HISTORY OF COMPOSITE MATERIALS —

OPPORTUNITIES AND NECESSITIES

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When the modern composites industry began

Although composite materials had been known in various forms throughout the history of mankind, the history of modern composites probably began in 1937 when salesmen from the Owens Corning Fiberglass Company began to sell fiberglass to interested parties around the United States. Fiberglass had been made, almost by accident in 1930, when an engineer became intrigued by a fiber that was formed during the process of applying lettering to a glass milk bottle. The Owens Corning Fiberglass Company was formed in 1935 by Owens-Illinois and Corning Glass Works to capitalize on this new fibrous material. A Japanese company (Nitto Boseki) had also made fiberglass and was attempting to market the fibers in Japan and the United States. The initial products for this finely drawn molten glass were as insulation (glass wool) but structural products soon followed.

The fiberglass salesmen realized that the aircraft industry was, in particular, a likely customer for this new type of material because the many small and vigorous aircraft companies seemed to be creating new aircraft designs and innovative concepts in manufacturing almost daily with many of these innovations requiring new materials.

One company, Douglas Aircraft, bought the first roll of fiberglass shipped to the west coast because they believed that the fiberglass would help them solve a production problem. They had a bottleneck in the making of metal molds for their sheet metal forming process (called hydropress forming). Each changed aircraft design needed new molds and metal molds were expensive and had long lead times. Douglas engineers tried using cast plastic molds, but they could not withstand the forces of the forging process. Maybe if the plastic molds were reinforced with fiberglass they would be strong enough to allow at least a few parts to be made so that the new designs could be quickly verified. If the parts proved to be acceptable, then metal dies could be made for full production runs. In collaboration with Owens Corning Fiberglass, dies were made using the new fiberglass material and phenolic resin (the only resin available at the time). What a success! Reinforced plastic dies for prototype parts became the standard.

Other applications in tooling for aircraft soon followed. Many of the tools (jigs and fixtures) for forming and holding aircraft sections and assemblies needed to be strong, thin and highly shaped, often with compound curves. Metals did not easily meet all of these criteria and so fiberglass reinforced phenolic tooling became the preferred material for many of these aircraft manufacturing applications.

Not long afterward, unsaturated polyester resins became available (patented in 1936) and they eventually (although not immediately) became the preferred resin because of the relative ease in curing these resins compared to phenolics. Peroxide curing systems were already available with benzoyl peroxides being patented in 1927, lauroyl peroxide in 1937, and many other peroxides following not too long afterward. Higher performance resin systems also became available about this time with the invention of epoxies in 1938. The materials and the applications seemed to be converging at the same time.

World War II Developments

The pace of composite development, already fast, was accelerated during World War II. Not only were even more aircraft being developed and, therefore, composites more widely used in tooling, but the use of composites for structural and semi-structural parts was being explored and then adopted. For instance, in the frantic days of the war, among the last parts on an aircraft to be designed were the ducts. Since all the other systems were already fixed, the ducts were required to go around the other systems, often resulting in ducts that were convulted, twisting, turning, and placed in the most difficult to access locations. Metal ducts just couldn't easily be made in these "horrible" shapes. Composites seemed to be the answer. The composites were hand layed-up on plaster mandrels which were made in the required shape. Then, after the resin had cured, the plaster mandrels were broken out of the composite parts. Literally thousands of such ducts were made in numerous manufacturing plants clustered around the aircraft manufacturing/assembly facilities.

Other early WWII applications included engine nacelles, which lightened the A-20 airplane and radomes (domes to protect aircraft radar antennas) which gave both structural strength and radar transparency. Phenolic-reinforced paper was used to make a structural wing box beam for the PT-19 airplane at about this time. Plastic airplane seats using combed and carded cotton fibers impregnated with urea and polyester were also made on an Air Force contract during the early war years. Non-aircraft applications included cotton-phenolic ship bearings, asbestos-phenolic switchgears, cotton/asbestos-phenolic brake linings, cotton-acetate bayonet scabbards, and thousands of others.

The early war period also marked the first production of a fiberglass reinforced boat molded by Basons Industries. However, when molding the boat, no mold release or parting agent was used and the part could not be extracted from the mold. After all attempts to separate the part from the mold had failed, the entire assembly was rolled into the Bronx River.

At about this time (1942), the government became concerned that supplies of metals for aircraft may not be available and so they instructed the engineers at Wright Patterson Air Force Base to survey all of the manufacturers of composite parts in the United States and try to determine the current best practices in composite manufacture. Wright Patterson personnel were also to promote the use of composites by develping design rules, by encouraging the development of new composite materials and applications, and by using their own expertise for the devopment of new and bold composite applications. Perhaps the boldest applications of all were the development of aircraft wings for the AT-6 and the BT-15, two training airplanes. A total of six wing sets were made, installed on aircraft, and successfully flown. In spite of the success of this project, aircraft structural parts were not made again for 50 years. Even more amazing, after the 50 year hiatus, the method of making the parts was nearly identical to the method employed at Wright Patterson Air Force Base in 1942.

Many other composite improvements were developed during WWII including some innovative manufacturing methods such as filament winding and spray-up. Sandwich structures using a cellular core, fire resistant composites, and prepreg materials were also developed during this time of development opportunity.

Post WWII development

When the war effort came to a sudden halt, the many companies who had been active in making war materials were faced with an acute problem. They needed to quickly identify new markets and new products which utilized the expertise they had developed. Companies like Goldsworthy Engineering were trying to make any composite part they could think of and were receiving support from the companies who manufactured fiberglass who would "sponsor" some of the projects. For instance, the fiberglass manufacturers would pay for the tooling for a new application just to reduce the development cost.

Some of the war-oriented applications were converted directly to commercial applications such as fiberglass reinforced polyester boats. By 1948 several thousand commercial boats had been made.

Almost everyone agreed that the pent-up demand for automobiles was a logical application for composites. By 1947 a fully composite body automobile had been made and tested. This car was reasonably successful and led to the development of the Corvette in 1953 which was made using fiberglass preforms which were impregnated with resin and molded in matched metal dies. Eventually the dominant molding method for automobile parts was compression molding of sheet molding compound (SMC) or bulk molding compound (BMC). Premix materials of these types were developed as early as 1948 by the Galstic Corporation.

One automotive innovation that deserves special mention is the auto/plane development led by Convair Aircraft Company. Convair reasoned that the many returning wartime pilots would like to continue with their flying, but would also like to combine it with family vacations. Hence, Convair made an automobile with an all-composite body (for weight savings) that would allow a special wing assembly to be attached. The wings would be available for rent at various airports, thus permitting the driver to rent a wing assembly at one airport, fly to the vacation site, turn in the wing assembly, and drive away. Prototypes were made and successfully demonstrated. What a boon they would be today in Los Angeles, although the skies might be more hazardous than the roads!

Some of the products made during the post-war era have now emerged as major markets for composite materials. These include tubs and shower assemblies, non-corrosive pipes, appliance parts, trays, storage containers, and furniture. Other composite products have also been successful, although not quite as well known or spectacular. For instance, sets for entertainment groups and stage productions, especially those that travelled like the Ice Follies, were made of composites. In the movie “Captain from Castile” the armor and helmets of the Spanish soldiers were made of composites and painted to resemble metal. The headdresses of the Aztecs were also molded composites.

Several innovative manufacturing methods were also developed in the late 1940's and early 1950's including pultrusion (by Goldsworthy), vacuum bag molding, and large-scale filament winding.

Aerospace

The push for aerospace dominance that began in the 1950's and really picked up speed in the 1960's was a new impetus for composite development. Richard Young of the W. M. Kellogg Company began using filament winding for making small rocket motors. This technology was purchased by Hercules and was the basis for the large-scale rocket motor business which was at the heart of the space race. By 1962 the need for highly accurate filament winding machines became apparent to Larry Ashton, an engineer at Hercules, who founded Engineering Technology to produce these machines. (Engineering Technology was started from an initial stake of money the founders obtained from selling their blood to a blood bank. That's giving it all for the company!)

In 1961 a patent was issued to A. Shindo for experimentally producing the first carbon (graphite) fiber but Courtalds Limited of the United Kingdom was the first to produce commercially viable carbon fibers several years later. With these fibers, part stiffness to weight was improved and even more applications in aerospace were introduced. Perhaps the crowning jewel of this period (1978) was the development of the first fully filament wound aircraft fuselage, the Beech Starship, by Ashton. The plane was successfully flown, but was not commercialized using the filament wound technology. Many people still believe that the filament winding technology is the best method to produce small aircraft fuselages.

Leading up to the present

New fibers were also introduced with boron filaments becoming available in 1965 and aramid fibers (Kevlar®) offered commercially by DuPont in 1971. Fibers made from ultra high molecular weight polyethylene were made in the early 1970's. These advanced performance fibers, along with fiberglass and carbon fibers, have led to tremendous developments in aerospace, armor (structural and personal), sports equipment, medical devices, and many other high performance applications. The development of new and improved resins has also contributed to the expansion of the composites market, especially into higher temperature applications and applications where high corrosion resistance is needed.

Today, the composites marketplace is widespead. As reported recently by the SPI Composites Institute, the largest market is still in transportation (31%), but construction (19.7%), marine (12.4%), electrical/electronic equipment (9.9%), consumer (5.8%), and appliance/business equipment are also large markets. The aircraft/aerospace market represents only 0.8% which is surprising in light its importance in the origins of composites. Of course, the aerospace products are fewer in number but are much higher in value.

Most of the markets continue to grow. Composites have found their place in the world and seem to be gaining market share, especially in products where performance is critical. Some of these products are very new, but isn't it interesting that construction is still a major market for composites, just as it was in 1500 B.C. when the Egyptians and Israelites were using straw to reinforce mud bricks.

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Additional Reading and References

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