An Overview of Aerospace Fasteners and Material Applications

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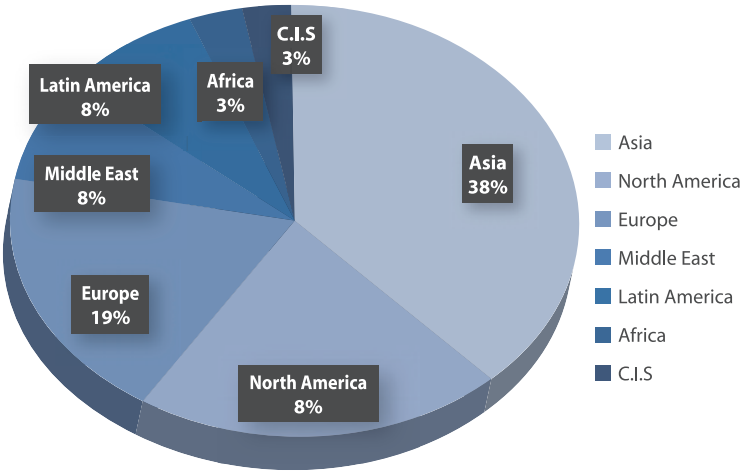
Aerospace Fasteners as the Key to Growth of the Fastener Industry

The aerospace industry covers a wide range of segments including manufacturing and R&D of aircrafts and components, engine development, mold production and logistical maintenance and repair. The production value of the global aerospace industry in 2015 reached USD 330 billion and the largest aircraft manufacturer, Boeing, also forecast that the newly added demand for aircrafts from global airlines within the next 20 years would reach 38,050 units and the total production value would reach USD 5.6 trillion. It is expected that Asia, in particular, would take 38% of the global total demand. See Graph 1.

Graph 1. Forecast Demand for Commercial Aircrafts and Cargos in Each Region Around the World in 2015-2034



Source: Boeing / compiled by MIRDC MII (July 2017)

According to an accurate calculation, one Boeing 747 would need 3 million pieces of fasteners, one Boeing 767 would need 1.8 million pieces of fasteners and the new 787 would need 0.5 million pieces of Ti-alloy fasteners. As aerospace fasteners are processed through special technical manufacturing procedures, their prices are higher than those of other traditional screws and nuts. For example, the unit price per kg of general hardware bolts is NTD 70, but the unit price per kg of aerospace bolts is over NTD 900 (5-20 times the price of general fasteners). The total cost of fasteners installed on a new aircraft represents around 1.5% of the total manufacturing cost and the production value of Taiwan represents around 0.8% of the world's total. In other words, there are still many opportunities for Taiwan.

If we look into the aerospace market dominated by Europe and USA, we will find that, within a few years, the demand for aerospace fasteners from European and U.S. aerospace industries will be one of the keys to growth of the fastener industry. The growth rate of fasteners in the aerospace industry is higher than that of the general market, mainly due to the growing production of aircrafts with larger sizes and more complicated design in recent years, which also directly results in more demand for fasteners.

Ever year USA imports a large amount of screws and wood screws, and Asian countries (e.g., Taiwan and China) remain the major import origins for U.S. fastener market. Among the imported and exported product categories, most of them are threaded screws, wood screws, helical hooks and rings. Generally speaking, after Boeing has signed the large bulk supply contracts with U.S. National Defense Department, we can expect that the dependence of the aerospace industry on the fastener market will last for several years.

Categories and Characteristics of Aerospace Fasteners

Fasteners can be divided into 4 categories by function: 1. Screws and Bolts 2. Nuts 3. Expansion Bolts/Rivets/Washers/Pins/Nails/Hooks/Rings 4. Special Products. In addition, they can be also divided into 2 categories by use, which are "for permanent use" and "for temporary use." The former includes rivets and the latter includes general screws and bolts, etc. The material selection for these aerospace fasteners must be based on the properties of mating parts. 5 basic parts will be mainly considered, which include:

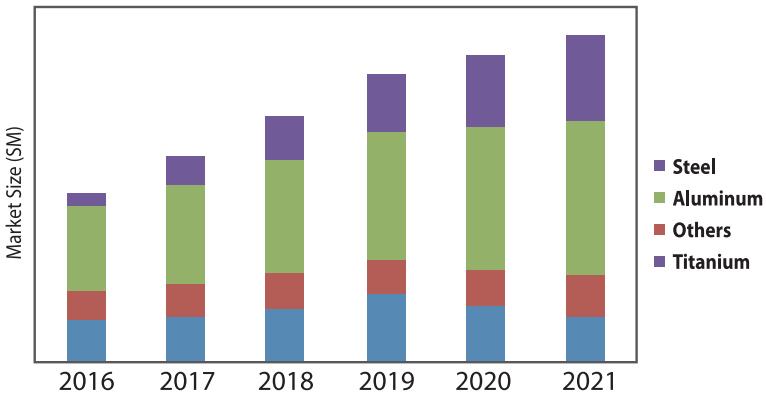
1. The highest and lowest operating temperatures
2. Corrosion in environments
3. Fatigue and impact loading
4. Anti-loosening performance of threads
5. Avoiding using SCC (Stress Corrosion Cracking) sensitive materials

Accordingly, basic material requirements for aerospace fasteners include: shear strength, tension strength, fatigue strength, high temperature strength and corrosion resistance, etc. Take the fasteners installed on jet wings to fix engines in place for example, fixing a 7-8 tons of engine requires only a low volume of fasteners. Take the engine of Boeing 777 for example, only one bolt is used. Fixing the engine of C-130 cargo only requires 4 bolts. In other words, all these bolts used to fix engines must be in larger sizes and of higher strengths. Fasteners currently used to fasten engines are mostly special Ti-alloy bolts. Below is an analysis that further explains what types of materials are currently used to manufacture aerospace fasteners.

Material Analysis of Aerospace Fasteners

The commonly used materials for aerospace fasteners are alloy steel, stainless steel, aluminum alloy, Ti-alloy, other Nickel-based superalloy, etc. Most aerospace fasteners are currently made of aluminum alloy and Ti-alloy. In the next 5 years, aluminum alloy will be still the first-choice material used and the second major material used will be steel. See Graph 2.

Graph 2. The Market Scale of Materials for Aerospace Fasteners in 2016~2021



Source: Lucintel/ compiled by MIRDC MII (2017)

These commonly used aerospace fasteners are made of different materials and show various features and applicability.

a. Alloy Steel

Alloy steel (also known as special steel) consists of carbon steel and one or more special elements with improved properties. It is suitable for use in various applications. The elements added into alloy steel are mainly Ni, Cr, W, Si, Mn, Mo, Co, V, Ti, B, etc., which can be also divided into two categories. One is alloy steel for structure that can make steel quenching easier and improve the mechanical property after tempering, and the other is alloy steel for specific purposes that can make steel gain special physical, mechanical and chemical features. Alloy steel heat treated to reach the strength of over 1517 MPa is prone to corrosion/decarburization/ hydrogen embrittlement, with a low elongation rate and sensitive to stress corrosion cracking, but it can be offered in cheaper prices. Due to the high cost/performance ratio, it is widely applied to aerospace fasteners. In practical application, the strength will be controlled within 1310 MPa in order to prevent hydrogen embrittlement from occurring and achieve excellent fatigue strength. In addition, in order to prevent surface corrosion from occurring, Cd is usually applied. This is common in landing gears and braking systems.

b. Aluminum Alloy

Aluminum shows the features of lightweight, excellent heat/electricity conduction, anti-corrosion and high malleability, making it easy to be processed into pipes, bars and wires. Aluminum alloy is usually used to manufacture rivets. It can be cold forged to 3.96 mm in dia. The 2024 aluminum is often stored at -18℃ before use in order to prevent deformation or cracking. So, it is often called Fridge Rivet. Some rivets are made of 5056 aluminum; however, they are sensitive to SCC. When the temperature rises, the strength will reduce sharply, so they cannot be used in high temperature environments. If 7075 aluminum is used, it can deform without cracking at room temperature. 7075 is the most commonly used aluminum with the highest strength.

c. Stainless Steel

As said in the previous paragraph about alloy steel, the most significant advantage of steel is its cheap price. As steel rusts easily, Cr and Ni are often added to improve its anti-corrosion ability. Stainless steel is a type of steel that has higher content of Cr. Stainless steel aerospace fasteners currently used are mainly made of precipitation-hardening stainless steel (though still some few others are made of 300 and 400 series). 300 stainless steel shows lower strength and generally will not be used to manufacture structural parts but electronics fasteners. However, 300 stainless steel can be strengthened through cold processing, so it can be used to manufacture bolts. The strength of 400 stainless steel can be heat treated to 1034 MPa and as its content of Cr is over 12%, the possibility of corrosion on the surface can be reduced to the lowest. The strength of precipitation hardening stainless steel (e.g., 17-4PH, 17-7PH, PH13-8Mo) can be heat treated to over 1100 MPa; however, it will be prone to stress corrosion cracking. As a result, if this type is used, environmental conditions must be considered first.

d. Ti-alloy

The strength of Ti-alloy is close to that of medium alloy steel, but its weight is 60% less than medium alloy steel. In addition to high strength, anti-corrosion and excellent high temperature resistance, its high fatigue strength and low magnetic/ heat conductive properties can effectively prevent loosening of bolts and the interference of magnetic field. As a result, it is widely used in the aerospace industry (such as bodies and engines). Ti-alloy can be used within the temperature range of -210℃~425℃, so it is suitable for manufacturing structural fasteners for engines despite the drawbacks like high cost and inferior workability. However, this material is still very attractive to manufacturers of military aircrafts that need high performance and of commercial aircrafts that require high fuel efficiency.

e. Ni-based Alloy

Ni shows various excellent properties. However, if Cu, Fe, Cr or Mo is also added into the alloy, a better material, which is also called Ni-based alloy, can be created. Ni-based alloy is a requirement for aerospace fasteners and A286/718/Wasp alloy/Haynes/MP35N/MP159 are the most commonly used aerospace fasteners. Although A286 (~1000 MPa) is not the largest strength, it shows an excellent elongation rate. Plus, it can be used in a wider temperature range (-253℃~650℃) and is not prone to stress corrosion cracking and hydrogen embrittlement, so it is the type of Ni-based alloy fastener that shows the most usage.

Conclusion

To conclude, aerospace fasteners currently used are not all made of one single material. The material is selected according to application, environment and feature. Whatever material fasteners are made of, fasteners do play a very essential role in achieving the tight assembly of aircrafts with hundreds of passengers on board. Due to these reasons, material selection and aerospace fastener manufacturing must be within strict quality control and certified to standards (e.g., AS9100 and Nadcap). According to statistics, more than 140 Taiwanese companies have gained aerospace certification. These companies include some leading fastener companies like San Shing, Chun Yu, Nafco, Ying Ming, etc. In fact, the history of Taiwan fastener industry is over 6 decades and its production value is ranked the 2nd place in all Taiwanese metal processing industries. Its fastener production in Gangshan (Kaohsiung) represents more than 60% of the total fastener production in Taiwan, making Gangshan the most clustered district with the highest density of fastener companies and the most complete fastener supply chain in the world. In the past, the added value of Taiwanese fasteners was not high and most of those exported fasteners (mostly standard parts) were applied to furniture, construction, electronics/electrics and machine industries which did not show high entry barriers. As the price competition in recent years becomes more and more fierce, Taiwan is unable to compete with low-price products from China and has turned its focus to the development of high value added products applied to vehicles. However, with the deployment of car manufacturers in Southeast Asia and China's "One Belt, One Road" initiative," the development in these ASEAN countries will also accelerate. As a result, staying away from seeking only high-volume orders but focusing on areas with high added value and high entry barriers may be one of the drives that could help Taiwanese fastener companies keep sustainable growth. The aerospace industry is an industry with high technical level, long certification periods, high entry barriers and very close relationships with the upstream/downstream. It requires the strictest quality management system and the most sophisticated system integrating technology. So, if one company has successfully become part of the aerospace supply chain, its customers will not change suppliers easily, which means it can enjoy the exclusive business opportunities only in the aerospace industry. ■