Barcelona, Spain, available from George.

[9]AMARG defined http://en.wikipedia.org/wiki/309th_Aerospace_Maintenance_and_Regeneration_Group

See also: Carbon Fiber: Life beyond the Landfill, Composites World, <http://www.compositesworld.com/hpc/issues/2007/May/111534>

For more information contact Bill Carberry, BCA, (425) 342-1676 (william.l.carberry@boeing.com), Pete George, EOT, (206) 662-0005 (pete.e.george@boeing.com), Paul Yount, IDS, (253) 657-4219 (paul.d.yount@boeing.com) or Les Harmon, IDS, (314) 233-9337 (leslie.g.harmon@boeing.com)

Your comments are Important to us! Contact Paul Rempes at (314) 233-1541 or mail to: paul.e.rempes@boeing.com
 Archived issues are located on the Boeing Internet at:
<http://www.boeing.com/companyoices/doingbiz/environmental/TechNotes.html>