

KEY[®]LOS 2001

Innovative Precipitation
Hardening alloyed steel:
a innovative approach to
highly resistant plastic moulds

General characteristics

KEYLOS® 2001 is a new alloy air hardening steel, useful for its hardening characteristics obtained by age hardening at a lower temperature than the phase transformation points.

KEYLOS® 2001 is patented by Lucchini RS with the patent number MI2001A001402 02/07/2001 and it is suggested for applications up to 500 mm in thickness.

KEYLOS® 2001 is obtained through a special 'super clean' production process technology.

KEYLOS® 2001 is supplied in the solution treated condition and is stress relieved, in order to reach hardness values of between 310 and 350 HB, comparable with a pre-hardened steel.

For the detected hardness values in standard sized products, the following correlation is usually valid and guaranteed:

$$(HB_{\text{Surface, min required}} - HB_{\text{Core}}) \leq 20HB$$

If high mechanical properties are required in the pattern and a homogeneous hardness throughout the whole mould is needed, KEYLOS® 2001 can be further hardened to reach 350-450 HB, by means of an age hardening process.

Since the heat treatment occurs below the phase transformation points, this process can also be carried out on a semi-finished mould, causing minimal deformation and no cracking during the hardening phase.

The mechanical characteristics of this steel are adaptable to a wide range of applications, much more so than those obtained through other grades that are normally used in this field.

KEYLOS® 2001 represents the ideal option for the end user who is looking for:

- high and homogeneous mechanical characteristics throughout the whole mould regardless of its complexity
- machinability
- micro-cleanness

KEYLOS® 2001 offers the following advantages:

- excellent machinability
- good suitability for embossing
- good suitability for polishing
- excellent wear resistance related to the mechanical properties obtained on a finished mould
- exceptional dimensional stability after age hardening.
- no cracking during heat treatment, regardless of shape and structure of the mould
- excellent weldability

Constant development in processing technologies require the use of KEYLOS® 2001, thanks to its high fatigue and wear resistance, combined with its excellent dimensional stability and extremely low distortions.

Thanks to its quasi-isotropic properties of ESR quality, KEYLOS® 2001 represents one of the most important tough options, for highly resistant plastic moulds that need very high pressure strength, excellent resistance to abrasion, also in combination with different surface coatings.

The increasing in the use of synthetic and abrasive materials has led manufacturers to use KEYLOS® 2001 also when suitability for polishing and graining, combined with abrasion and compression resistance, are required.

KEYLOS® 2001 is 100% ultrasonically inspected, according to the most demanding of NDT standards.

KEYLOS® 2001 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® 2001 grade.

Chemical analysis

	Range	C [%]	Si [%]	Mn [%]	Ni [%]	Cr [%]	Mo [%]	V [%]
KEY[®]LOS 2001	min	0,10	0,10	0,10	2,50	0,10	2,50	0,05
Alloying [% in weight]	max	0,20	1,10	1,10	4,50	1,10	4,50	0,25

KEYLOS[®] 2001 is patented by Lucchini Sidermeccanica with the following patent number: MI2001A001402 from 02/07/01

Main applications

KEYLOS[®] 2001 is suitable for the following applications.

Plastic moulding:

- medium and big sized moulds for the automotive industry
- moulds for food industry products
- moulds for rubber pressing
- pressure moulds (SMC, BMC)

Extrusion:

- dies and gauges for PVC extrusion
- mechanical parts for extrusion presses.

Physical and mechanical properties

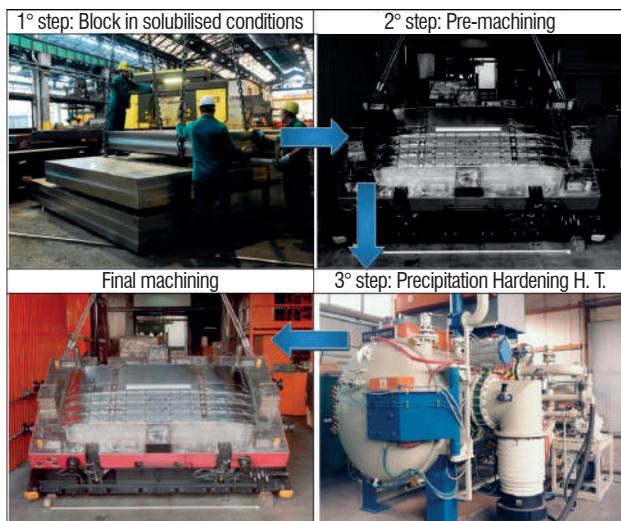
Main physical properties

KEY[®]LOS 2001	20°C	250°C	500°C
Modulus of elasticity [GPa] (1GPa=1000 MPa)	210	197	178
Coefficient of thermal expansion [10 ⁻⁶ /K]	27,5	28,3	29,0

Heat treatments

Precipitation Hardening steel grades as KEYLOS[®] 2001 are based on technological and theoretical principles that differ from 'traditional' ones.

They are supplied in solubilised condition with a hardness value similar to pre-hardened steels that can be further increased by Precipitation Hardening in a relatively low range of temperature.



The manufacturing cycle can be summarized as follows:

- purchase of the steel block in solubilised condition;
- pre-machining;
- Precipitation Hardening heat treatment;
- finish machining and eventual further nitriding, photo-engraving, mirror polishing;
- put into service.

The manufacturing cycle needs to be longer than that of a pre-hardened steel grade; mechanical characteristics can be calibrated in a wide range and remain homogeneous in all the thickness of the machined mould.

In particular cases, KEYLOS[®] 2001 can be also used in solubilised conditions or in pre-hardened conditions: in those cases, the manufacturing cycle is the same of Pre-Hardened steel grades.

Cooling	room temperature
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The purpose of solubilisation at 1.020°C is to bring the material back to its original condition and eliminate the effects of previous heat treatments; after solubilisation, stress relieving at min 400 °C is always needed.

Soft annealing

Suggested temperature	1020 °C
Soaking time	10 hours from when the core of the piece has reached the set temperature

The mechanical characteristics are obtained through a Precipitation Hardening heat treatment carried out at a temperature of 480 – 620 °C.

The hardening process occurs without exceeding the phase transformation points of the steel.

This means that there are few worries about unexpected cracks and damages induced by heat treatments of the mould; hence, dimensional and shape variations are certainly less than on 'traditional' steels but, in any cases, they are present and have to be taken in proper consideration on the manufacturing designing cycle of the mould.

Stress Relieving

Suggested temperature	400 °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

Stress relieving should be carried out to eliminate stresses caused by machining or by previous heat treatment. Solution treating is not needed before stress relieving.

Age hardening

Age hardening will be carried out on a solubilised piece, which hardness is around 355 HB.

Lucchini RS recommends carrying out this heat treatment on a pre-machined mould, in order to guarantee high hardness and homogeneous characteristics on the pattern.

As the heat treatment occurs at temperatures that are lower than the phase transformation points, the risk of cracking is very low; also volume variations are low, but they have to be carefully considered.

Soaking time shall be calculated after the achievement of the aimed temperature in the core of the section, according to the table below.

The attached data are for illustration purposes only; they can be modified with different heat treatment facilities, time-temperatures parameters and thickness of the die.

Thickness of the die [mm]	100	150	200	250
Suggested time for Precipitation Hardening heat treatment	4h	6h	8h	10h

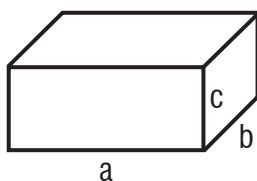
Once the heat treatment is completed, let the piece cool at room temperature.

In summary, KeyLos® 2001 can reach large margin of modulation of the Hardness (between 350 and 450 HB) and of the correspondents mechanical properties, obtained by means of aging in the interval of temperature 540°C - 610°C.

Main applications

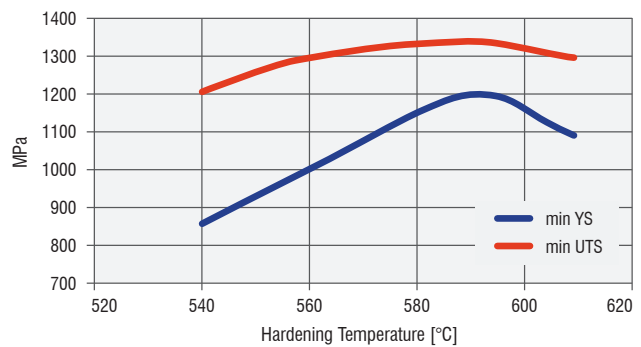
Dimensional variations [% in length] related to age hardening temperature on a block 100 x 100 x 50 mm of KEYLOS® 2001 is visible in the figure below.

This information is only indicative and must be adapted depending on the different dimensions and shape of the piece and on the heat treatment.

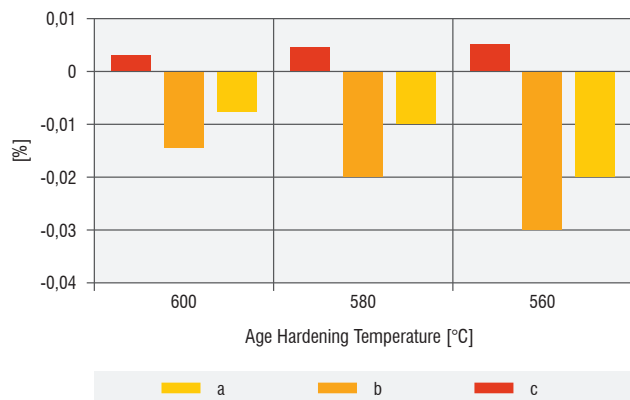


High uniformity of mechanical properties in the section can be obtained also for pieces of high sections.

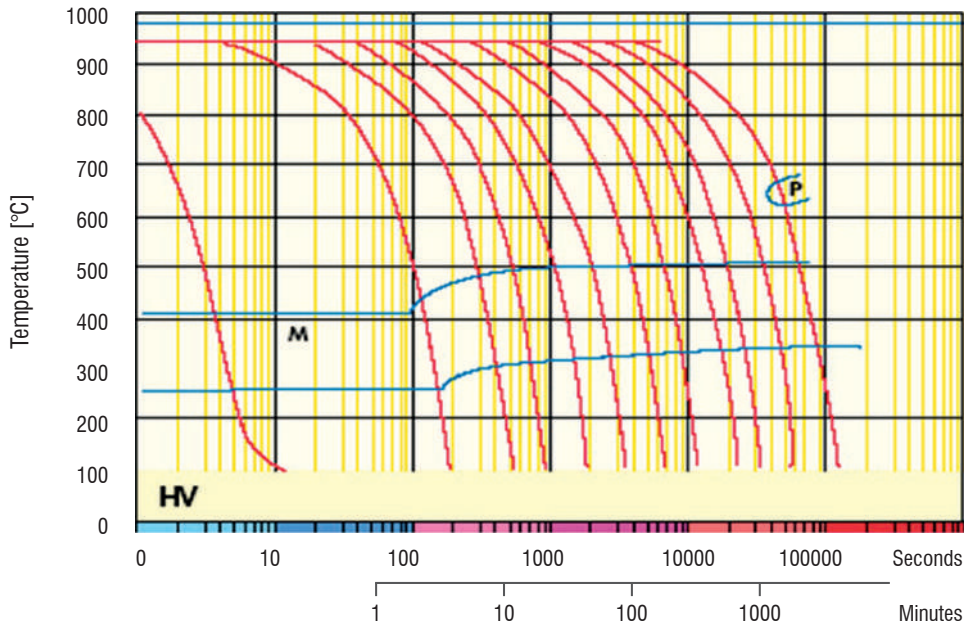
Precipitation Hardening Temperature	Min YS	Min UTS	Min Hardness
[°C]	[MPa]	[MPa]	[HB]
540	860	1.200	390
560	1.000	1.300	405
590	1.200	1.350	440
610	1.100	1.300	405



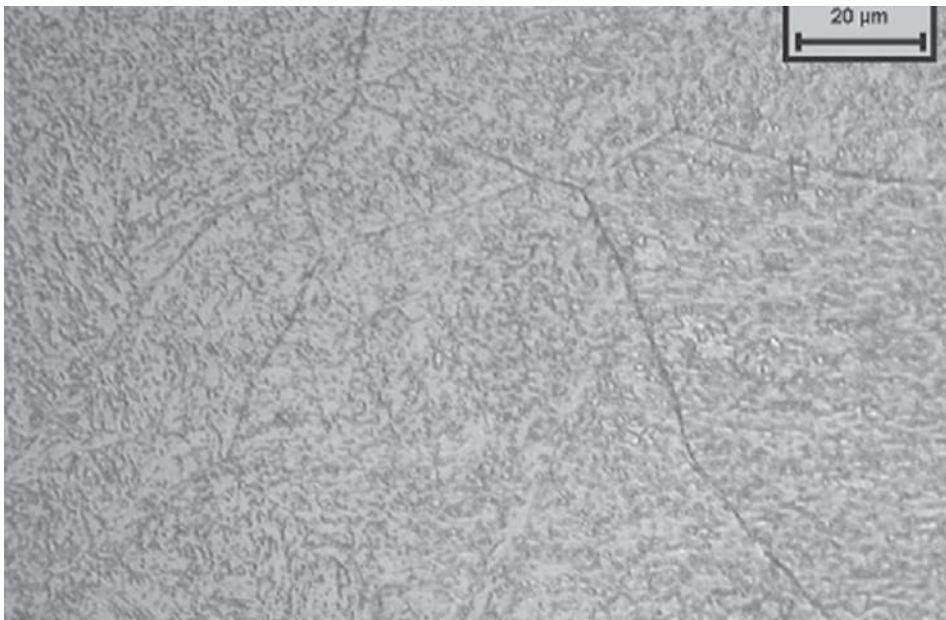
In any case, other properties can be analyzed and studied deeper by Lucchini RS on specific Customer request: please consult Lucchini RS specialists of MET Department.



CCT Curve



Microstructure of KEYLOS[®] 2001



The microstructure of KEYLOS[®] 2001 after age hardening, detected about 20 mm under surface, consists of a fine tempered martensite and bainite.

Why choose an age hardening steel?

Pre-hardened steels are suitable for several applications in the field of moulding, as they represent a balance of:

- good machinability;
- good mechanical characteristics;
- simple manufacturing cycle.

However, when it is necessary to obtain an elevated hardness in the piece together with homogeneity of values along the whole section, pre-treated steels display certain limits.

Moulds of pre-hardened steels are obtained by 'excavating' big sized blocks that inevitably possess mechanical characteristics that reduce towards the centre and are not homogeneous.

In order to limit this problem, the following options are available:

- start the production from a harder block; however the machining will be more difficult and the toughness will decrease
- hard the mould in the semi-finished state; however this increases the risk of cracking and deformation
- apply special surface heat treatments; however the finish machining could be limited by these treatments that are often expensive.

The solution is offered by KEYLOS® 2001, a Precipitation Hardening stainless steel grade.

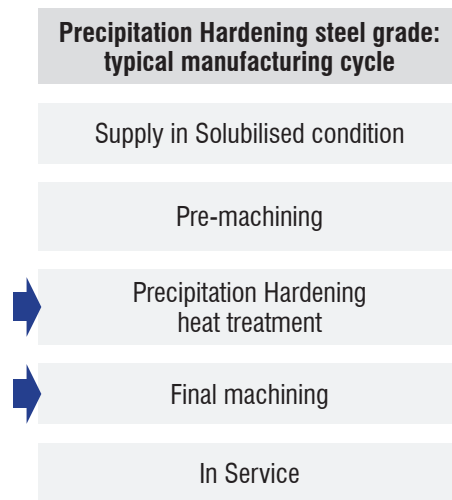
KEYLOS® 2001 gives all the advantages of pre-hardened steels, without the restrictions that they present when high mechanical properties are required.

The increase in the mechanical properties is obtained through age hardening, at a temperature between 480 and 620°C, depending on the mechanical characteristics required, without exceeding the transformation points.

Thanks to this technology, Users are able to obtain the required hardness in all whole surface of the mould.

In addition, KEYLOS® 2001 gives the following advantages:

- no cracking during Precipitation Hardening heat treatment regardless of the shape or thickness of the mould;
- limited deformation of the mould;
- limited machining allowance, leading to an optimisation of finish machining time after age hardening;
- constant fatigue limit throughout the whole mould and consequent increase of the total mould life cycle.



Should it be necessary to modify the shape of the mould or to further increase the mechanical properties of the mould, the original hardness and microstructure of KEYLOS® 2001 can be restored through solubilisation.

In any case, for specific Customer request, please consult Lucchini RS specialists of MET Department.

Guidance for machining

The following parameters are indicative only and must be adapted to the particular application and to the machinery employed.

Turning

Type of insert	Rough machining		Finish machining	
	P20-P40 coated	HSS	P10-P20 rivestite	Cermet
V _c cutting speed [m/min]	120 ÷ 160	(*)	160 ÷ 220	220 ÷ 270
a _r cutting depth [mm]	5	(*)	< 1	< 0,5

Milling

Type of insert	Rough machining		
	P25-P35 not coated	P25-P35 coated	HSS
V _c cutting speed [m/min]	80 ÷ 100	120 ÷ 150	(*)
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]	100 ÷ 125	145 ÷ 175	(*)
f _z feed [mm]	0,2 ÷ 0,3	0,2 ÷ 0,3	(*)
a _r cutting depth [mm]	< 2	< 2	(*)

Type of insert	Finishing		
	P10-P20 not coated	P10-P20 coated	Cermet P15
V _c cutting speed [m/min]	170 ÷ 210	220 ÷ 240	270 ÷ 310
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]	90 ÷ 120	(*)	50 ÷ 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® 2001 can give good results if the following procedure is observed:

Condition of material	Solution treating	Age hardening
Welding technique	TIG	
Pre-heating at	200 ÷ 250 °C	
Heat treatment	Age hardening aimed to obtain the required hardness	(*)

(*)The necessity for heat treatment is to be evaluated based on the zone welded.

In the case of a very extensive repair it will be necessary to solution heat treat the piece again and age harden it a second time.

Electrical Discharge Machining (EDM)

KEYLOS® 2001 can be machined by EDM to obtain complex shape.

Afterwards it is advisable to stress relieve the material at 400°C.

Photo-engraving

Thanks to modern production processes and to the low Sulphur content, KEYLOS® 2001 is suitable for photo-engraving to obtain various patterns.

Polishing

Due to the ESR (Electro-Slag-Remelting) manufacturing process, KEYLOS® 2001 has excellent suitability to mirror polishing.

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.