Overview of the Current Aerospace Industry

The aerospace industry involves aircraft manufacturing, R&D of related components, engine development, molds & dies fabrication, aftermarket maintenance & repair, etc. The current production value of the global aerospace industry in 2015 was USD 330 billion. The aircraft manufacturing giant, Boeing, also forecast that additional demand for aircrafts within the next 20 years (2015-2034) will be up to 38,050 units, equivalent to the total value at USD 5.6 trillion, and Asia is expected to show the greatest potential of 38% representation in the total global demand. See Picture 1.

Taiwanese aerospace industry has been developing for more than 35 years since the 1980s. With the current support of Taiwanese government, the development of Taiwanese aerospace industry appears to be promising. The total production value of Taiwanese aerospace industry in 2015 was about NTD 91.5 billion and is expected to reach NTD 100 billion in 2016. In fact, the Asian market with fast growth has been the most focused area in recent years, mainly due to the fast growing demand in China that boosts the demand growth in the transportation field, which is one of the drives that push the global aerospace market forward. In terms of the aerospace industry showing extremely high quality requirements, Taiwan’s manufacturing technology is definitely qualified to serve this market. Moreover, the geographical location of Taiwan in the fast growing East Asia with convenient transportation systems is one of the major advantages for the development of Taiwanese aerospace industry. There are roughly 200 companies in Taiwan that can manufacture aerospace parts and they are also aggressive to establish cooperation with Boeing or Pratt & Whitney. Last year (2015) more than 100 Taiwanese aerospace related companies including AIDC and Eva Air agreed to form the “A Team,” which is for integrating resources of Taiwanese companies and penetrating the global advanced aerospace manufacturing market with intelligent technology and service.

Change in Material Application in the Aerospace Industry

When it comes to the change in material application in the aerospace industry, the invention of the first aircraft by the Wright Brothers in the beginning of the 20th century should definitely be mentioned. Before the Wright Brothers invented the first aircraft, all the sailplanes were made in wood and a few steel wires, as wood showed an excellent strength-to-weight ratio, could be easily processed, and could absorb much more impact. The Wright Brothers were the first to install an internal combustion engine onto a sailplane, generating power for the sailplane to fly off the ground (this is the prototype of the aircrafts we see today). The 1st-generation internal combustion engine for aircrafts was already made in a few aluminum content in the outer case and inner parts to reduce the total weight. Then, after 1915 steel with higher strength was first used onto the fuselage and the landing gear of the first all-metal fixed-wing aeroplane in order to reduce the risk of air disintegration and increase the stability of landing. In WW1, machine guns were also installed on aircraft wings, which was the 1st prototype of fighter planes.
In 1930s, the use of aluminum was greatly increased due to its malleability and lightweight. In 1940s, fiber glass and other composite materials (in addition to aluminum) were used on cockpits and noses of aircrafts for easy radio and radar signals transmission. The aluminum alloy developed in WW2 contained Co and Ni, making it highly heat resistant, so it was used on turbine engines.

After the 1970s, carbon fiber (in addition to aluminum) was used on engines. Its tensile strength was 5 times that of steel, showing better tensile strength to weight ratio. In 1981, ceramic fiber was used on the heat resistant layers of aircrafts and spaceships. The range it can stand is as high as 2,200 Celsius degrees, making space-ships stand less heat shock while re-entering the atmosphere after completing missions and lengthen the service life of space shuttles. Afterwards, the application of Al-Li alloy was used on oil tanks of aircrafts and more than 20% of parts (fuselage and wings) of new commercial aircrafts (e.g., A350) were also made in Al-Li alloy to reduce the consumption of fuel.

**The Application of High Strength Aluminum Alloy in the Aerospace Industry**

(a) **What is High Strength Aluminum Alloy:**

Aluminum is the 3rd richest element in the Earth (compared to the first 2 richest oxygen and Silicon) and represents 8.1% of the total Earth’s weight. The density of pure aluminum is only 1/3 of that of steel, so it is lighter, malleable, easy to process, electricity-conductive, and corrosion resistant. However, aluminum is too soft to be forged directly, and it will show greatly enhanced strength, tenacity, and malleability only after being processed. By different processing methods aluminum alloy can be categorized into forged aluminum alloy and cast aluminum alloy. Forged aluminum alloy is internationally named as 1000 series, 2000 series, etc. In the manufacturing procedures of aluminum alloy, aluminum alloy with the tensile strength of over 500Mpa is categorized into high strength aluminum alloy and all high strength aluminum alloy is categorized as 2000 series or 7000 series.

The 2000 series high strength aluminum alloy is mostly added with copper (often called duralumin), which is a German engineer, Alfred Wilm, first made in 1903 by adding some copper into aluminum alloy and hardening it by quenching and cooling. Although this process helps enhance the strength, it reduce its ability to resist corrosion due to the existence of cooper.

It was modified later by putting a layer of nearly pure aluminum plate onto the alloy to reinforce corrosion resistance. The commonly seen types such as “2024” show the advantages of high strength and fatigue strength and have been thus widely used in the exterior wing plates, rivets, bolts, and outer cases of engines of aircrafts where high tensile strength is required. However, this series is prone to intergranular corrosion and has been gradually replaced by 7000 series.

In addition to 2000 series, 7000 series of aluminum alloy shows the highest strength among all the other aluminum alloy series, as it is added with zinc that greatly enhances its strength. Moreover, after precipitation hardening its strength can be nearly the same as those of most steels and lighter in weight. The most significant advantages of it are its very high specific strength and fatigue strength. It is also easy to be processed, but the price is higher than that of other aluminum alloy. The common type is 7000 series (especially the 7075 type), which is generally used where the highest sustaining force is required. Its high compressibility makes it often used on longitudinal beams and ribs of main wings and tail wings.

High strength aluminum alloy is not only used in the aerospace industry, but also in many other industries (e.g., bodies of cars or trucks). “7075” is also commonly used in rock climbing facilities and bicycle parts.

(b) **The Current Application of High Strength Aluminum Alloy in the Aerospace Industry:**

So far, high strength aluminum alloy has been mainly used in structural parts for resisting high stress, such as fuselage, wings, landing gears, turbine engines, oil tanks, etc. As the main landing gear has to sustain the weight of the entire aircraft and the impact while landing, it is generally made in super high strength structural steel that can absorb the impact. Below are illustrations for 2000 series Cu-Al alloy, 3000 series Mn-Al alloy, 5000 series Mg-Al alloy, 6000 series Mg-Si-Al alloy, and 7000 series Zn-Al alloy.

2000 series aluminum alloy (e.g., 2024-T3 Al. plate) is a high strength aluminum alloy commonly used in the aerospace industry, as it features high tensile strength, sleek surface, high fatigue strength, and slow spreading of fracture. It is often used in the exteriors of fuselage, structures underneath wings, longitudinal beams, and outer cases of engines and is sometimes used in reinforcing structures and maintenance & repair of aircrafts. 3000 series aluminum (e.g., 3003-H32 added with Mn) shows moderate strength, better corrosion resistance, and good malleability. This alloy can still keep its shape in high temperature, so it is often used to make parts for aircraft engines.

5000 series aluminum alloy (e.g., 5052-H3) is a type of alloy with the highest strength that can’t be heat treated. As it is highly heat resistant, it is suitable for the making oil tanks of aircrafts. Its high weldability makes it widely used in various parts joints and easy to be welded with other series of alloy. 6000 series aluminum alloy (6061-T6 Al. plate and 6063) shows lower strength, but it has very good malleability, making it commonly used on structures of aircrafts, bolting parts, window &
door frames. 7000 series aluminum (e.g., 7075) is the type of aluminum alloy with the highest strength, commonly used on places that require high strength and high fixing force. Such alloy is also used in the wind facing areas of aircrafts, like upper plates and longitudinal beams of wings, tail wings, ribs, etc. In addition, it is also used in gear, shafts, turbines, etc.

Conclusion

Carbon fiber reinforced plastics have been recently used as the major material. With modifications and reinforcements, it has been gradually considered force sustaining parts rather than non-force sustaining parts. It is mainly used in fuselage, wings, and interiors, which has successfully proved that composite plastics can meet the requirements of both high strength and light weight. More than 50% of materials used in New Boeing 787 are composite carbon fiber. The fiber glass reinforced metallic plates with high malleability, fireproof ability, and corrosion resistance are widely used in inner parts of fuselage and interiors. Although composite materials are considered as ones that are very likely to replace aluminum alloy, they are more expensive than aluminum alloy. Take thermosetting plastics as example, its cost is 15 times the cost of aluminum alloy, while the cost of thermoplastics is 75 times the cost of aluminum alloy. In addition, decomposition and recycling of aluminum alloy is easier than those of composite materials, so before the issue of unbonding in composite materials is solved, aluminum alloy can be still commonly used in industries for a period of time. The current demand from the end application in the aerospace industry also secures the stable growth in the demand for aluminum alloy. However, given the continuously increasing requests for lighter materials, energy saving, and reduced carbon emission, the specific strength to weight ratio must definitely be enhanced and the applicability has to be widened, should aluminum alloy remain competitive in the market. In addition, more and more diverse materials will be used in aircrafts and the optimum performance of aircrafts and engine efficiency can be achieved through fix parts in different materials together. As a result, how to fixing parts in different materials together will be one major point in future research. The high stability, malleability, weldability of aluminum alloy make it easier to be fixed with other materials, which can be one major advantage for the application of aluminum alloy in the future aerospace industry.