

KEY[®] LOS 2316

Stainless steel for processing
chemically aggressive and
acid-releasing plastic moulds

General characteristics

KeyLos® 2316 is a martensitic stainless steel, resistant to corrosion, manufactured through a 'super clean' technology that guarantees high microcleanness levels.

KeyLos® 2316 is the ideal option if the following characteristics are required at the same time:

- good toughness;
- resistance to corrosion;
- homogeneous mechanical properties throughout the mould.

Resistance to corrosion allows the surface characteristics of the mould to be maintained over time.

This means that the die can be stocked with no need for special precautions to be taken and with the certainty of being able to use the mould whenever needed. The expensive and complicated operations of cleaning and setting up the die are not needed before usage.

KeyLos® 2316 is normally supplied in the soft annealed condition with surface hardness lower than 250 HB, in order to guarantee excellent machinability.

Upon request, KeyLos® 2316S can be supplied in the pre-hardened condition to hardness required, up to about 48 HRC.

In this case, it has a wear-resistant surface, is pressure-resistant and tough.

Should a very complex finish machining be required, we recommend choosing KeyLos® 2316 treated with sulphur, known as KeyLos® 2316S.

KeyLos® 2316 offers the following advantages:

- excellent machinability;
- excellent suitability for photo-engraving;
- excellent suitability for polishing;
- excellent suitability for nitriding, in order to increase the wear resistance;
- excellent wear resistance;
- good weldability;
- Good resistance to corrosion.

This grade is suitable for the production of moulds up to 500 mm in thickness, subject to corrosive action due to aggressive polymers (PVC, recycled polymers, etc.) or to unfavourable atmospheric conditions (high humidity / salinity)

KeyLos® 2316 is 100% ultrasonically inspected, according to the most demanding of NDT standards.

Chemical analysis

| | Range | C [%] | Si [%] | Mn [%] | Cr [%] | Mo [%] | Ni [%] |
|------------------------|-------|-------|--------|--------|--------|--------|--------|
| KEYLOS 2316 | min | 0,33 | / | / | 15,0 | 1,00 | / |
| Alloying [% in weight] | max | 0,43 | 1,00 | 1,00 | 17,50 | 1,30 | 1,00 |

Table for comparison of international classification

W. Nr. 1.2316
DIN EN ISO 4957 ≈X38CrMo16

Lucchini RS's tool steels have been researched and formulated in order to optimize the material performances.

The brand name identifies the Lucchini RS product and the number evokes the Werkstoff classification or other means of reflecting the characteristics of use.

KeyLos® 2316 is also designed with the aim to guarantee the minimum use of virgin materials, moving toward the use of scrap categories difficult to be recycled, that can become food for the steel making production of KeyLos® 2316 grade.

Main applications

KeyLos[®] 2316 is suitable for the following applications:

- moulds for corrosive plastic materials (PVC, recycled polymers, etc.);
- moulds for the automotive industry (head lamp components);
- moulds for medical instruments;
- moulds for food industry products;
- moulds for the cosmetics industry;
- moulds for rubber pressing;
- dies and gauges for PVC extrusion;
- mechanical parts for extrusion presses (ex. extrusion heads).

Environmental factors such as the plastic, the operating temperature and the actual properties of the cooling water have to be taken into account, in order to avoid inter-crystalline corrosion effects, surface and pitting corrosion.

Physical and mechanical properties

Main physical properties

| KEY[®]LOS 2316 | 20°C | 250°C | 500°C |
|---|------|-------|-------|
| Modulus of elasticity [GPa] (1GPa=1000 MPa) | 210 | 198 | 177 |
| Coefficient of thermal expansion [10 ⁻⁶ /K] | - | 11,4 | 12,2 |
| Thermal conductivity [W/mK] | 17,5 | 20,7 | 23,2 |

Main mechanical properties

| KEY[®]LOS 2316 | 20°C | 200°C |
|--|-------|-------|
| Ultimate tensile strength (UTS) [MPa] | 1.100 | 980 |
| Yield stress (YS) [MPa] | 900 | 780 |

These values are average values obtained on a sample which has been hardened at 1020° C, quenching and tempering at 580° C to obtain 35 HRC hardened.

Heat treatments

KeyLos® 2316 is supplied in the annealed condition with hardness lower than 220 HB, or in the pre-hardened condition. We suggest applying the following parameters if a different hardness is required or if heat treatment is needed.

This information is only indicative and must be adapted depending on the different heat treatment facilities employed and on the thickness of the bar.

Soft annealing

| | |
|-----------------------|--|
| Suggested temperature | 750 °C |
| Soaking time | 60 min every 25 mm thickness |
| Cooling | Slow in the furnace at max 20 °C/h to 600 °C , then at room temperature |

Soft annealing is useful to improve machinability. The obtained hardness is lower than 220 HB.

Stress Relieving

| | |
|-----------------------|--|
| Suggested temperature | 650 °C |
| Soaking time | 60 min every 25 mm thickness |
| Cooling | Slow in the furnace at max 20 °C/h to 200 °C , then at room temperature |

If the suggested temperature is lower than the tempering temperature, the stress relieving temperature will be 50° C lower than the tempering temperature previously applied.

Stress relieving is recommended where it is necessary to eliminate residual stresses induced by mechanical working or by a preceding heat treatment.

Hardening

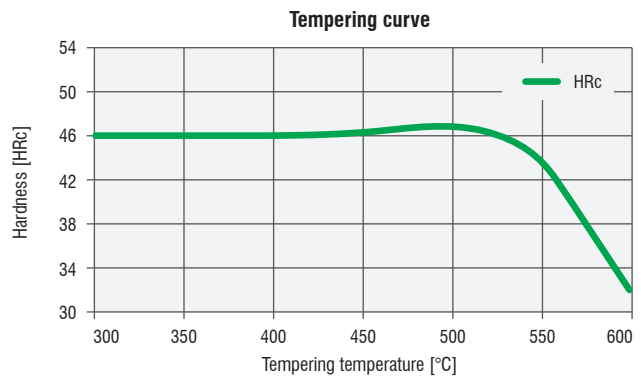
| | |
|--------------|------------------------------|
| Pre heating | 700 °C |
| Heating | 50 °C/h max |
| Soaking time | 60 min every 25 mm thickness |

| | |
|-----------------------------------|------------------------------|
| Austenising suggested temperature | 1020 °C |
| Heating | 50 °C/h max |
| Soaking time | 60 min every 25 mm thickness |
| Cooling | Polymer or water quench |

We suggest to carry out hardening on material supplied in the annealed condition and tempering immediately afterwards.

Tempering

| | |
|-----------------------|---|
| Suggested temperature | The tempering temperature to be applied to the material depends on the required mechanical properties. See following graph. |
| Soaking time | 60 min every 25 mm thickness |
| Cooling | Room temperature |

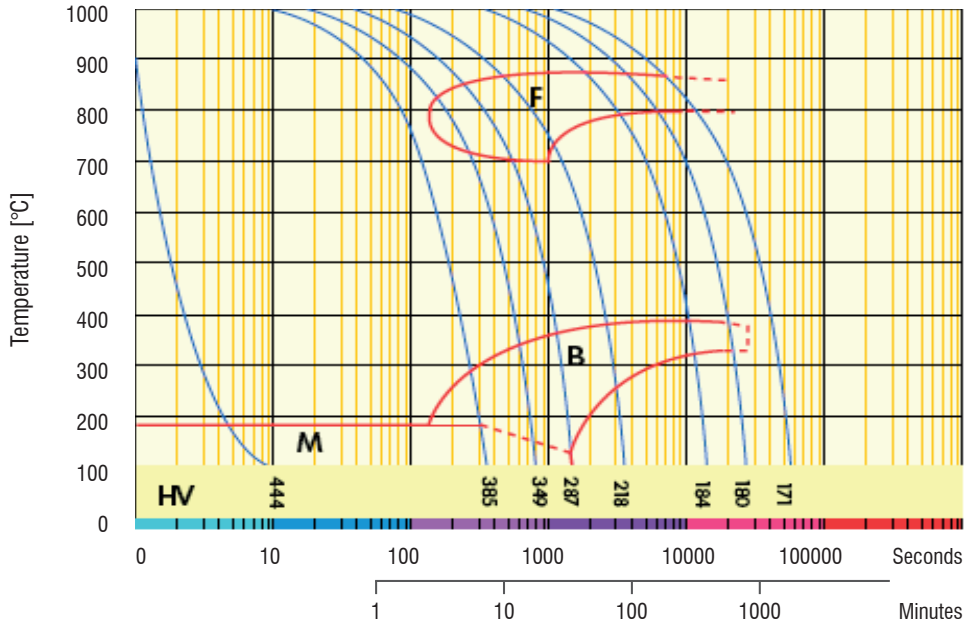


Tempering curve of a sample which has been austenitised at 1020 °C.

After tempering we suggest stress relieving at a temperature lower than 50 °C.

In any case, other properties can be analyzed and studied deeper by Lucchini RS on specific Customer request: please consult Lucchini RS specialists of MET Department.

CCT Curve



Microstructure of KEYLOS® 2316



KEYLOS® 2316 in hardening condition: Tempered Martensite with dispersed Carbides

Quick comparison guide among the different grades

The following table shows a quick comparison among the most important characteristics of the annealed and pre-hardened grades normally applied in corrosion resistant plastic moulding.

| Lucchini RS Mould steel Family for plastics Industry | | | | | | | | |
|--|------------------------------|-----------|-----------|-----------|-----------|-------------------------|-----------|-----------|
| Special features and delivered conditions | Annealed Corrosion Resistant | | | | | Precipitation Hardening | | |
| | KEYLOS | | | | | ESKYLOS | ESKYLOS | |
| | 2083 | 2084 | 2085 | 2316 | 2316S | 2083 | 4542 | 2001 |
| HB in surface in Annealed condition | < 220 | < 220 | < 220 | < 220 | < 220 | < 220 | < 355 | 310 - 350 |
| HB in surface Pre-hardened or Hardened after machining | 400 - 450 | 400 - 450 | 400 - 450 | 400 - 450 | 400 - 450 | 400 - 450 | 300 - 400 | 350 - 450 |
| Maximum thickness [mm] | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| Hardness and Wear Resistance | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 3 |
| Degree of Through Hardening in the section | 3 | 2 | 2 | 2 | 2 | 3 | 4 | 3 |
| Toughness | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 2 |
| Machinability after Annealing | 2 | 3 | 3 | 2 | 3 | 2 | 2 | 3 |
| Machinability after Hardening | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| Etch-Grainability | 2 | 1 | 1 | 2 | 1 | 4 | 4 | 4 |
| Polishability | 2 | 1 | 1 | 2 | 1 | 3 | 3 | 3 |
| Repair by Welding | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 1 |
| Thermal Conductivity | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Corrosion Resistance | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 0 |

4 Excellent 3 Very Good 2 Good 1 Normal 0 Unsuitable

The information and the data presented here are typical or average values and are not a guarantee of maximum or minimum values.

Applications specifically suggested for materials described herein and in the quick comparison guide among the different grades are made solely for the purpose of illustration to enable the reader to make his own evaluation and are not intended as warranties, either express or implied, of fitness for these or other purposes.

Guidance for machining

The following parameters are indicative only and must be adapted to the particular application and to the machinery employed. The data refer to material in the annealed condition. Hardness 250 HB max.

Turning

| Type of insert | Rough machining | | Finish machining | |
|--------------------------------------|-----------------|-----|------------------|-----------|
| | P20-P40 coated | HSS | P10-P20 coated | Cermet |
| V _c cutting speed [m/min] | 170 ÷ 220 | (*) | 200 ÷ 250 | 240 ÷ 300 |
| a _r cutting depth [mm] | 1 ÷ 5 | (*) | < 1 | < 0,5 |

Milling

| Type of insert | Rough machining | | |
|--------------------------------------|--------------------|----------------|-----|
| | P25-P35 not coated | P25-P35 coated | HSS |
| V _c cutting speed [m/min] | 140 ÷ 200 | 180 ÷ 260 | (*) |
| f _z feed [mm] | 0,15 ÷ 0,3 | 0,15 ÷ 0,3 | (*) |
| a _r cutting depth [mm] | 2 ÷ 4 | 2 ÷ 4 | (*) |

| Type of insert | Pre-finishing | | |
|--------------------------------------|--------------------|----------------|-----|
| | P10-P20 not coated | P10-P20 coated | HSS |
| V _c cutting speed [m/min] | 160 ÷ 240 | 240 ÷ 280 | (*) |
| f _z feed [mm] | 0,2 ÷ 0,3 | 0,2 ÷ 0,3 | (*) |
| a _r cutting depth [mm] | 1 ÷ 2 | 1 ÷ 2 | (*) |

| Type of insert | Finishing | | |
|--------------------------------------|--------------------|----------------|------------|
| | P10-P20 not coated | P10-P20 coated | Cermet P15 |
| V _c cutting speed [m/min] | 200 ÷ 260 | 240 ÷ 300 | 240 ÷ 330 |
| f _z feed [mm] | 0,05 ÷ 0,2 | 0,05 ÷ 0,2 | 0,05 ÷ 0,2 |
| a _r cutting depth [mm] | 0,5 ÷ 1 | 0,5 ÷ 1 | 0,3 ÷ 0,5 |

(*) not advisable

Drilling

| Type of insert | tip with interchangeable inserts | HSS | brazed tip |
|-------------------------------|----------------------------------|-----|-------------|
| V_c cutting speed [m/min] | 190 ÷ 220 | (*) | 60 ÷ 80 |
| f_z feed per turn [mm/turn] | 0,05 ÷ 0,15 | (*) | 0,15 ÷ 0,25 |

(*) not advisable

General formulae

| Type of machining | Drilling | Milling |
|-------------------------------|---|--|
| n: number of turns of mandrel | $V_c * 1000 / \pi * D_c$ | $V_c * 1000 / \pi * D_c$ |
| V_f : feed speed [m/min] | $V_f = f_z * n$ | $V_f = f_z * n * z_n$ |
| f_z feed per turn [mm/turn] | - | $f_n = V_f / n$ |
| Note | D_c : Milling cutter or tip diameter [mm] V_c : cutting speed [m/min] f_z : feed [mm] | f_n : feed per turn [mm/turn] z_n : No. of milling cutter inserts |

Approximate equivalent values between hardness and ultimate tensile strength.

| | | | | | | | | | | | | | |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| HB | 530 | 520 | 512 | 495 | 480 | 471 | 458 | 445 | 430 | 415 | 405 | 390 | 375 |
| HRc | 54 | 53 | 52 | 51,1 | 50,2 | 49,1 | 48,2 | 47 | 45,9 | 44,5 | 43,6 | 41,8 | 40,5 |
| MPa | 1.900 | 1.850 | 1.800 | 1.750 | 1.700 | 1.650 | 1.600 | 1.550 | 1.500 | 1.450 | 1.400 | 1.350 | 1.300 |

| | | | | | | | | | | | | | |
|-----|-------|-------|-------|-------|-------|-------|-----|-----|-----|-----|-----|-----|-----|
| HB | 360 | 350 | 330 | 320 | 305 | 294 | 284 | 265 | 252 | 238 | 225 | 209 | 195 |
| HRc | 38,8 | 37,6 | 35,5 | 34,2 | 32,4 | 31 | 29 | 27 | -- | -- | -- | -- | -- |
| MPa | 1.250 | 1.200 | 1.150 | 1.100 | 1.050 | 1.000 | 950 | 900 | 850 | 800 | 750 | 700 | 650 |

Welding

Welding of KeyLos® 2316 can give good results if the following procedure is observed:

| | | |
|----------------------------|---|---|
| Welding technique | TIG | TIG |
| Pre-heating at | Annealed | Hardened and tempered |
| Hardness after welding | 250 ÷ 300 °C | |
| Recommended heat treatment | Heating at 680 °C and cooling at room temperature | Tempering at 10-20 °C below the temperature of the last tempering |

Process and materials selection for product recyclability

According to the potential of steel recycling, Lucchini RS is adopting a strategy for environmental excellence in designing and manufacturing of its tool steel grades, putting eco-effectiveness into practice.

The main adopted steps are:

- conducting an environmental assessment on processes and products, with the minimum use of virgin materials and non-renewable forms of energy;
- moving toward zero-waste manufacturing processes, considering that the ultimate destiny of a scrapped steel mould becomes food for the next steel making process, that is the “waste equals food” philosophy;
- conducting a life cycle assessment for-each product and process, minimizing the environmental cost of product and service over its entire life cycles, from creation to disposal, that is the “Cradle to Cradle” philosophy.

Electrical Discharge Machining (EDM)

KeyLos® 2316 can be machined by EDM to obtain complex shape.

Afterwards it is advisable to stress relieving the material.

Photo-engraving

Thanks to modern production processes and to the low Sulphur content, KeyLos® 2316 is suitable for photo-engraving to obtain various patterns.

Polishing

KeyLos® 2316 is particularly suitable for polishing.