Metals in the world of Aviation
Stainless steels in Aircraft

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Stainless steel is an alloy of Iron with a minimum of 10.5% Chromium.Stainless steels as the name implies do not form 'stains or corrode' thus maintaining a shiny metallic lusture.

The property of 'stainless' is imparted due to the presence of Chromium in the alloy which forms a tenacious film of Chromium oxide on its surface which forms a protection barrier from the environment. This prevents further corrosion of the surface. Increasing the amount of Chromium gives an increased resistance to corrosion. This property is widely exploited in its application in Aviation where corrosion of parts and eventual failure can be disastrous.

Stainless steels are the most commonly used among ferrous alloys for manufacture of a part for an Aircraft. These are used where relatively good corrosion resistance and high strengths are required. In many applications, Nickel base alloys can be used as an alternate to stainless steels but are expensive when compared with stainless steel. Almost all grades of stainless steels can be found in a large commercial transport aircraft.

Stainless steels, also contains varying amounts of Carbon, Silicon and Manganese in addition to Chromium. Addition of other elements like Nickel and Molybdenum impart other useful properties such as improved formability and increased corrosion resistance. The ease of forming to different shapes makes it an ideal candidate alloy for fabrication of parts with complex geometry and profiles which are very common in Aircraft.

Stainless steels are classified according to its microstructure and the strengthening mechanism. Austenitic, Ferritic and Martensitic stainless steels fall under the first category and the Precipitation Hardening stainless steels under the second.

a. Ferritic : These steels have a similar microstructure to carbon and low alloy steels but cannot be hardened by heat treatment. Ferritic steels are magnetic and are preferred for their resistance to stress corrosion cracking. These steels are not as formable as austenitic stainless steels. These steels are based on Chromium with small amounts of Carbon usually less than 0.10%. Due to lack of toughness exhibited at welds these are used for small thickness sections or where welding is not required. These are not used much in Aircraft parts though some engines use high pressure compressor blades and vanes from this type.

b. Austenitic : The most commonly used stainless steel in an Aircraft for fabrication of parts due to their characteristic combination of weldability, formability, corrosion resistance. They cannot be hardened by heat treatment but can be work hardened to high strength levels whilst retaining good ductility and toughness. Standard austenitic steels are susceptible to stress corrosion cracking but austenitic steels with higher nickel content have increased resistance to stress corrosion cracking.

These steels are non magnetic, corrosion resistant, and has a austenitic face centered cubic structure at room temperature. These steels contain 18 % Cr, 8 % Nickel and are commonly known as 18/8 stainless steel. The AISI has classified the steel by a three digit numbering system and are designated as 2xx, 3xx, 4xx etc (For eg, 304, 316, 321, 440).

This type of steel, mainly the AISI 304 & 321 grades are used for sheet metal parts requiring higher strength. Many Fuel & Hydraulic tubes, Ducts, Line fittings, Valve housings, Brackets, Access panels etc use these steels. Ref. Figs 1, 2 & 3.

c. Martensitic : These steels are similar to ferritic steels in being based on Chromium but have higher Carbon levels up as high as 1% enabling them to be hardened and tempered much like carbon and low-alloy steels. They are used where high strength and moderate corrosion resistance is required. These steels are magnetic and have poor weldability and formability. These are used for Pins, Casings etc.

d. Duplex : These steels have a microstructure which is approximately 50% ferritic and 50% austenitic. This gives them a higher strength than either ferritic or austenitic steels. They are resistant to stress corrosion cracking. These steels are used for fabrication of parts as alternate to those made from austenitic steels stated above.

e. Precipitation hardening (PH) : These steels are widely used for fabrication of aircraft parts. These steels have high strength with the addition of elements such as Copper,

TABLE I
MOST COMMONLY USED P-H STAINLESS STEEL WITH COMPOSITION

Grade	C %	Mn %	Si %	Cr %	Ni %	Mo %	Others %
17-4 PH	0.04	0.40	0.50	16.5	4.25	-	0.25Cb, 3.60Cu
17-7 PH	0.07	0.70	0.40	17.0	7.00	-	1.15 Al
PH 15-7 Mo	0.07	0.70	0.40	15.0	7.00	2.25	1.15 Al
17-10 P	0.12	0.75	0.50	17.00	10.50	-	0.28P
15-5 PH	0.07	1.00	1.00	14 .75	4.0	-	3.0% Cu

TABLE II : HEAT TREATMENT PARAMETERS FOR AGING 17-4 PH TO OBTAIN REQUIRED STRENGTH LEVELS

To obtain min UTS (KSI)	Time	Temperature	Cooling Method	To obtain min Hardness Rc Min.
190	1 hr	4805C (90010F)	Air	41.5
170	4 hrs	4955C (92510F)	Air	38
155	4 hrs	5505C (103010F)	Air	35
150	4 hrs	5655C (105010F)	Air	34
145	4 hrs	5805C (107510F)	Air	32.5
135	4 hrs	6205C (115010F)	Air	30

Fig .1 - Fuel & Oil Lines

Fig. 2 - Air flow Duct

Niobium and Aluminium to the steel. With a suitable "aging" heat treatment, very fine particles form in the matrix of the steel which imparts strength. These steels can be machined to quite intricate shapes requiring good tolerances before the final aging treatment as there is minimal

Fig. 3 - Aircraft fittings fabricated from Precipitation Hardening Stainless steels

distortion from the final treatment. A property which is of immense value in close tolerance parts requiring high strength. Corrosion resistance is comparable to standard austenitic steels like AISI 304. These steels find application in the manufacture of high strength fittings, housings, springs, tubes ends, bellows etc.

The 17-4 PH is the most commonly used alloy gradeamong PH steels due to relatively lower cost compared to other grades. These steels are normally supplied in soft 'solution annealed' condition. These are aged after forming in Solution annealed soft state to attain increase in hardness, strength, toughness and resistance to stress corrosion.17-4 PH alloy is not put into service in any application in the solution treated condition because its ductility can be relatively low and its resistance to corrosion cracking poor. Several hardening sequences are possible in some alloys for eg. 17-7 PH can be hardened by temper hardening (TH), refrigeration hardening (RH) or cold work hardening (CH). PH stainless steels can be distinguished from austenitic stainless steels by the fact that they are magnetic. TIG welding is possible similar to 18/8 (Austenitic Stainless Steel) but with copper chills to avoid local ageing which could lead to cracking. The heat treatment time and temperature as shown in Table II determine the strength levels that can be achieved in the 17-4 PH grade to suit the required application in an aircraft.