FORGING & CASTING DIVISION

LUCCHINI RS GROUP

ESKY® LOS 2340

The new approach
in the world of Hot Work Tools
and highly resistant plastic
moulds in ESR quality

LOOK BEYOND

General characteristics

EskyLos® 2340 is a high alloyed Chromium-Molybdenum-Vanadium Hot Work Tool steel characterised by a low Silicon content and by special micro-alloying elements.

This steel grade has been expressly designed for tools that have to work in a wide temperature range, without compromising toughness.

Because it is produced by ESR process, EskyLos® 2340 is particularly suited for production of complex tools subjected to high mechanical stress.

The advantages offered by the technology of Electro Slag Remelt ESR are:

- increasing in toughness;
- elevated grade of micro purity;
- high isotropy of the material;
- extremely low segregation level.

EskyLos® 2340 is the result of years of research and experimentation of Lucchini RS in the field of Hot Work Tool steels.

This new steel is able to support the most severe thermal stresses, without significant reduction in mechanical properties, due to high temperature.

The strong points of this steel are:

- high resistance to thermal shock and to heat cracking;
- good mechanical characteristics in hot and cold condition;
- excellent mechanical properties in the ductile-brittle transitional phases;
- excellent toughness in hot and cold conditions;
- high resistance to tempering;
- excellent machinability in annealed conditions.

EskyLos® 2340 is the ideal choice in hot applications where it is necessary to maintain unaltered the mechanical properties of the material in all the phases of the process, including the most critical moments on start-up.

EskyLos® 2340 is normally supplied in sections up to 500 mm in thickness, in annealed condition with hardness below 220 HB, to guarantee optimum machinability.

With suitable hardening followed by at least two appropriate tempers, EskyLos® 2340 can even reach a hardness up to 50 HRC without penalising toughness.

Constant development in hot processing technologies require the use of EskyLos® 2340, thanks to its high resistance to thermal fatigue and to temperature wear.

Thanks to the quasi-isotropic properties of ESR quality, EskyLos® 2340 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® 2340 also when suitability for polishing and graining, combined with abrasion and compression resistance, are required.

EskyLos® 2340 is 100% ultrasonically inspected, according to the most demanding of NDT standards and it represents a innovative way to obtain high quality tools, collecting a very long mould life and optimizing the environmental sustainability of the product, with a suited steel grade design, that guarantees the minimum use of virgin materials.

It is difficult to predict the improvement that a innovative material will provide over the traditional one: it's only the feedback from service and the cooperation with customers that can validate the longer mould life of the proposed materials.

EskyLos® 2340 is demonstrating impressive resistance to fatigue in many applications and a significantly longer mould life than conventional Hot Work Tool steel grades.

Continuous improvement of materials technology is managed in safety and in accordance with eco-consistency and sustainability criteria, because Lucchini RS believes that Safety and Environment are the main priorities in all the phases of the manufacturing process.

EskyLos® 2340 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 became food for the steel making production of EskyLos® 2340.

Chemical analysis

	Range	C [%]	Si [%]	Mn [%]	Cr [%]	Mo [%]	V [%]	S [%]	P [%]
ESKYLOS® 2340 Alloying [% in weight]	min	0,32	0,10	0,30	4,80	1,20	0,30	-	-
	max	0,40	0,30	0,50	5,50	1,50	0,50	0,003	0,015

Heat analysis obtained during the pouring of the steel: in accordance with NADCA #207, as show in the table.

Product analysis: in order to consider the possible deviations due to the analytical reproducibility and the heterogeneity of the steel, the range of the chemical composition applicable to product analysis is usually wider than the one applicable to the heat analysis for C and Cr values. This point is regulated by the Table 6 of DIN 17 350.

Main applications

EskyLos® 2340 lends itself to the following applications:

- dies for aluminium stamping;
- low pressure dies;
- moulds for gravity casting;
- containers for presses;
- matrices for aluminium extrusion;
- heels for extrusion presses;
- jackets for extrusion presses;
- injection moulds;
- special plastic moulds for the automotive industry and optical parts (head lamp components);
- dies and gauges for PVC extrusion.

Physical and mechanical properties

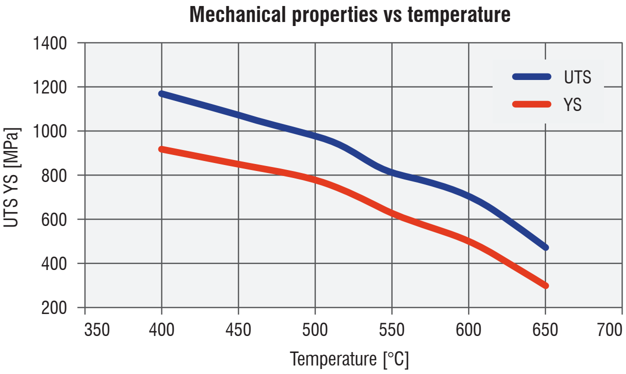
Main physical properties

ESKYLOS® 2340	20°C	400°C	600°C
Modulus of elasticity [GPa] (1GPa=1000 MPa)	210	186	167
Coefficient of thermal expansion from 20 °C at [10^{-6}/K]	-	12,0	12,8
Thermal conductivity [W/mK]	24,7	27,8	29,5

Main mechanical properties

ESKYLOS® 2340	400°C	500°C	600°C
Ultimate Tensile strength (UTS) [MPa]	1.170	970	660
Yield stress (YS) [MPa]	920	760	485

The data are average values taken from a test piece hardened at 980° C, quenched and with a final temper to give a hardness of 44HRc.



Heat treatments

EskyLos® 2340 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. For any question and particular requirement don't hesitate to contact our technical staff of Metallurgy & Laboratories Department.

Soft annealing

Suggested temperature	850 °C
Temperature increase	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 where it is necessary to improve the machinability of the tool. After annealing a hardness of max 220 °C is achieved.

Stress Relieving

Suggested temperature	650 °C
Temperature increase	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.

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

Hardening

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

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

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

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

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

The first preheat at 400 °C is advisable to eliminate the accumulated stresses caused resultant from mechanical working. The successive preheats at 600°C and 800°C are necessary to homogenise the temperature of the piece. Rate of increase is 150°C per hour.

The soaking time is calculated from the thickness of the piece and will vary with the temperature, as indicated in 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	980-1010 °C
Temperature increase	> 150°C/h
Soaking time	t = (x + 39) / 2 or 30 min from when (Ts-Tc) < 15 °C
Cooling	Air, vacuum cooling, salt bath, polymer in H2O

A controlled quench rate provide optimim metallurgical properties, while minimizing distorsion and risk of cracking. Methods can be different, such as molten salt austenitizing, quenching, vacuum austenitizing and pressurized gas quenching.

Faster quench rates result in increased toughness. The cooling rate is a function of the size of the tool and the quenching power of the equipment used.

Directly after quenching, EskyLos® 2340 is hard, brittle and higly stressed; it is vulnerable to cracking spontaneously and must be tempered while still warm. Further tempering will reduce the stress level and hardness, but increase toughness and resistance to cracking in service.

The final hardness level chosen depends on the application and is normally in the range of 42-48 HRc. This is achieved by careful control of temperature and time of tempering.
A minimum of two tempers is required to give dimensional stability and the correct metallurgical structure.

Hardness is not the only indicator of how a tool will perform, because tool life is more dependent on the metallurgical structure of the steel, before and after heat treatment.

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.

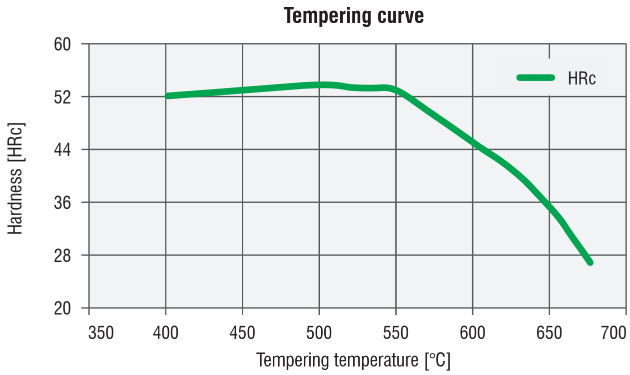
The soaking time for the third temper are calculated by applying the following empirical formula:

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 980 °C. The diagram shows values obtained after the second temper.

Variation in dimensions during heat treatment

During the heat treatment of EskyLos® 2340 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.

Remarks

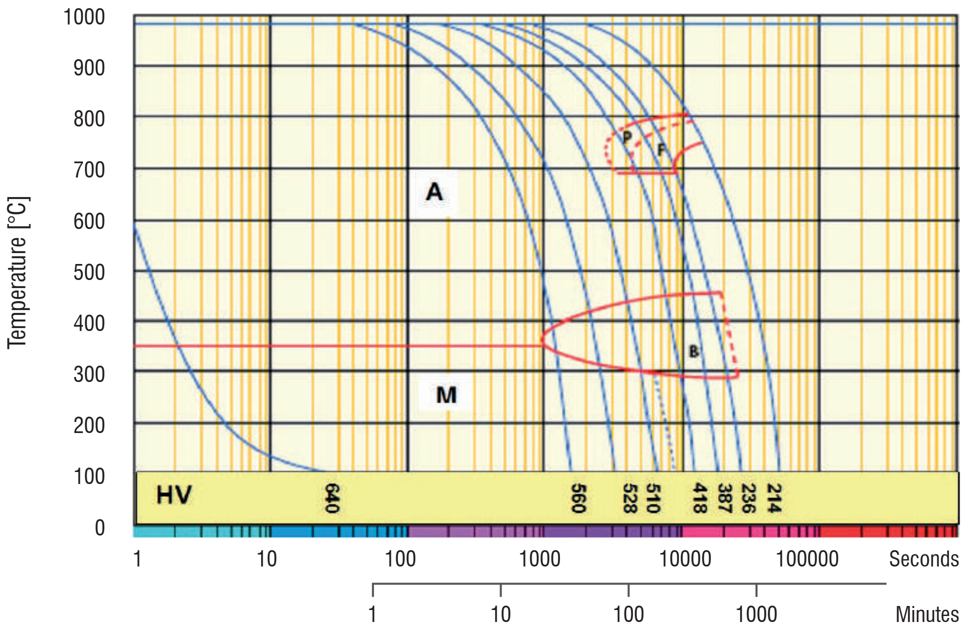
In accordance with its internal technical instruction I.T. MET U002 Lucchini RS has selected highly specialized heat treatment companies, which perform the vacuum hardening complying with Lucchini RS heat treatment procedure I.T.MET – U001.

We strongly recommend to send your dies to one of the heat treatment companies officially approved by Lucchini RS.

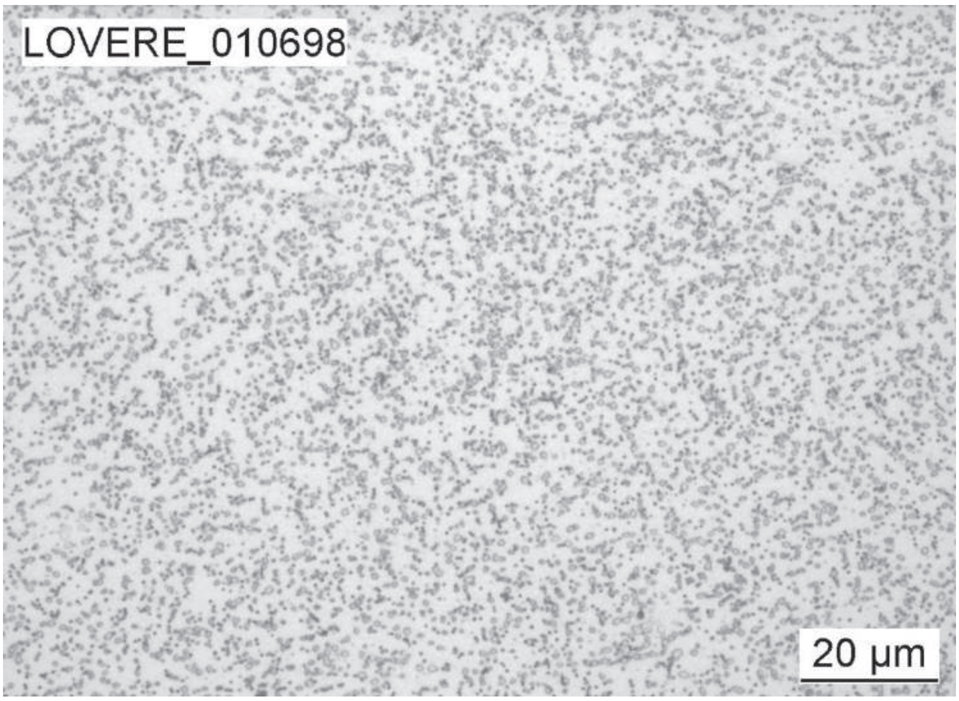
For more information don't hesitate to ask to our local Distributor – Service Center or to our Sales Department. In case of different needs of heat treatment (like salt bath) please contact our technical staff of Metallurgy & Laboratories Department.

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

CCT Curve



Annealed microstructure of Eskylos® 2340



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, free of excessive banding.

Quick comparison guide among the different grades for Plastics Industry

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

Lucchini RS Mould steel Family for plastics Industry																			
Special features and delivered conditions	Pre-hardened Not Corrosion Resistant Mould Steel Grades																		
	KEYLOS													ESKYLOS				BEYLOS	
	1730	1730 M	7225	ON	2312	2311	UP	2738 MSH	2738	PLUS	2738 MHH	2002	6959	2002	6959	2340	2365 M	2711	2714
HB in surface in Annealed condition	/	/	/	/	/	/	/	/	/	/	/	/	< 220	/	< 220	< 220	< 220	< 250	< 250
HB in surface Pre-hardened	≤ 200	≤ 210	220 - 270	280 - 330	280 - 330	280 - 330	280 - 330	280 - 330	290 - 340	300 - 350	320 - 360	360 - 400	370 - 410	360 - 400	370 - 410	400 - 450	400 - 450	370 - 410	370 - 410
Maximum thickness [mm]	300	300	500	500	600	600	800	800	1.000	800	1.200	1.200	500	500	500	500	500	500	700
Hardness and Wear Resistance	1	1	1	2	2	2	2	3	2	3	3	3	3	3	3	4	4	3	3
Degree of Through Hardening in the section	1	1	1	1	2	2	3	3	3	3	4	4	4	4	4	3	3	3	3
Toughness	1	1	2	2	1	3	3	3	2	3	3	3	4	3	4	3	2	4	4
Machinability after Annealing	/	/	/	/	/	/	/	/	/	/	/	/	3	/	3	3	3	3	3
Machinability after Hardening	3	3	2	1	4	2	2	2	2	2	2	2	1	2	1	1	1	1	1
Etch-Grainability	1	1	1	2	0	3	3	3	3	3	3	3	2	4	4	4	4	2	2
Polishability	2	2	2	2	0	3	3	3	3	3	3	3	2	4	4	4	4	3	3
Repair by Welding	1	1	1	0	0	1	1	2	1	2	2	2	1	2	1	1	1	1	1
Thermal Conductivity	3	3	2	2	2	2	2	3	2	3	3	3	2	3	2	1	1	2	2
Corrosion Resistance	0	0	0	0	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**

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 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.

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.

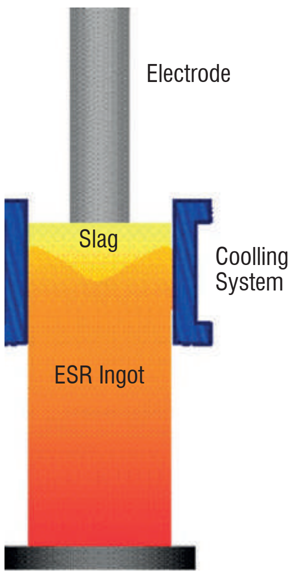
The ESR process is based on ingot remelting, through a traditional VD (vacuum degassing) process, using a particular copper ingot mould that contains basic slag.

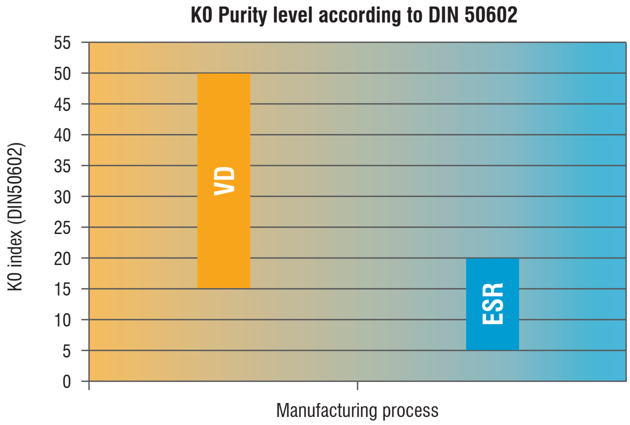
The ingot is remelted in a way that the liquid metal passes through the slag, which acts as a filter and retains the inclusions.

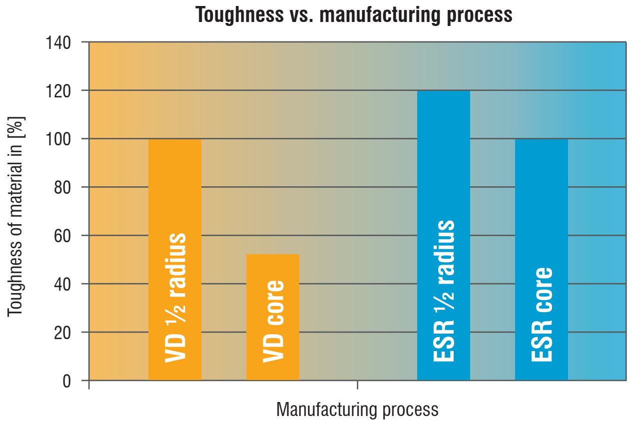
The process of solidification inside the ingot mould is faster than in a traditional process.

The result is homogeneous and isotropic steel.

ESKYLOS® 2340	Moulds painted or transparent plastic components for automotive sector. Moulds for cars' trims, cars' head–rear lights, lenses.
ESKYLOS® 2340DC	Special version dedicated to high pressure Al & Mg Die-Casting according to SEP1614.96 / VDG M82-1993 specifications.
ESKYLOS® 2340HDC	New version designed for the strictest application of high pressure Al & Mg Die-Casting according to NADCA specification #207.







Thanks to the ESR process, EskyLos® 2340 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

EskyLos® 2340 can be welded with excellent results if the following procedures are observed. Being a steel of high Carbon Equivalent, it is very susceptible to cracking.

The user is advised to follow carefully the recommendations for preheating 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® 2340 can be machined by EDM to obtain complex shape.

Afterwards it is advisable to stress relieving the material.

Chrome Plating

EskyLos® 2340 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.

Photo-engraving

Thanks to modern production processes and to the low Sulphur content, EskyLos® 2340 is suitable for photo-engraving to obtain various patterns.

Polishing

Due to the ESR Electro-Slag-Remelting manufacturing process, EskyLos® 2340 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 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.