1.4472 IMPLANT

1.4472/ F 1586 – Austenitic stainless steel for implants

Features and peculiarities

This 1.4472 IMPLANT steel is PESR (Pressure ESR) remelted. Its N content is high, but the S and C contents are kept as low as feasible. The contents in Cr and Mn are also high. This steel contains also a small addition of Nb. The average value of its PREN indices is 35.8 against 28.9 for the standard 1.4441 IMPLANT grade. It indicates a very good pitting corrosion resistance. This steel does not contain any ∂ (Delta) ferrite and is off course non-ferromagnetic up to the highest amounts of cold working. Its high toughness renders the machining somewhat more difficult, requiring an adaptation of both the cutting conditions and the tooling.

Uses

The corrosion resistance of this steel, mechanical properties and fatigue resistance indicate it as the material of choice for numerous medical applications in bone surgery, such as for internal fixation devices and endo-prothesis, as well as for various others medical and surgical applications. The particular mechanical properties and reproducibility, make this steel a prime material for micromechanical devices.

Standards

Material number	1.4472
ISO	5832-9
EN 10088-3 09/05	X4CrNiMnMo 21-9-4
DIN	X4CrNiMnMo 21-9-4
ASTM	F 1586
NF	S 94-090
UNS	S31675

Chemical composition (%wt)

C	Si	Mn	P	S	Cr	Ni	Mo	N	Nb	Fe
max.	max.	2.00	max.	max.	19.5	8.0	2.00	0.25	0.25	balance
0.08	0.75	4.25	0.025	0.008	22.0	11.0	3.00	0.50	0.80	

Dimensions and tolerances

- Bars Ø mm: 3 – 20 ISO h6 (h9)
- Out of roundness max.: ½ diameter tolerance

Other dimensions on request

Delivery condition

Standard: Bars : 3 m (+50/0 mm),
- Bars Ø ≥ 3.00 mm: cold drawn, ground, polished, Ra max. 0.4 µm (N5) pointed and chamfered

Mechanical properties

- Bars:

Condition	Rm (MPa)	$R_{0.2\%}$ (MPa)	A_{4d} (%)
annealed	≥ 740	≥ 430	> 40
cold worked	900-1500	600-1200	35-13

Availability

Dimensions courantes en stock, see: Delivery program

Cutting conditions

Machining: relatively difficult
better in the cold worked condition
Cutting speed: V_c ≈ 20 - 25 m/min.
Lubricant-coolant: Individual choice

- The optimal cutting conditions depend on the machine tool, the cutting tools, the chip dimensions, the lubricant-cooling fluid, as well as the tolerances and surface the roughness to be achieved.

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Cleanliness

According to: ASTM 45 (E 1122):

Class designation	A	B	C	D
Type of inclusions	sulfides	Al oxide	silicates	globular oxide
Thin	≤ 1.5	≤ 2.0	≤ 2.0	≤ 2.5
Heavy	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5

δ (Delta) ferrite

This steel does not contain any δ (Delta) ferrite. It is non-ferromagnetic.
According to the Schaeffler-DeLong diagram revised by the formulas:

- Cr_{eq} = 1.5Si + Cr + Mo + 2Ti + 0.5Nb
- Ni_{eq} = 30(C + N) + 0.5Mn + Ni + 0.5(Cu + Co)
- $\%_{vol.}$ δ ferrite or Ferrite Number FN
  FN = ([{1.375 (Cr_{eq} – 16)} + 10] - Ni_{eq}) 2.586
- Negative values indicate the absence of δ (Delta) ferrite

PREN indices

- PREN = %Cr + 3.3%Mo + 18%N
- Computed values: min. 30.6
  max. 40.9

Forming

Warm: forging : 1050 – 1150°C/fast quenching/cooling
Cold: no restriction
strong cold work hardening

Solution anneal

1050-1150°C/ fast quenching/cooling

- A ≥10 à 15% amount of cold work before annealing is recommended to prevent a too fast grain growth.
- The 450 - 970°C temperature range should be avoided. It can lead to the formation and precipitation of intercristalline σ (Sigma) and/or ψ (Chi).
- The formation of these phases may lead to intercristalline corrosion, brittleness, reduction of ductility and the polishing abilities and adequacies. In such cases, a 1050-1080°C/ fast quenching/cooling solution anneal is recommended, but the mechanical properties provided by a cold working will loose at the same time.

Hardening

- This 1.4472 IMPLANT steel cannot be thermally hardened.
- This steel can be hardened by cold work only.

Microstructures

Delivery condition: hot rolled austenite, annealed
Cold worked: cold worked deformed austenite

Polishing

Mirror polishing: well adapted
Electropolishing: well adapted

Laser marking

The HAZ (Heat Affected Zone) produces by a normal laser marking, should not affect the microstructure, but not in case of overheating (over blackening). More info

∂ (Delta) Ferrite

- This1.4472 IMPLANT steel does not contain any ∂ (Delta) ferrite.

Surface oxidation

Thermal oxidation build up an oxide layer which should be eliminated either mechanically of by pickling.

- The presence of surface oxide such as a colored oxidation, or a scaling, may strongly decrease the corrosion resistance.

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Pickling - Passivation

A thermal oxidation forms an oxide layer, which should be entirely eliminated either mechanically or chemically by pickling. These oxides may significantly decrease the corrosion resistance.

- The presence of an oxide scale or rests of it reduces strongly the corrosion resistance.
- The passivation treatment of the surface cannot by itself only decreases the corrosion risk of an oxide surface.

Corrosion resistance

The pickling as well as the passivation procedures, and the products used to that end, should be conform to the requirements of austenitic stainless steels

- A staining “Flash back“ reaction can be avoided by pickling the surface before the passivation treatment. More info
- A passivation treatment is not necessary after electro polishing.

Elementary precautions

- The most elementary protection is to always keep the surfaces very clean, polished and passivized.
- The parts should always be very well cleaned (no usage residual) and dried.
- Only use adapted chlorine free disinfection, cleaning and washing products.

Physical properties

Properties	Unit	Temperature (°C)				
		20	200	300	400	500
Density	g cm^{-3}	7.90				
Young modulu E	GPa	195				
Poisson coefficient		0.29				
Electrical resistance	$\Omega.mm^2.m^{-1}$	0.75				
Thermal expansion	m m^{-1} K^{-1} 10^{-6}	20–100°C	20–200°C 16.6	20–300°C	20–400°C 17.4	20–600°C 18.1
Thermal conductivity	$W.m^{-1}.K^{-1}$	14			15.2	
Specifique heat	$J.kg^{-1}.K^{-1}$	500				
Relative permeability	µr	max. 1.01				
Magnetism	is not ferromagnetic					

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