FORGING & CASTING DIVISION

LUCCHINI RS GROUP

ESKY® LOS 2367

Special Hot Work Tool steel
very highly resistant
to thermal fatigue
and high temperature
wear in ESR quality

LOOK BEYOND

General characteristics

EskyLos® 2367 is a special high alloyed Chromium-Molybdenum-Vanadium Hot Work Tool steel designed for the manufacture of dies, moulds, punches and other tools subjected to high working temperatures that need very highly resistant to thermal fatigue and high temperature wear.

The best features of this special Hot Work Tool steel grade are:

- high resistance to thermal shock and to heat cracking;
- excellent mechanical characteristics in hot condition;
- excellent toughness in hot condition;
- resistance to temper;
- excellent machinability.

EskyLos® 2367 is obtained through a special 'super clean' manufacturing process and the ESR Electro-Slag-Remelting technology.

This technology offers the following advantages:

- increase of material toughness;
- high micro-cleanness level;
- total isotropy of the material;
- very low segregation level.

EskyLos® 2367 is normally supplied in sections up to 500 mm in thickness, in the annealed condition with hardness values lower than 220 HB, thereby guaranteeing a good machinability.

If subjected to suitable hardening, followed by at least two suitable tempers, EskyLos® 2367 can reach a hardness of 52 HRc without strongly affecting the toughness.

In order to improve further the mechanical characteristics of the surface, EskyLos® 2367 can be coated with PVD or PA/CVD methods. Alternatively it can be subjected to nitriding; this allows a hardness value of of the nitrided layer up to about 900-1000 HV.

The high micro-purity and structural homogeneity levels give this grade good suitability to polishing and photo-engraving.

If required, it is possible to carry out welding operations with TIG or MMA methods on dies made of EskyLos® 2367.

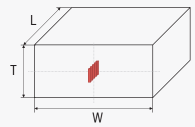
Constant development in hot processing technologies suggests the use of EskyLos® 2367, thanks to its high resistance to thermal fatigue and high temperature wear.

Thanks to its quasi-isotropic properties of ESR quality, EskyLos® 2367 represents also 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, and improved toughness in the mean time.

The increasing in the use of synthetic and abrasive materials has led manufacturers to use EskyLos® 2367 also when suitability for polishing and graining, combined with abrasion and compression resistance, are required.

EskyLos® 2367 is 100% ultrasonically inspected, according to the most demanding of NDT standards.

EskyLos® 2367 is demonstrating impressive resistance to thermal fatigue in many applications and a significantly longer mould life than conventional Hot Work Tool steel grades.

A	Grade	ESKYLOS® 2367
B	Annealed Brinell Hardness	≤ 220 HB
C	Chemical Analysis (as Product Analysis)	LRS Standard **1/2W + 1/2T**
D	Micro Cleanliness	ASTM E45 Method A (0,5 field) NADCA #207 **1/2W + 1/2T**
E	UT Quality	UNI EN 10228-3 Class 4
F	Grain Size	ASTM E112 ≥ 5 **1/2W + 1/2T**
G	Annealed Micro structure	NADCA #207 I.T. MET U003 **1/2W + 1/2T**
H	Banding Segregation	NADCA #207 **1/2W + 1/2T**
I	Impact Capability Testing	NADCA #207 Kv ≥ 14 (11) J **1/2W + 1/2T**
Sketch of sampling location		

Chemical analysis

	Range	C [%]	Si [%]	Mn [%]	Cr [%]	Mo [%]	V [%]	S [%]	P [%]
ESKYLOS® 2367 Alloying [% in weight]	min	0,32	0,10	0,30	4,80	2,80	0,40	/	/
	max	0,40	0,30	0,50	5,50	3,20	0,70	0,003	0,015

Table for comparison of international classification

W. Nr.	**1.2367**
DIN	**X38CrMoV5-3**

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.

Main applications

EskyLos® 2367 is suitable for the following applications:
- dies for aluminium die-casting;
- dies subjected to low pressure;
- chill moulds for gravity casting;
- containers for die-casting presses;
- dies for aluminium extrusion;
- extrusion press blocks;
- sleeves for extrusion presses;
- injection moulds.

Physical and mechanical properties

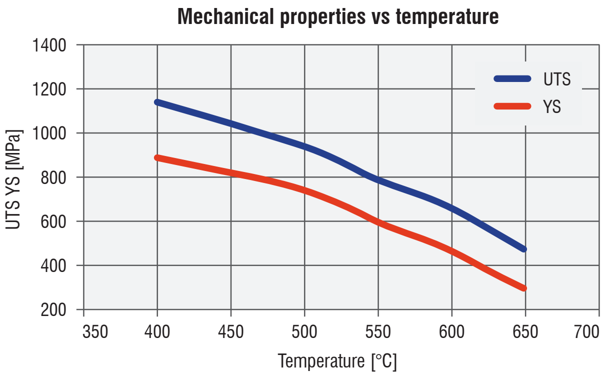
Main physical properties

ESKYLOS® 2367	20°C	400°C	at 6C
Modulus of elasticity [GPa] (1GPa=1000 MPa)	210	175	166
Coefficient of thermal expansion from 20 °C at [10^{-6}/K]	-	12,1	12,9
Thermal conductivity [W/mK]	25,8	27,2	31,4

Main mechanical properties

ESKYLOS® 2367	400°C	500°C	600°C
Ultimate Tensile strength (UTS) [MPa]	1.240	1.060	760
Yield stress (YS) [MPa]	1.020	850	520

These values are average values obtained on a sample which has been hardened at 1030 °C, quenched and tempered at 680 °C to achieve a hardness of 44 HRc.



Heat treatments

EskyLos® 2367 is supplied in the annealed condition. If a different hardness is required or if heat treatment is needed, we suggest applying the following parameters.

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	850 °C
Heating	Max 50 °C/h
Soaking time	Minimum 120 min from when the temperature settles
Cooling	Slow in the furnace at max 25 °C/h to **600 °C**, then at room temperature

Soft annealing is recommended if optimum machinability of the material is important. After soft annealing a hardness of around 220 HB is achieved.

Stress Relieving

Suggested temperature	650 °C
Heating	Max 100 °C/h
Soaking time	Minimum 120 min from when the temperature settles
Cooling	Slow in the furnace at max 25 °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.

We strongly recommend to perform the stress relieving:
- After rough machining in order to minimize distortions and avoid quenching cracks by hardening treatment;
- After the finish machining, before the very first sampling, to avoid possible damages to cavity surface and sub-surface caused by not optimized hard milling.

Hardening

Hardening should be carried out after the material has been pre-heated according to the following table.

First pre-heating temperature	400 °C
Heating	Max 150 °C/h
Soaking time	25 min for every 25 mm thickness or when (Ts-Tc) < 90 °C

Second pre-heating temperature	600 °C
Heating	Max 150 °C/h
Soaking time	20 min every 25 mm thickness or when (Ts-Tc) < 90 °C

Third pre-heating temperature	800 °C
Heating	Max 150 °C/h
Soaking time	20 min every 25 mm thickness or when (Ts-Tc) < 90 °C

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

The aim of the first pre-heat at 400 °C is to eliminate stresses caused by machining. The following pre-heating cycles at 600 °C and 800 °C are necessary to homogenise the temperature of the piece. We recommend a rate of heating of 150 °C/h. The time of the different stages of pre-heating is calculated on the basis of the thickness of the piece and the temperature, as shown on the table.

Alternatively, the time can be adjusted on the basis of the difference between the internal temperature (Tc) and the Surface temperature (Ts) of the piece, measured by means of two thermocouples.

After the third pre-heat at 800 °C, the austenitising temperature should be reached as quickly as possible and maintained for 30 min from when (Ts-Tc) < 15 °C or on the basis of the following formula:

$$t = (x + 39) / 2$$
t = soaking time [min]
x = thickness [mm]

Austenitizing temperature	2020 - 1030°C
Heating	>150°C/h
Soaking time	t = (x+39) / 2 or from $(T_s-T_c) < 15$°C
Cooling	Air, vacuum cooling, salt bath, polymer in H2O

Tempering

It is recommended to set the temperature of the first temper at 580 °C, close to the secondary hardness. The temperature of the second temper must be set on the basis of the required mechanical properties, and must be higher than the temperature applied for the first temper.

The soaking time for the first and the second temper are calculated by applying the following empirical formula:

$$t' = t'' = 0,8\,x + 120$$
t' = t" = soaking time [min]
x = thickness [mm]

A third temper at a temperature of 30-50 °C below the maximum temperature previously applied will function as a stress relieving cycle.

Tempers at a temperature between 400 and 550 °C are not advisable, as they reduce the material toughness. Tempers at a temperature lower than 200 °C should not be carried out.

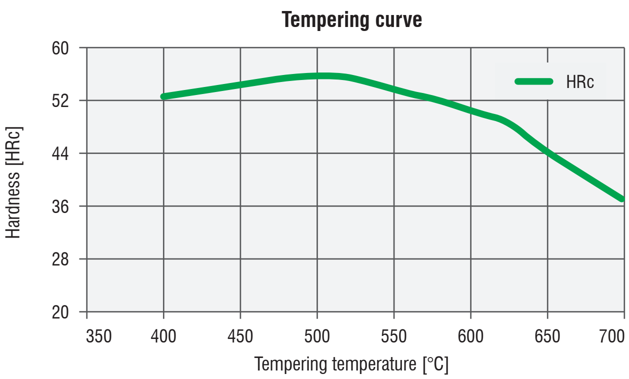
The soaking time for the third temper are calculated by applying the following empirical formula:

$$t''' = 0,8\,x + 180$$
t''' = soaking time [min]
x = thickness [mm]

First tempering temperature	550 - 580 °C
Soaking time	t' = 0,8 x + 120
Cooling	Room temperature

Second tempering temperature	Set on the basis of the required mechanical properties, in any case higher than the temperature applied for the first temper.
Soaking time	t'' = 0,8 x + 120
Cooling	Room temperature

Third tempering temperature	30-50 °C lower than the max temperature previously applied
Soaking time	t''' = 0,8 x + 180
Cooling	Slow cooling in the furnace up to 250 °C, then at room temperature



Tempering curve of a sample which has been austenitised at 1030 °C. The diagram shows values obtained after the second temper.

Variation in dimensions during heat treatment

During the heat treatment of EskyLos® 2367 the phase transformation points are exceeded. Inevitably this causes a variation in the volume of the material. For this reason we recommend leaving enough machining allowance to compensate for the change of dimension due to heat treatment. All the corners should be rounded off.

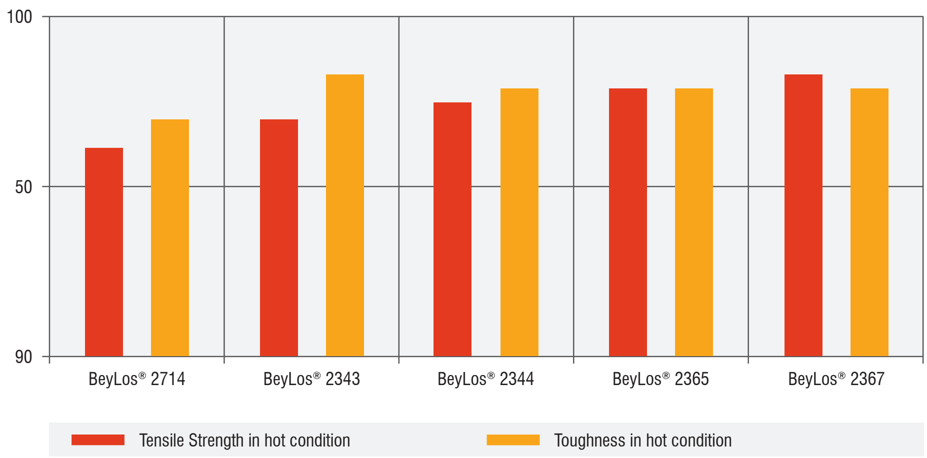
Nitriding

The purpose of nitriding is to increase the resistance of the material to wear and abrasion. This treatment is very useful for components where high performance is necessary, as it extends the life of the material. We suggest nitriding the component in the hardened and tempered condition. The tempering temperature must be at least 50 °C higher than the nitriding temperature.

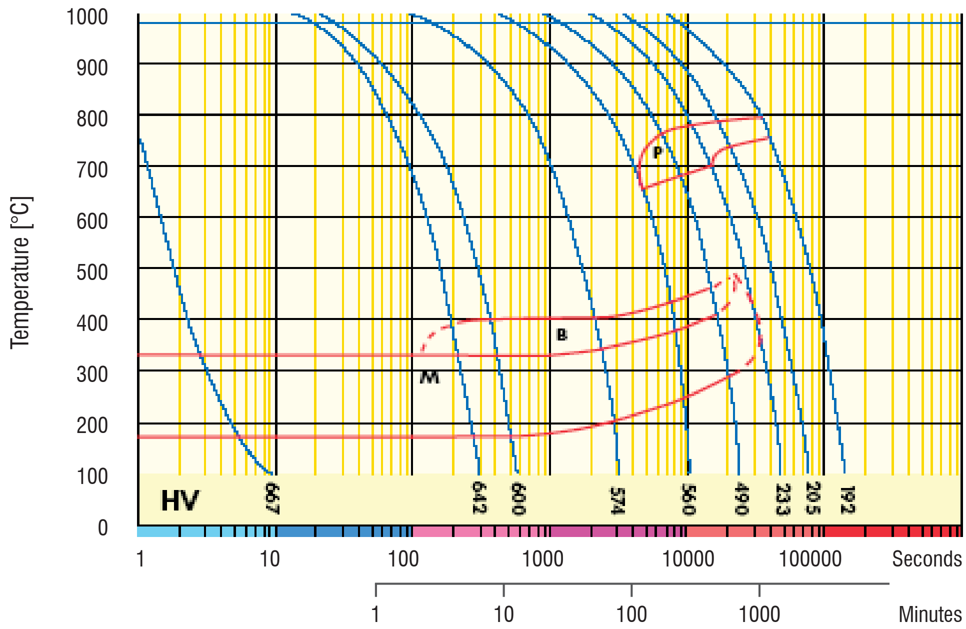
Modern nitriding processes allow the original dimensions of the component to be maintained. We recommend heat treating the component in the finish machined condition.

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

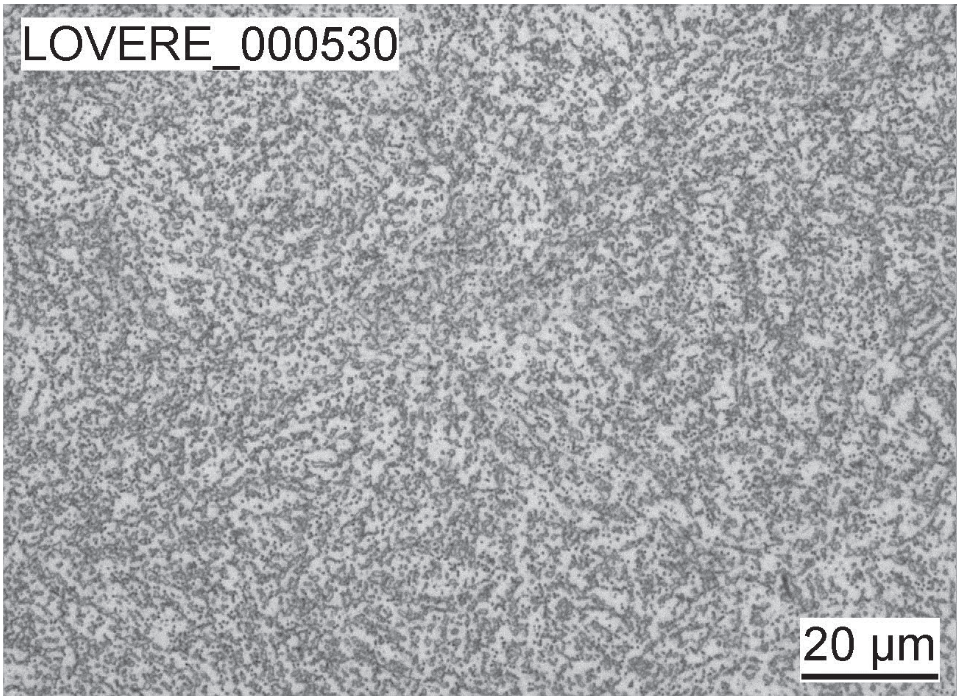
Comparison of properties of different hot work tool steels



CCT Curve



Annealed microstructure of EskyLos® 2367



The annealed microstructure of the as received steel consists essentially of a ferritic matrix with a homogeneous distribution of spheroidized carbides, when examined at 500X, after being polished and etched with 4% Nital.

Quick comparison guide among the different Hot Work Tool Steel Grades

The following table shows a quick comparison among the most important characteristics of the Hot Work tool Steel grades produced by Lucchini RS.

Lucchini RS Hot Work tool Steel Family															
Special features and delivered conditions	Annealed Not Corrosion Resistant														
	KEYLOS	BEYLOS								ESKYLOS					
	6959	2329	2711	2714	2340	2343	2344	2365M	2367	6959	2340	2343	2344	2365M	2367
HB in surface In Annealed condition	<220	<220	<220	<220	<220	<220	<220	<220	<220	<220	<220	<220	<220	<220	<220
HB in surface Hardened after machining	370 - 410	370 - 410	370 - 410	370 - 410	400 - 450	400 - 450	400 - 450	400 - 450	400 - 450	370 - 410	400 - 450	400 - 450	400 - 450	400 - 450	400 - 450
Maximum thickness [mm]	500	600	500	700	500	500	500	500	500	500	500	500	500	500	500
Hardness and Wear Resistance	3	3	3	3	4	4	4	4	4	3	4	4	4	4	4
Degree of Through Hardening in the section	4	2	3	3	3	3	3	3	3	4	3	3	3	3	3
Toughness	4	1	4	4	3	3	2	2	2	4	3	3	2	2	2
Machinability after Annealing	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Machinability after Hardening	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Etch-Grainability	2	2	2	2	2	2	2	2	2	4	4	4	4	4	4
Polishability	2	2	2	2	2	2	2	2	2	4	4	3	3	4	3
Repair by Welding	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Thermal Conductivity	2	2	2	2	1	1	1	1	1	2	1	1	1	1	1
Corrosion Resistance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4 Excellent **3 Very Good** **2 Good** **1 Normal** **0 Unsuitable**

The advantages of the ESR technology

The ESR (Electro-Slag-Melting) manufacturing technology offers the following advantages:

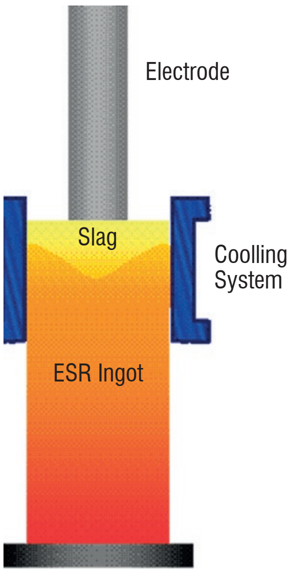
- increase of material toughness;
- high micro-cleanness level;
- total isotropy of the material;
- very low segregation level.

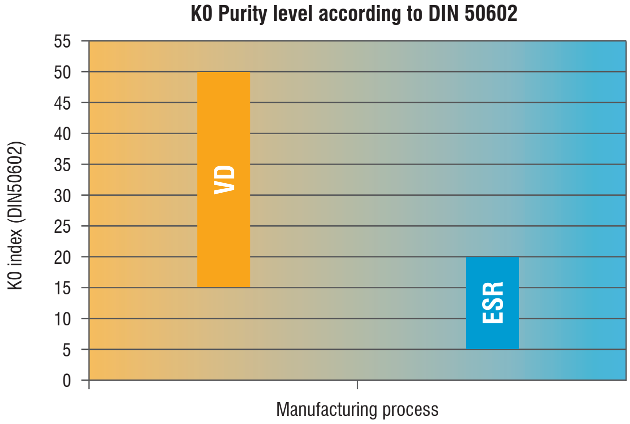
The ESR process is based on ingot remelting, through a traditional VD (vacuum degassing) process, using a particular copper ingot mould that contains basic slag.

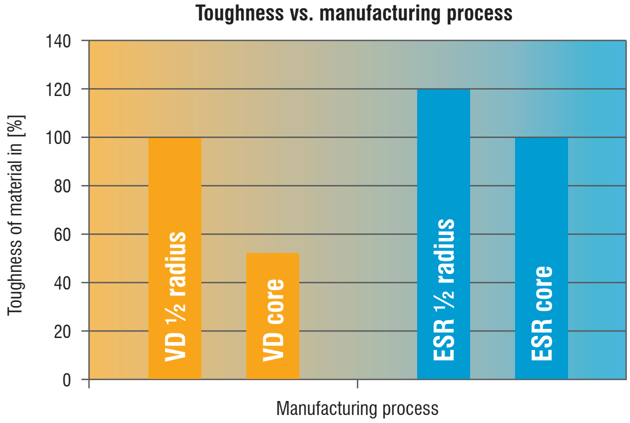
The ingot is remelted in a way that the liquid metal passes through the slag, which acts as a filter and retains the inclusions.

The process of solidification inside the ingot mould is faster than in a traditional process.

The result is homogeneous and isotropic steel.







Thanks to the ESR process, EskyLos® 2367 satisfies the most difficult requirements in terms of toughness and suitability to polishing. It is suitable for the manufacture of moulds subjected to mirror polishing and to high mechanical stress.

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 220 HB max.

Turning

	Rough machining	Finish machining		
Type of insert	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

	Rough machining		
Type of insert	P25-P35 not coated	P25-P35 coated	HSS
V_c cutting speed [m/min]	160 ÷ 240	180 ÷ 280	(*)
f_z feed [mm]	0,15 ÷ 0,3	0,15 ÷ 0,3	(*)
a_r cutting depth [mm]	2 ÷ 4	2 ÷ 4	(*)

	Pre-finishing		
Type of insert	P10-P20 not coated	P10-P20 coated	HSS
V_c cutting speed [m/min]	180 ÷ 260	200 ÷ 280	(*)
f_z feed [mm]	0,2 ÷ 0,3	0,2 ÷ 0,3	(*)
a_r cutting depth [mm]	1 ÷ 2	1 ÷ 2	(*)

	Finishing		
Type of insert	P10-P20 not coated	P10-P20 coated	Cermet P15
V_c cutting speed [m/min]	200 ÷ 280	220 ÷ 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 EskyLos® 2367 can give good results if the recommended procedure is followed. Being steel with high Carbon Equivalent content, EskyLos® 2367 is very sensitive to cracking. We recommend carrying out pre-heating and heat treatment after welding.

Condition of material	Annealed with hardness 220 HB max	
Welding technique	TIG	MMA
Pre-heating at	330÷380 °C	
Recommended heat treatment	Heating of the material at 850 °C, cooling in the furnace to 600 °C at a rate of 20 °C/h, cooling at room temperature	
Condition of material	Hardened and tempered	
Welding technique	TIG	MMA
Pre-heating at	330÷380 °C	
Recommended heat treatment	650 °C or 50 °C lower than the tempering temperature previously applied	

Electrical Discharge Machining (EDM)

EskyLos® 2367 can be machined by EDM to obtain complex shape.

Afterwards it is advisable to stress relieving the material.

Chrome Plating

EskyLos® 2367 can be Chrome plated in order to enhance the mechanical characteristics on the surface.

Within 4 hours of Chrome plating, in order to prevent Hydrogen embitterment it is advisable to carry out heat treatment at 200 °C for about 4 hours.

Polishing

EskyLos® 2367 is particularly suitable for mirror polishing, due to the ESR (Electro Slag Remelting) process.

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 destinity 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.

FORGING & CASTING DIVISION

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