BREAKTHROUGHS IN AEROSPACE COMPOSITES MANUFACTURING

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Poised for the breakthroughs

Two events, one very public and the other quite private, have both occurred this year and together they suggest a significant breakthrough in how airplanes will be made in the future. The public event was the announcement and following work on the new Boeing 7E7 Dreamliner – a commercial airplane committed to composites like no other. The private event is the development of highly sophisticated and automated techniques for making aircraft parts using a unique patent pending winding process called *f*ibeX™ . The manufacturing system produces light weight and low cost aircraft components. Rocky Mountain Composites (RMC)– has developed the processes over a period of many years.

Both events, taken separately, are highly significant. If Boeing can take advantage of the innovation that small companies offer, the effect of these events could be as great as any event in aerospace in the last 30 years.

Aerospace needs a breakthrough

The history of aerospace has traditionally been full of exciting innovations in materials, designs and manufacturing techniques. The Wright Brothers' plane, itself, had innovations in the lightweight engine, propeller design, steering and flight control mechanism, and overall design. (Not bad for two young bicycle mechanics.) Their work was soon enhanced by the development of flight control surfaces (like ailerons) that were separate from the primary flight surfaces, the introduction of aluminum structures (requiring new alloys), radar, mass production techniques (remember Rosy the Riveter), jet engines, computer control (fly by wire), composites (including the introduction of carbon fibers and new resins), new weapons (from bombsights to missiles), and stealth. The overall design and efficiencies kept pace with the developments in materials and manufacturing techniques so that the entire aerospace industry was infused with excitement.

A strong conservatism in design and manufacturing has taken away from that innovative spirit. This conservatism was caused by liability fears and also by the nature of the marketplace. The number of aerospace companies was reduced dramatically by consolidation, thus removing some of the small companies where innovation was most likely to occur. The market came to be dominated by a few large companies with tremendous capital investments and bureaucracies who were reluctant to change much beyond just making airplanes with seating capacities and ranges to compete in niches not adequately serviced by the current fleet selection. Price and politics came to be dominant marketing forces, not innovation and performance. Market share became a major focus and, perhaps because of the erosion in market share that Boeing saw throughout the 1990s, the need for a new direction and new innovative spirit became critical for the recovery of position that Boeing management saw as critical to their company's future well being. Hence, the birth of the 7E7.

The Boeing 7E7 Dreamliner

More than any commercial plane ever made, the 7E7 is dedicated to the use of advanced composites. Up to now the use of composites has been mostly "black aluminum," that is, using composites as a replacement for parts that were originally designed as aluminum parts. There was little effort to use the advantages of moldability and part unification that are inherent in composites but lacking in aluminum. Therefore, some weight savings and other minor advantages were achieved but the breakthrough advances were not. The 7E7 promises impressive improvements in range (up to 8500 miles for a medium-sized airplane), fuel efficiency (20% improvement), speed (up to Mach 0.85, not available for medium-sized airplanes), and cargo carrying capacity (up to 60% more).

These performance breakthroughs come directly from the new attitude of Boeing management towards using composites. Depending on the final manufacturing process used this plane may not be "black aluminum" but will look at composites as a unique material with properties that should be taken advantage of. The majority of the primary structure, fuselage and wings, will be largely made of composites. The company is also looking at incorporating smart structures into these components to monitor the health of the components.

Because the composite structures are stronger and stiffer than the previous metal structures used on other airplanes, the plane will be certified to allow higher pressurization and that means that customers will feel better during the flight, as confirmed in an actual pressurization study conducted for Boeing at the Farnborough Air Show in the United Kingdom.

As has been the case with previous Boeing aircraft, an international consortium of partners will actually build the various systems for Boeing's final assembly. Inevitably, this worldwide focus will improve composites manufacturing throughout the world. It will also help develop new composite manufacturing techniques that will work their way into other composite products, including fiberglass reinforced plastics (FRP)

The Rocky Mountain Composites technology

The ability to manufacture light weight, low cost aircraft parts represents serious potential for cost savings in aircraft manufacturing. Indeed, it would constitute the accomplishment of the dream of composites manufacturing.

Larry Ashton, the technical guru at Rocky Mountain Composites, headed a project about 20 years ago in which his company filament wound fuselages for the Beech Starship. While seven of the bodies were eventually made using traditional wet-filament winding methods, they were not commercialized. The problems were, however, largely political and bureaucratic rather than technical. (Such as convincing the FAA that such a part could be made reliably and inspected thoroughly.)

Even though the Starship was a great technical success, some important new innovations have been made since that time, principally involving integral stiffening. The inclusion of the integral stiffeners is an important step in manufacturing process. The material that is put into the components is made by *f*ibeX™ process. This material is, effectively, about one-third to one-half of material cost as compared to typical equivalent high performance competitive materials.

RMC's processes avoid the use of autoclaves. The process developers believe that autoclaves are impractical (and expensive) in the long run and so they use a relatively inexpensive pressure mold system.

That type of innovation breakthrough is most often accomplished in small, entrepreneurial companies such as RMC. A similar type of innovation was recently shown in the spacecraft launched by Burt Rutan. Small, private companies can be agile and creative far beyond the government and most large companies. Hence, it is known in the industry that big companies, like Boeing, are visiting small companies to learn and, perhaps, adopt the technology.

What it all means for aerospace

There seems to be three areas of opportunities emerging for innovative composite structures development. The most glaring break in the stagnant commercial jet liner market is the Boeing 7E7, or Dreamliner. Boeing is on the lookout for new and innovative ways of manufacturing composites. The concept of large, integrally stiffened and low cost co-cured structures has to have great appeal to any airframe company that wants to take the bold steps to develop, qualify and certify new materials and processes. This opens the door to break through experiments and product development. In addition, materials and processing companies cannot ignore AirBus's need for the optimization of their own composite structures for added cost savings and increased performance.

The landscape of composites manufacturing is dotted with a myriad of new generation aircraft that are emerging to bring private jet convenience to corporate and personal travel. Affordable business jets play directly into the hands of easing the frustration at airports because of delays and inconvenience experienced since the world changed on 9-11. General Aviation's predicted growth numbers are impressive. The marketplace will not be able to resist the temptation to address the needs of all the new high performance airplanes that are currently in various stages of development. It will be the composite structures innovators that directly address the cost of composite structures who will take the technology to the next step of acceptance.

Another area of opportunity lies in the small 2-4 place, piston driven aircraft. The adoption of composite materials and processes will truly bring this generation of workhorse aircraft into the age of modern technology. With the exception of two or three new companies (i.e. Cirrus, LanceAir, etc.) this market segment is still dominated by an aging fleet of aircraft that begs for replacement with stronger, lighter and more efficient airplanes. Computer and space age navigational systems will make it possible for these airplanes to be flown with a minimum of training and instruction. Articles are being written about the convenience of air taxi services being developed for small, out of the way airports. Lightweight, cost-effective structures have every right to be included in basic airplanes as they do in the so-called high performance genre. In fact, the advancements being made for the new generation airliners will enhance the viability of the private, personal piston driven aircraft. It is reported, for example, that Toyota is spending heavily to document materials and processes that can be easily adapted to a number of large, co-cured, integrally stiffened aircraft structures, fuselages and wings specifically. The Toyota experience was reported last year at the AIAA Meeting held in Dayton, OH to commemorate the 100th Anniversary of flight. The goal of their efforts was to demonstrate three cost reducing features:

1. A one piece co-cured fuselage design with integrated structural elements
2. The layup of fuselage skins using low cost materials with automated placement of skin plies.
3. Co-cured frames from material generated by advanced winding techniques.

The illustration below show a typical structural configuration and the major elements for a fuselage for a small airplane fuselage.

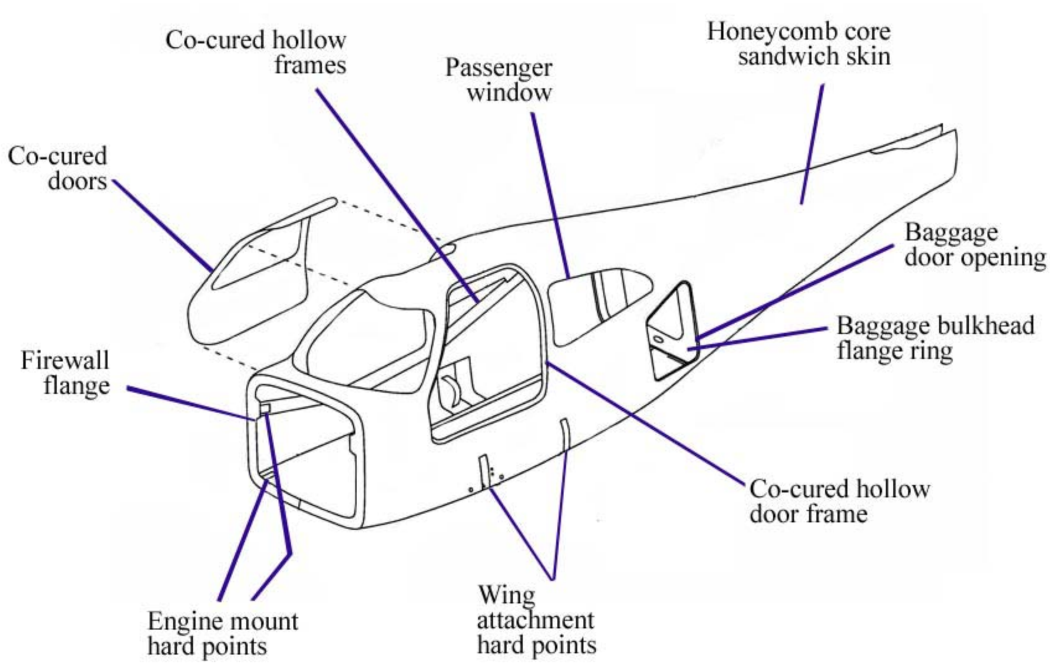

Figure 1 Diagram of the design of a filament wound body for small propeller driven aircraft

The selection of composite materials for aircraft structures has several advantages:

- Ease of obtaining the desired aerodynamic shape and surface smoothness.
- Provides the ability to highly integrate many structural requirements.
- Creates the ability to mold large structures in one piece.

These three reasons satisfy the essential requirements for the design and fabrication of airframe structure, which are aerodynamic efficiency (low drag), structural efficiency (lightweight) and low cost. Obviously, there are several key technologies involved in the achievement of these goals. Most of them are proprietary to the companies who develop them – and rightly so. However, only through traditional testing methods and certification will these emerging innovations be validated and accepted as viable to move to the mainstream of composites manufacturing.

Figure 2 Filament wound body for small propeller driven aircraft

The industry press buzzes daily with stories, rumors and speculations about who will be first to enter these respective markets with credible materials and processing technologies that have the desired pay-out for the manufacturer and operators alike.

In the not too distant future, aircraft with transonic and supersonic capabilities will emerge from the drawing boards and begin to take shape. While composites have been used in military versions of these performance specific types of airplanes, the commercial world will be as demanding as the government to assure performance and cost effectivety in their day-to-day operation. There is also pressure from the developers of UAV's that see the advantages of lightweight, low cost, one piece, integrally stiffened fuselages, wings and other primary structural technology.

RMC, like other composites manufacturing firms, tries constantly to position itself in these specific markets in order to optimize opportunities and focus.

The next 100 years of aircraft manufacturing must be simpler and smarter. Simpler means fewer parts and streamlined manufacturing processes. Smarter means elimination of costs and use of materials that are suited to the application without being exotic. If Boeing or other aerospace/aircraft companies take advantage of the RMC technology, who knows what might happen in the aircraft industry? Perhaps a total rejuvenation of manufacturers and operating airlines because of the much lower costs and improved performance. We may see new life in the industry reminiscent of the 1930s and 1940s. Let's hope so.