

# DURIMPHY

1.6358/ASTM A-538 Precipitation hardening martensitic steel

**Features and particularities**

The DURIMPHY is a clean double vacuum VIM-VAR melted low C precipitation hardening martensitic steel. In the 830°C annealed /quenched condition, it exhibits a soft martensitic microstructure amenable to plastic deformation up to very high reductions and to machining. Its age hardening is preferably made at 480°C. The cumulative contributions of cold deformation and age hardening permit to obtain reproducibly hardness values of HRc 52-55. The precipitation hardening causes neither the formation of internal stresses, nor dimensional changes. In the hardened condition this steel shows high UTS/Rm and YS<sub>0.2</sub>/R<sub>0.2</sub> strengths, as well as fatigue resistance, and notch impact resistance. This steel does not have a ductile-brittle transition temperature down to the coldest cryogenic temperatures. It can continuously be used up to max 400°C. It can easily be welded and brazed.

**Uses**

The DURIMPHY steel is used in a large number of applications in various industrial segments. For example for components for the aerospace industry, as well as parts for the micro-mechanical engineering and the watch making industry. However its low to fair corrosion resistance is a limiting factor.

**Standard**

Material number	1.2709
EN/DIN	X3NiMoTi 18-9-5
ASTM/ANSI	A-538
AMS	6514
UNS	K93160

**Chemical composition (%wt.)**

C	Si	Mn	P	S	Ni	Co	Mo	Ti	others	Fe
max. 0.03	max. 0.10	max. 0.10	max. 0.010	max. 0.010	18.00 19.00	8.50 9.50	4.60 5.20	0.50 0.80	max. 1.20	balance

**Dimensions and executions**

Round bars: 3 – 13 mm, cold drawn, 3m straightened, h6 ground  
UTS/Rm and A% see Figure 2

**Availability**

Dimensions courantes en stock, see: [Delivery program](#)

**Strength and machining**

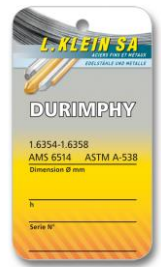
- In the annealed and cold worked conditions, the high ratio R<sub>0.2</sub>/Rm ≥0.98% support and assist its machinability.
- In the cold deformed condition, the machining is influence by the actual UTS/Rm strength level.

**Machining**

- Machining: favorable
- Cutting speed: slow, Vc ≈ 20-40 m/min
- Feed: average up to high
- 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.
- The DURIMPHY steel is tough. Its machining requires the use of rigid machine tools, tooling and tools.

**Deformation and shaping**

- Warm: forging: 1050-850°C  
The coldest forging or warm forming temperature is 850°C
- Cold deformation: max. 400°C



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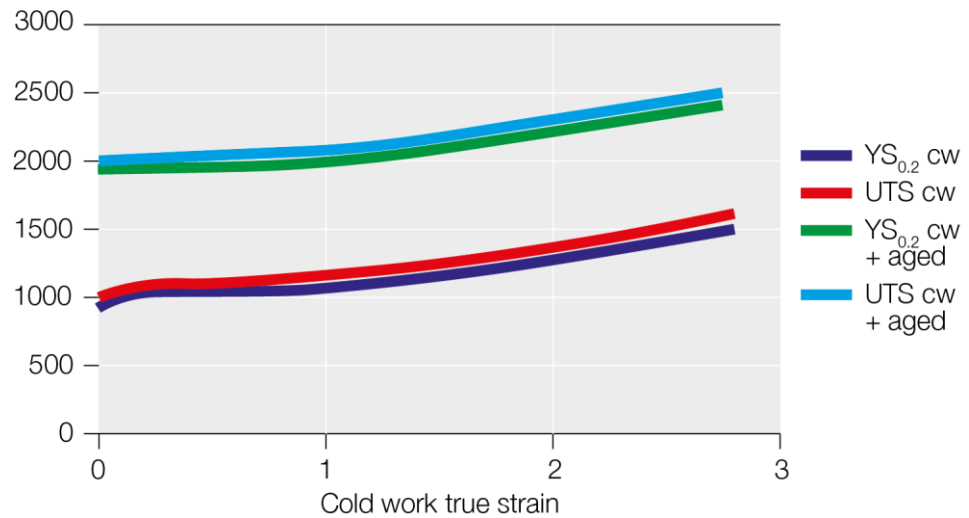
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**Melting** • VIM (Vacuum Induction Melting) + Remelting: VAR (Vacuum Arc Remelting)

**Cleanliness** • Clean microstructure, Double vacuum melting and remelting

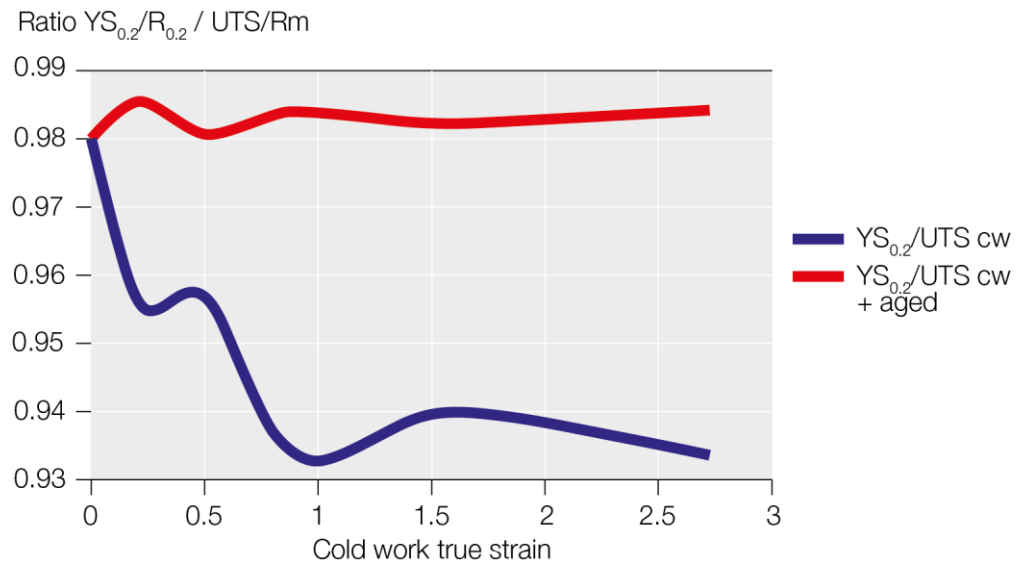
**Strengthening** UTS/Rm &  $YS_{0.2}/R_{0.2}$  (MPa)

**Figure 1**  
Influence of a cold deformation on UTS/Rm and  $YS_{0.2}/R_{0.2}$  with and without 480°C/3h aging

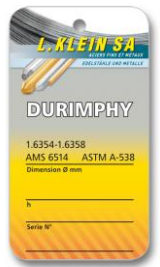


- The main feature of the DURIMPHY steel is its beneficial high  $YS_{0.2}/R_{0.2}$  yield strength  $YS$ , in all its conditions, annealed, cold deformed and aged.
- Figure 2 shows the ratio  $YS_{0.2}/R_{0.2} / UTS/Rm$  as function of the cold work. As shown, this ratio is above 98% in the annealed and cold worked conditions, its machining condition. A supportive situation for the chip formation during machining. After aging, this ratio decreases with the amount of cold work.
- The DURIMPHY steel is mostly used because of its high  $YS_{0.2}/R_{0.2}$  yield strength.

**Figure 2**  
Ratio  $YS_{0.2}/R_{0.2} / UTS/Rm$



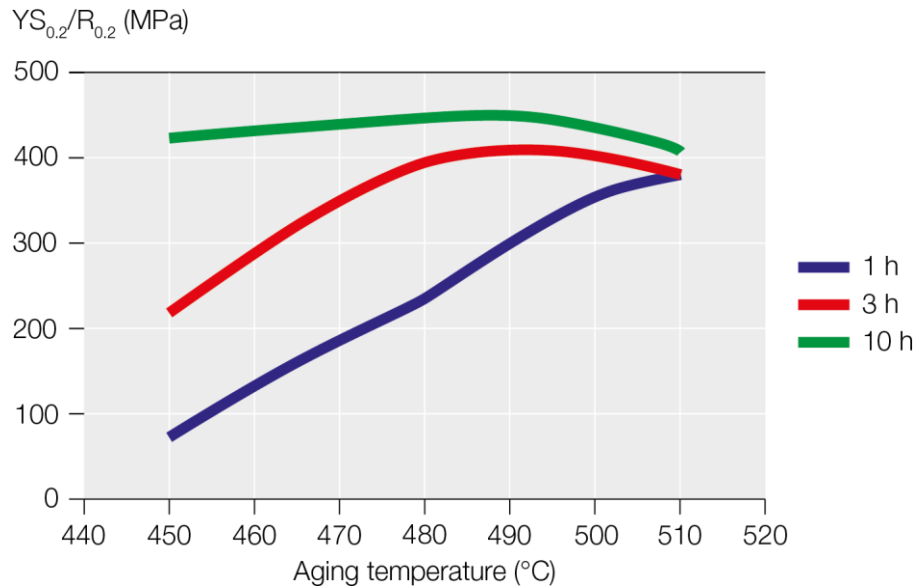
- The precipitation hardening or aging of the DURIMPHY steel is first due to the precipitation of the intermetallic compound  $Ni_3Ti$ , and second of the  $Fe_2Mo$  compound. These precipitates are very fine, low on the nanometric scale.



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**Figure 3**  
Relative influence of the aging temperature and holding time on  $YS_{0.2}/R_{0.2}$



**Thermal treatments**  
**Annealing**

- Annealing: 830°C/1-4h/rapid cooling
- small parts 830°C/0.5-1h/rapid cooling
- Solution anneal: 830°C/1-4h/rapid cooling
- The rapid cooling prevents the retention of residual austenite.

**Microstructures**

Delivery condition: annealed: Martensite + cold worked martensite  
 Microstructure for machining: annealed soft martensite, 830°C/rapid cooling  
 cold worked annealed martensite  
 Microstructure for polishing: annealed soft or cold worked martensite

- The DURIMPHY steel is well adapted for “Haut de gamme” requirements of the watch making industry.

**Aging**

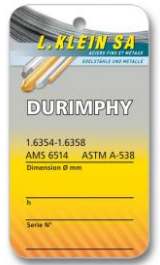
- Optimum aging: 480°C/3h
- The intensity of the aging is independent of prior cold work or forming.
- A too long aging decreases progressively the notch impact resistance.
- The aging contribution to Rm and R<sub>0.2</sub> are additive to the strengths present before aging.
- The additive contribution of an 480°C/3h aging is the same for all starting conditions. It amounts to 940 MPa on UTS/Rm and 920 MPa on YS<sub>0.2</sub>/R<sub>0.2</sub>.

**Protective atmospheres**

- The DURIMPHY steel is sensitive to H<sub>2</sub> (Hydrogen). H<sub>2</sub> embrittles it.
- All protective containing non-bound H<sub>2</sub> should be avoided.
- H<sub>2</sub> contaminated DURIMPHY steel can be purged by a 150°C/1-3h treatment, to eliminate all H<sub>2</sub> traces.

**Laser marking**

- The heated HAZ (Heat Affected Zone) during a normal laser marking absent of overheating, should not lead to changes of the microstructure and the fatigue resistance. [More info](#)

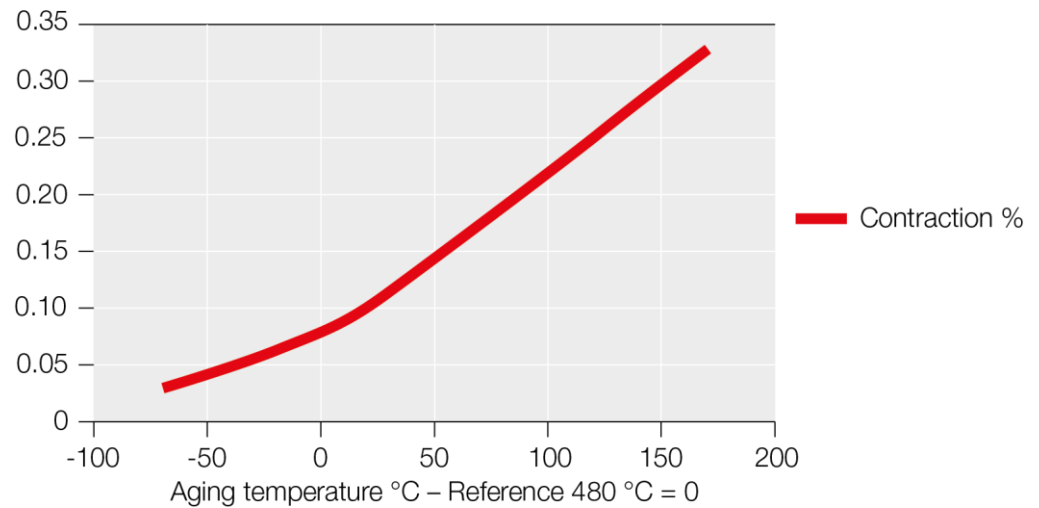


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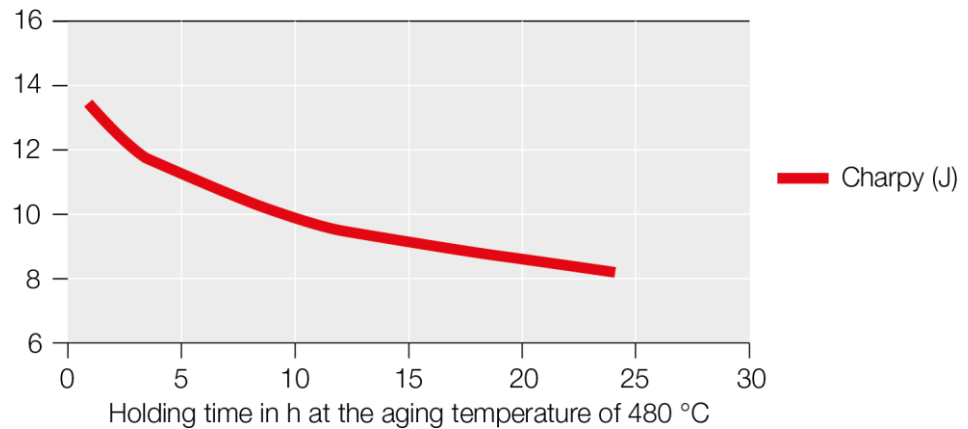
**Figure 4**  
Contraction due to aging

Triaxial / volume contraction (%)



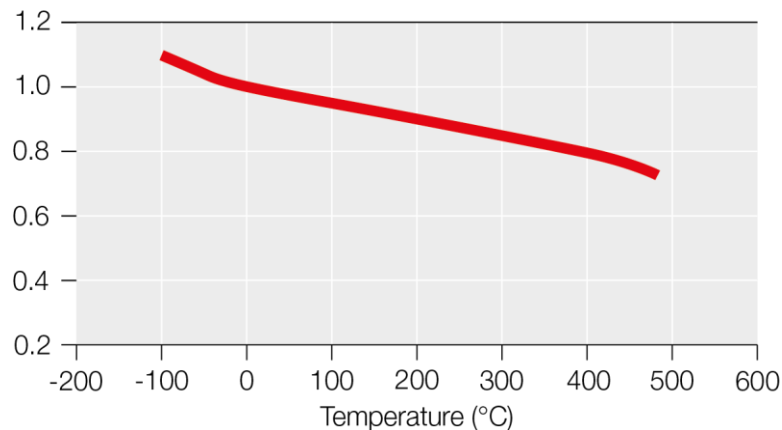
**Figure 5**  
Influence of the aging holding time at 480°C on the Charpy impact resistance  
la résilience Charpy

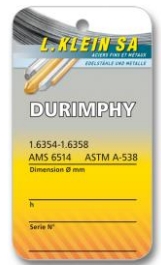
Charpy energy absorption (J)



**Figure 6**  
Influence of the temperature on the ratio  $YS_{0.2}/R_{0.2}$  at T /  $YS_{0.2}/R_{0.2}$  at 20°C

$YS_{0.2}/R_{0.2}$  at T /  $YS_{0.2}/R_{0.2}$  at 20°C





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## Corrosion resistance

- The DURIMPHY steel has a limited corrosion resistance only. In humid air it builds a rust layer.

## Pickling solutions and processes

- Process 1:  
Chlorhydric acid: 4 parts  
Water: 3 parts  
Temperature: 70°C  
Holding time: 20-30 min.  
Intensive rinsing and drying
- Process 2:  
Nitric acid 70%: 5 parts  
Fluorhydric acid 5%: 1 part  
Water: 14 parts  
Temperature: 25-30°C  
Holding time: 90-120 sec.  
Intensive rinsing and drying
- Process 3:  
Sulfuric acid: 93%: 3 parts  
78%: 4 parts  
Water: 20 parts  
Temperature: 65-75°C  
Holding time: 15 min.  
Intensive rinsing and drying
- Process 4:  
Sulfuric acid: 18%  
Temperature: 65°C  
Intensive rinsing and drying

## Surface condition

- The DURIMPHY steel is mostly used because of its high elastic strength always near its UTS/Rm. Accordingly, the surfaces prior and after pickling should always be free of micro notches and defects which could reduce or limit its use.

## Nitrification

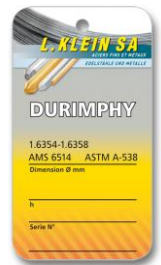
- Simultaneously to aging, the DURIMPHY steel can be enriched in N to obtain surface hardness up to 800 Hv and an improved wear resistance.

## Welding

- The DURIMPHY can be easily welded.
- It is recommended to make an 820°C anneal after welding.

## Brazing

- The DURIMPHY can be easily brazed.
- A degassing treatment at 150°C is recommended after brazing.



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## Physical properties

Properties	Unit	Temperature (°C)				
		20	200	300	400	500
Density	g cm <sup>-3</sup>	8.0				
Young modulus E						
cold worked and aged	GPa	186-190				
Shear modulus G						
annealed		72-73				
Poisson coefficient	-	0.30				
Thermal conductivity	W.m <sup>-1</sup> .K <sup>-1</sup>	20°C	100	200	300	400
	10 <sup>-6</sup>	21	23	26	27	28
			480			
	10 <sup>-6</sup>		28			
Electrical resistance	μΩ.cm	20°C				
- annealed 820°C	10 <sup>-6</sup>	60-70				
- aged 480°C/3h	10 <sup>-6</sup>	35-70	1128	1153	1179	
Thermal expansion	m/m <sup>-1</sup> .K <sup>-1</sup>	20-100°C	20-200°C	20-300°C	20-400°C	20-480°C
	10 <sup>-6</sup>	9.9	10.2	10.6	11.0	11.3
Specific heat	J.kg <sup>-1</sup> .K <sup>-1</sup>	460				
Curie temperature	°C	450				
Magnetic saturation	T	1.9				
Aging contraction	%	0.08				
Coercitive force	Oe			A/m		
annealed		23-24		1750-2700		
aged		21-54		1670-4300		
Remanence Br	T	0.55				
Melting	°C	1430-1460				

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