Why Engineers Specify Precipitation Hardened Stainless Steel for CNC Machined Parts

Stainless steel is an iron-based alloy, with minimum 10.5 wt.% chromium content, widely used for its anti-corrosive properties and high strength. It is low-maintenance and is 100% recyclable.

Stainless steel is an integral part of modern society and is found in many applications including construction, architecture, automotive, medicine, and energy. Stainless steel properties are improved by the precipitation hardening (PH) process and engineers tend to specify this material most of the time for their products.

Let's find out why.

CNC Machining PH Stainless Steel. See Challenge Engineering in Sydney.

What is the precipitation hardening process?

Precipitation hardening is a heat treatment process that hardens stainless steel through ageing. This process allows stainless steel to cope with its susceptibility to stress corrosion cracking. Precipitation hardened stainless steels (PHSS) possess the combined properties of martensites (high strength) and austenites (high corrosion resistance). PHSS is hardened through strengthening its particles by the formation of intermetallic precipitates. PHSS has base elements of iron, chromium, and nickel and hardening is achieved by adding one or more of the following elements:

- Aluminium
- Copper
- Titanium
- Molybdenum
- Niobium

Three types of PH hardened characterisation

PHSS is classified by the characterisation of its final microstructure after heat treatment.

1. Martensitic Alloys

Martensitic PH stainless steel has a primarily austenitic structure at annealing temperatures. These alloys undergo a transformation that changes the austenite to martensite when brought to cool down in room temperature. Martensitic grade 17-4PH (17% Chromium, 4% Nickel, 4% Copper, and 0.3% Niobium) is the most common martensite PH alloy and its transformation occurs typically at 250°C, and is then strengthened further by ageing between 480 and 620°C.

2. Semi-austenitic alloys

Semi-austenitic PH stainless steels are fully austenitic after solution treatment and are then subjected to a second heat cycle before cooling to room temperature to form martensite. Some semi-austenitic alloys require very low temperatures at -50°C to -60°C for eight hours, in order to facilitate the full formation of austenite and martensite structures. Some alloys such as FV520 and 17-7PH though, do not require refrigeration to develop its optimum properties.

3. Austenitic alloys

Austenitic PH stainless steels retain their austenitic structure after annealing (1095°C to 1120°C) and hardening by ageing. These alloys are typically stable down to room temperature and strength is developed at ageing between 650°C to 750°C. The austenitic PH alloys have lower hardness in comparison to martensitic alloys but they exhibit good toughness in cryogenic applications. Austenitic alloys are also excellent in applications where high strength and non-ferromagnetism is required.

Composition of common PH hardened stainless steel

Specification	Common Name	Type	Typical Chemical Analysis %								
			C	Mn	Cr	Ni	Mo	Cu	Al	Ti	Others
A693 Tp630	17/4PH	martensitic	0.05	0.75	16.5	4.25	-	4.25	-	-	Nb 0.3
	FV 520	austenitic-martensitic	0.05	0.6	14.5	4.75	1.4	1.7	-	-	Nb 0.3
A693 Tp631	17/7PH	austenitic-martensitic	0.06	0.7	17.25	7.25	-	-	1.25	-	-
	PH 15/7 Mo	austenitic-martensitic	0.06	0.7	15.5	7.25	2.6	-	1.3	-	-
A 286		austenitic	0.04	1.45	15.25	26.0	1.25	-	0.15	2.15	V 0.25 B 0.007
	JBK 75	austenitic	0.01	0.04	14.75	30.5	1.25	-	0.30	2.15	V 0.25 B 0.0017
	17/10P	austenitic	0.07	0.75	17.2	10.8					P 0.28

Table 1 Source: https://www.twi-global.com/technical-knowledge/job-knowledge/precipitation-hardening-stainless-steels-102

Why do engineers specify PHSS?

Due to the high strength to weight ratio of PHSS, it is vastly used in a variety of applications including:

- Aerospace engineering
- Automotive engineering
- Chemical engineering
- Medical applications
- Metalworking industries

The formability and machinability of PHSS are excellent for parts that require CNC machining. For example, in aerospace applications, engineers commonly specify martensitic PHSS for CNC machined landing gear parts, valves, shafts, pins, and blades where hi-strength and toughness are required. Designers prefer semi-austenitic PHSS in applications where severe plastic deformation is required to achieve the final part geometry.

With these many advantages, PHSS is widely used and specified in applications where high-strength, corrosion resistance, and formability is desired.