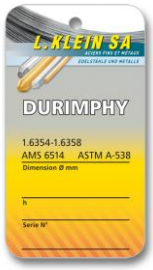



# DURIMPHY

## 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 $YS_{0.2}/R_{0.2}$ 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. Hoeever 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. | max. | max. | max. | max. | 18.00 | 8.50 | 4.60 | 0.50 | max. | balance |
| 0.03 | 0.10 | 0.10 | 0.010 | 0.010 | 19.00 | 9.50 | 5.20 | 0.80 | 1.20 | |

**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**

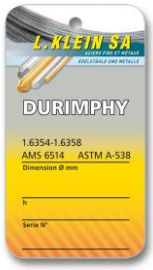
- In the annealed and cold worked conditions, the high ratio $R_{0.2}/Rm \geq 0.98\%$ support and assist its machinability.
- In the cold deformed condition, the machining is influence by the actual UTS/Rm strength level.

**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




# DURIMPHY

1.6358/ASTM A-538 Precipitation hardening martensitic steel

**Melting**

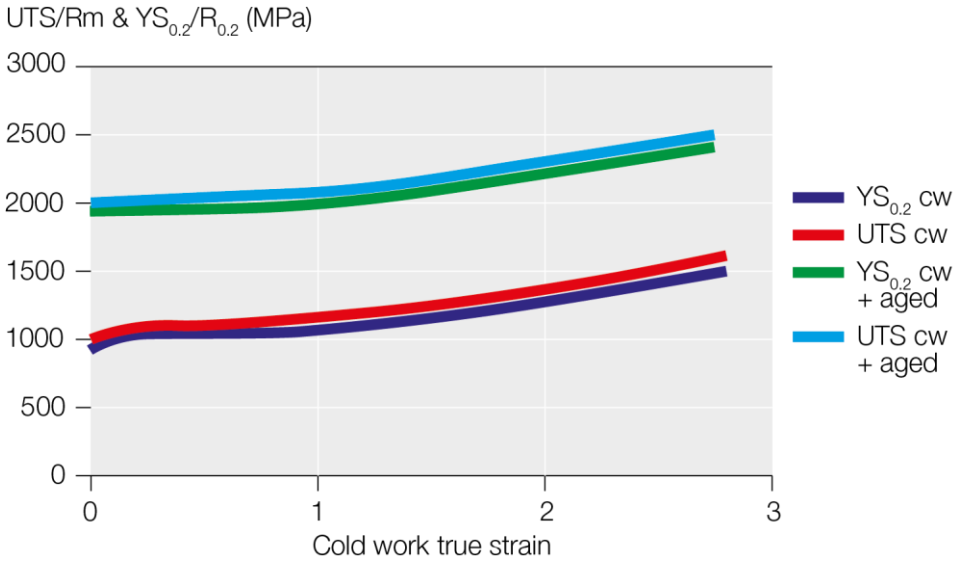
- VIM (Vacuum Induction Melting) + Remelting: VAR (Vacuum Arc Remelting)

**Cleanliness**

- Clean microstructure, Double vacuum melting and remelting

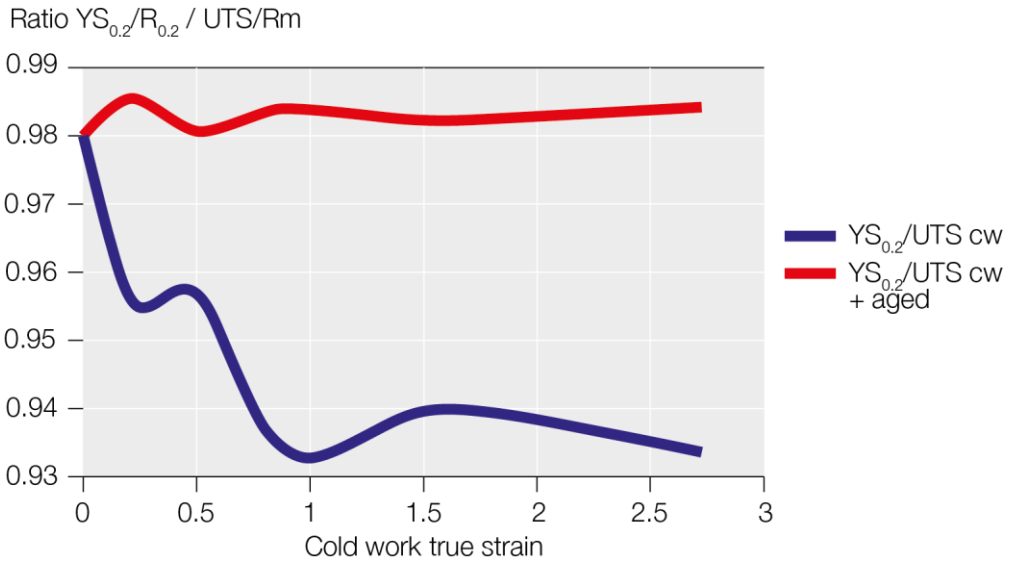
**Strengthening**

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

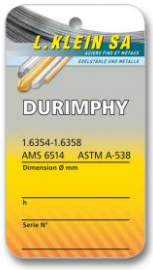



- The main feature of the DURIMPHY steel is its beneficial high $YS_{0.2}/R_{0.2}$ yield strength YS, in all its conditions, annealed, cold deformed and aged.
- Figure 2 shows the ratio $YS_{0.2}/R_{0.2}$ / UTS/Rm as function of the cold work. As shown, this ratio is above 98% in the annealed and cold 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**



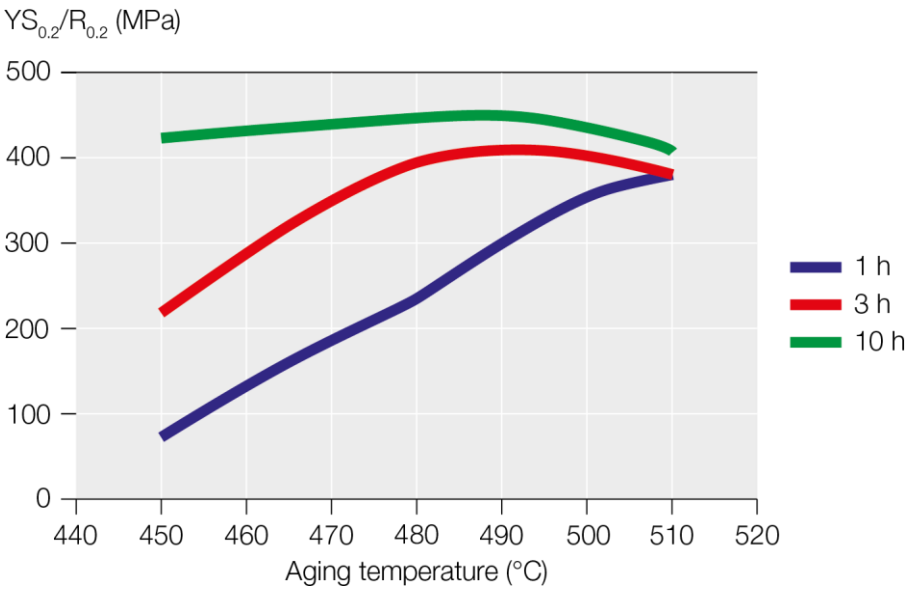

- The precipitation hardening or aging of the DURIMPHY steel is first due to the precipitation of the intermetallic compound $Ni_3Ti$, and second of the $Fe_2Mo$ compound. These precipitates are very fine, low on the nanometric scale.




# DURIMPHY

1.6358/ASTM A-538 Precipitation hardening martensitic steel

**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**

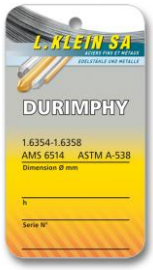
- Optimum aging: 480°C/3h
- The intensity oft he aging is independent of prior cold work or forming.
- A too long aging decreases progressively the notch impact resistance.
- The aging contribution to Rm and $R_{0.2}$ are additive tot he strengths present before aging.
- The additive contribution of an 480°C/3h aging is the same for all starting conditions. It amount to 940 MPa on UTS/Rm and 920 MPa on $YS_{0.2}$/ $R_{0.2}$.

**Protective atmospheres**

- The DURIMPHY steel is sensitive to $H_2$ (Hydrogen). $H_2$ embrittles it.
- All protective containing non-bound $H_2$ should be avoided.
- $H_2$ contaminated DURIMPHY steel can be purged by a 150°C/1-3h treatment, to eliminate all $H_2$ 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




# DURIMPHY

## 1.6358/ASTM A-538 Precipitation hardening martensitic steel

**Figure 4**
**Contraction due to aging**

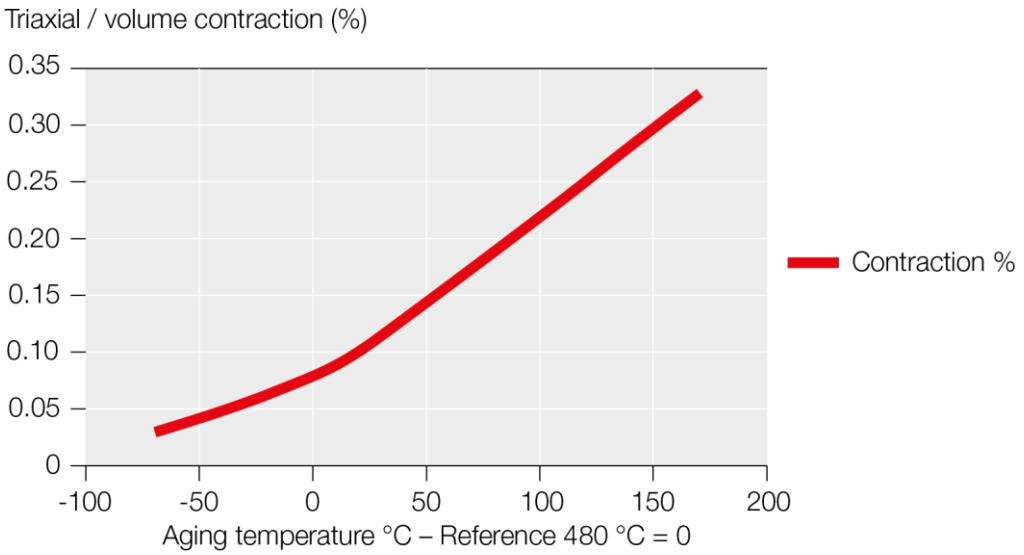



**Figure 5**
**Influence of the aging holding time at 480°C on the Charpy impact resistance**
**la résilience Charpy**

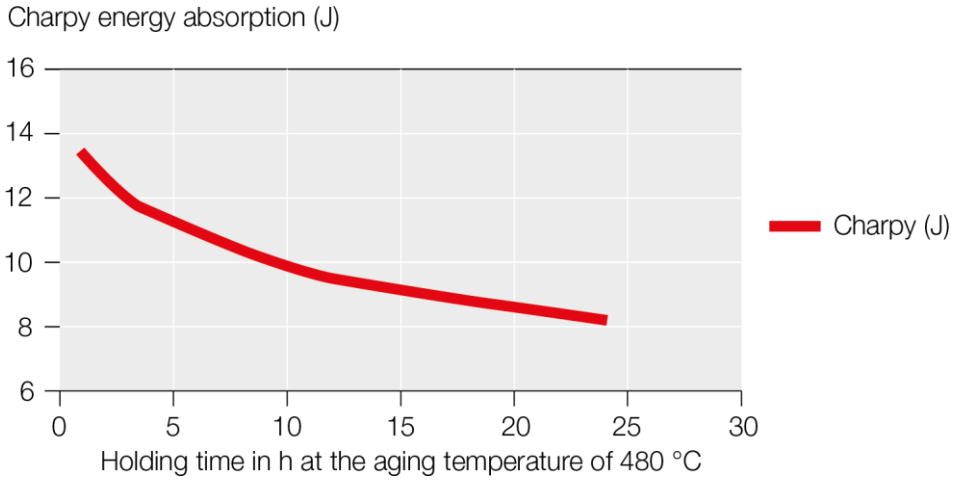
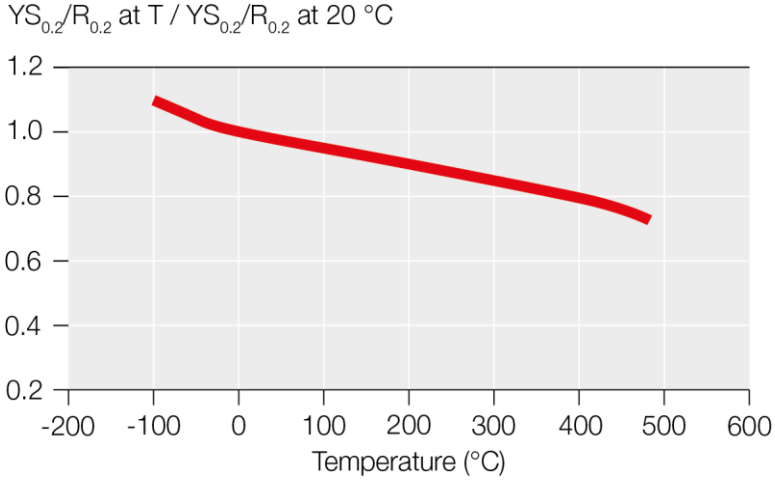
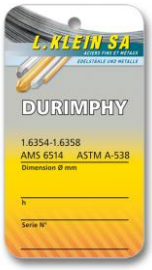



**Figure 6**
**Influence of the temperature on the ratio $YS_{0.2}/R_{0.2}$ at T / $YS_{0.2}/R_{0.2}$ at 20°C**






# DURIMPHY

1.6358/ASTM A-538 Precipitation hardening martensitic steel

**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**

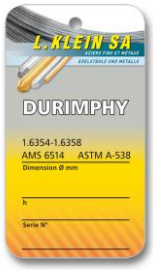
- The DURIMPHY can be easily welded.
- It is recommended to make an 820°C anneal after welding.

**Brazing**

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



L. Klein AG • Längfeldweg 110 • CH-2504 Biel/Bienne
Telefon 0041 (0)32 341 73 73 • Telefax 0041 (0)32 341 97 20 • www.kleinmetals.swiss • info@kleinmetals.swiss




# DURIMPHY

1.6358/ASTM A-538 Precipitation hardening martensitic steel

**Physical properties**

| Properties | Unit | Temperature (°C) | | | | |
|---|---|---|---|---|---|---|
| | | 20 | 200 | 300 | 400 | 500 |
| Density | g $cm^{-3}$ | 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.$m^{-1}$.$K^{-1}$ | 20°C | 100 | 200 | 300 | 400 |
| | $10^{-6}$ | 21 | 23 | 26 | 27 | 28 |
| | | | 480 | | | |
| | $10^{-6}$ | | 28 | | | |
| Electrical resistance | µΩ.cm | 20°C | | | | |
| - annealed 820°C | $10^{-6}$ | 60-70 | | | | |
| - aged 480°C/3h | $10^{-6}$ | 35-70 | 1128 | 1153 | 1179 | |
| Thermal expansion | m/$m^{-1}$.$K^{-1}$ | 20–100°C | 20–200°C | 20–300°C | 20–400°C | 20–480°C |
| | $10^{-6}$ | 9.9 | 10.2 | 10.6 | 11.0 | 11.3 |
| Specific heat | J.$kg^{-1}$.$K^{-1}$ | 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 | | | | |