PHYNOX® KL

2.4711/ASTM F 1058 – Co based alloy with high strength, corrosion resistance, and biocompatible

Features and peculiarities

The Co based PHYNOX® KL alloy is VIM melted and ESR remolded. It permits to reach very high strength by cold forming and heat treatment while keeping its very good corrosion resistance in salt containing mediums. This alloy is biocompatible, non-magnetic and implantable. Its a high fatigue resistance makes it the material of choice for medical and space applications. This alloy is largely used for joint replacement implant. As wire material, it is used for stents, lines and electrodes for stimulation devices, and drill lines. Its elastic properties make it a material of choice for watch making components and various parts in micro engineering.

Uses

The PHYNOX® KL is the Co based alloy of choice for applications requiring high toughness, ductility, fatigue, corrosion and wear resistances, such as in the medical, aerospace and marine fields. But it is difficult to machine.

Standards

Material number	2.4711
AFNOR	K13C20N16Fe15D07
ASTM	F 1058
AMS	5833, 5834
ISO	5832-7
UNS	R30003
	R30008

Chemical composition ($\%_{wt}$)

C	Si	Mn	P	S	Cr	Mo	Ni	Co	others	Fe
max.	max.	1.50	max.	max.	19.00	6.50	15.00	39.00	max.	balance
0.15	1.20	2.50	0.015	0.015	21.00	7.50	18.00	41.00	1.00	

Executions Dimensions Delivery condition

- Round bars: cold drawn, tensile cold straightened, cold drawn ISO h6 (h8), 3 m
  UTS/Rm 1000 -1150 MPa, A up to 55%
- Round bars: cold drawn straightened and ground h6
  UTS/Rm and A% see Figure 2
- Round wires: cold drawn, rings for Escomatic
  UTS/Rm > 1100 MPa, A% according to the cold reduction

Tolerances

- Standard: ISO h8-h6

Availability

Dimensions courantes en stock, see: Delivery program

Machining

- The machining of this alloy requires machine tools and tooling as rigid as possible.
- This alloy builds an extensive plastic deformation and strengthening in the cutting shear plane.

Machinability:	difficult
Cutting speed:	low, Vc ≈ 20-40 m/min
Feed:	moderate to high
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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Melting
Remelting

VIM Vacuum Induction Melting
ESR Electroslag Remelting

Cleanliness

according to ISO 5832/7, AFNOR NF S90-4

Non metallic inclusions			
Type A	Type B	Type C	Type D
sulfides	aluminates	silicates	globular oxides
1	3	1	1

Figure 1
Cold forming and deformation

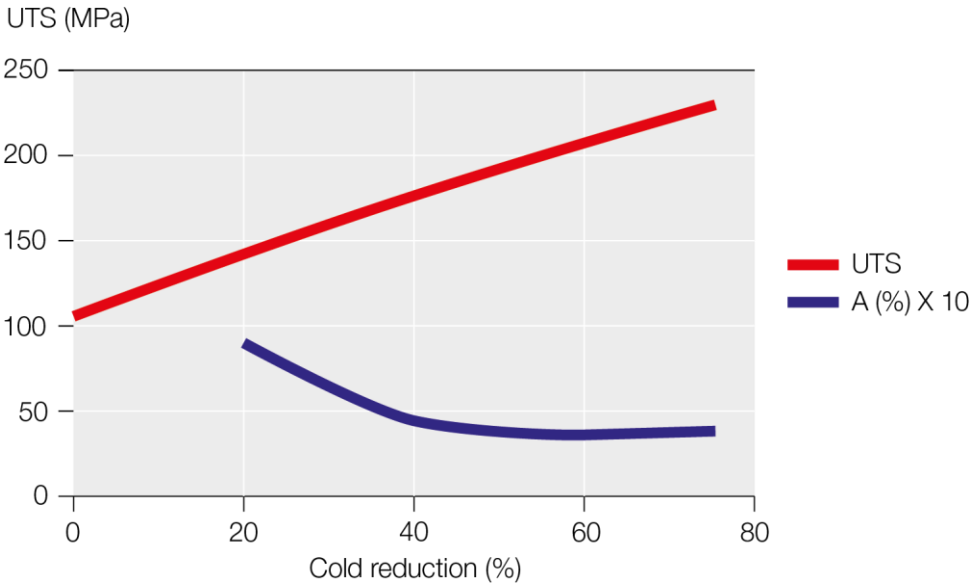

Figure 2
Rm / UTS
Cold deformation
Response to aging

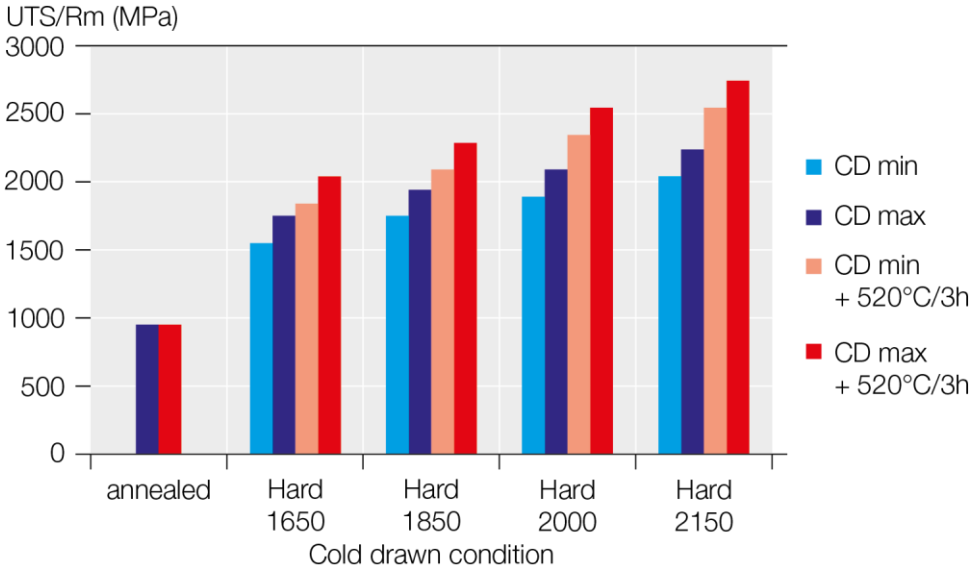

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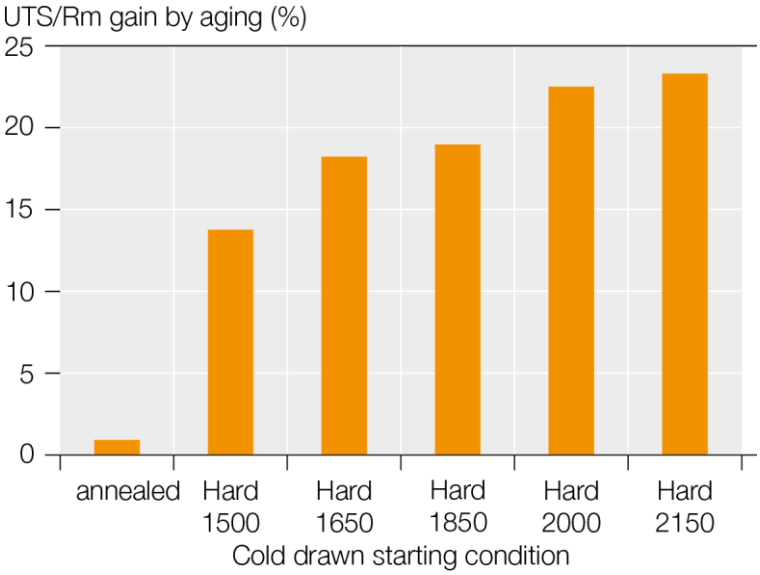
Figure 3
Strength increase by aging



Aging

- The aging intensity of the Phynox KL alloy is function of the previous cold deformation.
  Figure 3 shows the increase of UTS/Rm in % in function of the UTS/Rm prior to aging. The hard 1500 condition corresponds to a cold reduction of 30%.
- Aging cannot strengthen this alloy in the annealed condition.
- The conversion of VHN (Vickers Hardness Number) in UTS/Rm is Hv = 2.44 Rm.
- The aging reaction of this alloy is not a true structural hardening. It requires a previous cold deformation of the microstructure to activate the hardening reaction and potential corresponding to its cold deformed condition. The highest it is the strongest the hardening will be.

Heat treatments

Annealing:	1050°C/0.5h/fast cooling in air, gas or water
Aging:	480-540°C / 2-5h preferably in a 10^{-5} T vacuum 10^{-5} T or under argon protective atmosphere. A treatment in air oxidizes the surface by forming a yellowish oxide layer.
Stress relieving:	< 250-300°C/1-2h

- A stress relieving treatment of the cold deformed products is recommended.
- A stress relieving treatment of the cold deformed products to uniformize their internal stresses before machining is recommended.

Atmospheres of heat treatment Elementary precaution

- Heat treatment under protective atmospheres containing hydrogen should, by elementary precaution, be avoided.

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Microstructure

Delivery condition, annealed and annealed + cold deformation:
Austenite: Cfc cubic faced centered
Microstructure for classical machining: Annealed austenite or cold deformed
Optimum microstructure for polishing: Cold worked austenite

Polishing

- Well adapted to the requirements of the watch making industry
- The polishing is easier in the cold worked condition. More info

Laser marking

- The heating of the HAZ (Heat Affected Zone) due to the laser marking, normally, free of overheating, should not modify the microstructure and the mechanical properties and the fatigue resistance. More info

Pickling and passivation

- It is highly recommended to use pickling and passivation procedures and products effectively adapted to the treatment of Co based alloys.

- Strong pickling:
  5% Fluor hydric acid + 12% nitric acid / boiling
  + intensive rinsing with warm or cold water and total drying

- Final pickling solution for finished parts or items:
  1. Phosphoric acid 6%/ 70°C /15-20 minutes
  2. Nitric acid 30%/40°C/2 to 3 minutes
  3. Hydrochloric acid 40% + nitric acid 5%/ room temperature
  4. Passivation: nitric acid 40%/ room temperature
  1-4. + intensive rinsing with warm or cold water and total drying

Résistance à la corrosion

The Phynox alloy exhibits a good corrosion resistance in numerous mediums.

Biocompatibility

The Phynox alloy has a well-proven biocompatibility.

Magnetic properties

The low relative magnetic permeability of μr > 1.005 allows to expose implants made of this Phynox alloy to the high magnetic fields of the magnetic resonance imaging without incurring the risk of implants displacements.

Range of temperature

- from -269°C (liquid helium) to max 400°C in permanent exposure
- Short exposure time up to max 500°C

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Physical properties

Properties	Unit	Temperature (°C)				
		20	200	300	400	500
Density	g cm^{-3}	8.30				
Youg modulus E						
annealed	GPa	198				
cold worked		182				
cw + aged 520°C/3h		208	205	203	201	197
Thermal coefficient of E			20–50°C 4.10^{-4}			
Shear modulus G						
annealed	GPa	77				
cold worked		75				
cw + 520°C/3h		82	79.5	78	75	72
Poisson coefficient	-	0.34				
Thermal conductivity	$W.m^{-1}.K^{-1}$	12.5				
Electrical reistance	µΩ.cm	0.95				
Thermal expansion	$m/m^{-1}.K^{-1}$ 10^{-6}	20–100°C 12.5	20–200°C	20–300°C	20–500°C	20–815°C
Thermal coefficient of the resistivity	$µΩ.cm.K^{-1}$			20–300°C		
annealed				4.10^{-4}		
cold worked				$4.3.10^{-4}$		
Specific heat	$J.kg^{-1}.K^{-1}$	450				
Relative permeability						
5.10^{2}-10^{3} Oe, annealed	µr	<1.002				
5.10^{2}-10^{3} Oe, cw	µr	<1.005				