FORGING & CASTING DIVISION

LUCCHINI RS GROUP

ESKY® LOS 2343HDC

New ESR version according to NADCA #207-2016 PUBLICATION #229 for Light Alloys die casting applications

LOOK BEYOND

General characteristics

EskyLos® 2343 HDC is the new version of the high alloyed Chromium-Molybdenum-Vanadium Hot Work Tool steels family, designed by Lucchini RS for the most demanding high pressure Light Alloys (Al-Mg) die casting dies according to the specification NADCA #207-2011 PUBLICATION #229.

The above mentioned specification, as one of the most important worldwide reference for die-casting application, with very effective acceptance criteria, focuses on two macro-phases of the mould's manufacturing process.

- The Manufacturing process of the steel block, that needs an annealed steel capability;
- The procedure for the heat treatment of the die, that needs an HT capability.

With particular reference to the first one, NADCA #207-2011 PUBLICATION #229 requires the "Annealed steel capability" assessment by samples' location in the core of the block, the most critical one, according to the key quality indicators described in Table 1.

Annealed steel capability indicators are tested and certified according to Lucchini RS' internal technical instruction I.T.MET U003.

Thanks to the optimized chemical analysis (P<0.0015%, S<0.003% and low secondary elements content), together with the Electro Slag Re-melting process, followed by special forging and specifically designed heat treatment procedures, Lucchini RS is able to achieve the above mentioned "Annealed steel capability", guaranteeing an high level of material's quality also for EXTRA LARGE sizes.

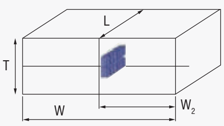
The main features of EskyLos® 2343 HDC are:

- excellent isotropy;
- high mechanical properties and strength
- high hardenability
- high thermal conductivity
- high tempering resistance;
- high thermal stability
- high thermal fatigue and hot cracking resistance;
- excellent fracture toughness in hot and cold conditions;
- high ductility
- high wear and erosion resistance
- high oxidation resistance
- high ductility

EskyLos® 2343 HDC is usually supplied as forged block, rough machined, annealed for 220 HB max with the following standard sizes' range: width 600-800-1050 mm x thickness 200-600 mm x length.

Upon customer's request, bigger dimensions can be manufactured by a special forging process for EXTRA LARGE blocks.

Table 1: Annealed steel capability

A	Grade	ESKYLOS® 2343HDC
B	Annealed Brinell Hardness	≤ 220 HB
C	Chemical Analysis (as Product Analysis)	According to Lucchini RS Standard. Sampling location: **1/2 W + 1/2 T**
D	Micro Cleanliness	According to ASTM E45 Method A (0,5 field) NADCA #207-2016 Sampling location: **1/2 W + 1/2 T**
E	UT Quality	UNI EN 10228-3 Class 4
F	Grain Size	No. 7 or finer according to ASTM E112 Sampling location: **1/2 W + 1/2 T**
G	Annealed Micro structure	NADCA #207-2016 Sampling location: **1/2 W + 1/2 T**
H	Banding Segregation	
I	Impact Capability Testing	NADCA #207-2016 Sampling location: **1/2 W + 1/2 T**
Sketch of sampling location		

NADCA requires the "Heat Treatment process capability" assessment of the die: this is a very effective requirement usually not included in other specifications.

Chemical analysis

	Range	C [%]	Si [%]	Mn [%]	Cr [%]	Mo [%]	V [%]	S [%]	P [%]
ESKYLOS® 2343HDC Alloying [% in weight]	min	0,35	0,80	0,30	5,00	1,20	0,30	-	-
	max	0,40	1,10	0,50	5,50	1,50	0,50	0,003	0,015

Table for comparison of international classification

W. Nr.	**1.2343**
ISO 4957-02	**X37CrMoV5-1**
AISI	**H11**
UNI	**X37CrMoV5.1KU**

Heat analysis obtained during the pouring of the steel: in accordance with NADCA #207-2011 PUBLICATION #229, 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.

Lucchini RS's tool steels are designed in order to optimize the material's performances.

The brand name identifies the Lucchini RS product, the number refers to the Werkstoff classification; "HDC" stands for "HIGH DIE CASTING".

Main applications

- High pressure Aluminium/Magnesium die casting moulds;
- Moulds for low pressure Aluminium die castings;
- Moulds for Aluminium gravity die castings;
- Plastic injection moulds with optical mirror polishing.

Physical and mechanical properties

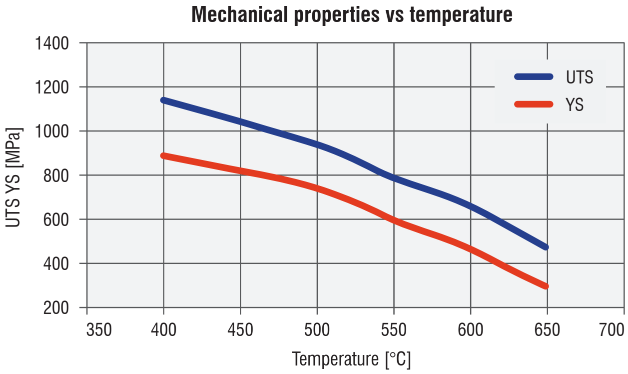
Main physical properties

ESKYLOS® 2343HDC	20°C	400°C	600°C
Modulus of elasticity [GPa] (1GPa=1000 MPa)	210	183	168
Coefficient of thermal expansion from 20 °C at [10^{-6}/K]	-	11,8	12,4
Thermal conductivity [W/mK]	24,4	27,1	28,5

Main mechanical properties

ESKYLOS® 2343HDC	400°C	500°C	600°C
Ultimate Tensile strength (UTS) [MPa]	1.150	950	670
Yield stress (YS) [MPa]	900	750	470

The above mentioned are average values of a sample hardened at 980 °C, quenched and tempered at 600 °C to achieve hardness 44 HRC.



Heat treatments

EskyLos® 2343 HDC is usually supplied in annealed condition with hardness 220 HB max. If different hardness is required and/or further heat treatment is needed, we suggest to apply the following parameters.

This information is just indicative and must be adjusted depending on the different heat treatment facilities and the thickness of the block: for any question and particular requirement don't hesitate to contact our technical staff of Metallurgy & Laboratories Department.

Soft annealing

Suggested temperature	850 °C
Heating	Max 50 °C/h
Soaking time	Minimum 120 min from the temperature's settlement
Cooling	Slow in the furnace at max 25 °C/h to **600 °C**, afterward at room temperature

Soft annealing is recommended if excellent machinability of the material is needed. After soft annealing an hardness of approx. 220 HB max is achieved.

Stress Relieving

Suggested temperature	For material in annealed condition: 650 °C For material in H+T condition or after machining: 50°C less than the last tempering
Heating	Max 100 °C/h
Soaking time	Minimum 120 min from the temperature's settlement
Cooling	Slow in the furnace at max 25 °C/h to **200°C**, afterward at room temperature

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

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

Hardening should be carried out after the material pre-heating according to the following table.

First pre-heating temperature	400 °C
Heating	Max 150 °C/h
Soaking time	25 min 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

The aim of the first pre-heat at 400 °C is to eliminate stresses caused by machining: if stress relieving is performed earlier, this step could be avoided. The following pre-heating cycles at 600 °C and 800 °C are necessary to homogenize the temperature of the piece. We recommend an heating rate of 150 °C/h max.

The time of the different stages of pre-heating is calculated on the basis of the thickness of the piece and the temperature, as described in the above attached 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 two thermocouples.

After the third pre-heating at 800 °C, the austenitizing 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	990-1010°C
Heating	> 150°C/h
Soaking time	t = (x + 39) / 2 or 30 min from (Ts-Tc) < 15 °C
Cooling	Air, vacuum cooling, salt bath, polymer in H2O

Tempering

It is recommended to set the temperature of the first tempering between 560 and 590 °C, close to the secondary hardness.

The temperature of the second tempering must be set according to the required mechanical properties and must be higher than the temperature of the first tempering.

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

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

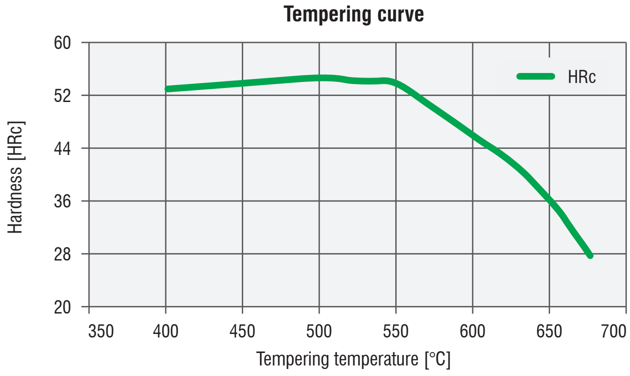
A third tempering at 30-50 °C less than the maximum temperature previously used will work as a stress relieving process.

Tempering at a temperature between 400 and 550 °C is not advisable, as it may reduce the material toughness. Tempering at a temperature lower than 200 °C should not be carried out.

First tempering temperature	560 - 590 °C
Soaking time	t' = 0,8 x + 120
Cooling	Room temperature

Second tempering temperature	To be set according to the required mechanical properties, in any case higher than the temperature used 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 used
Soaking time	t''' = 0,8 x + 180
Cooling	Slow cooling in the furnace up to 250 °C, afterward at room temperature



Tempering curve of a sample 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® 2343 HDC the phase transformation points are exceeded, which inevitably causes a variation in the volume of the material. Due to this reason we recommend keeping the proper machining allowance to compensate the change of dimensions 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 when very high tools' performance is needed, as it extends the life of the material.

We advise to carry out the nitriding on the tool in hardened and tempered condition. The nitriding temperature must be at least 50 °C less than the tempering temperature.

Today's nitriding procedures allow to keep the original dimensions of the tool.

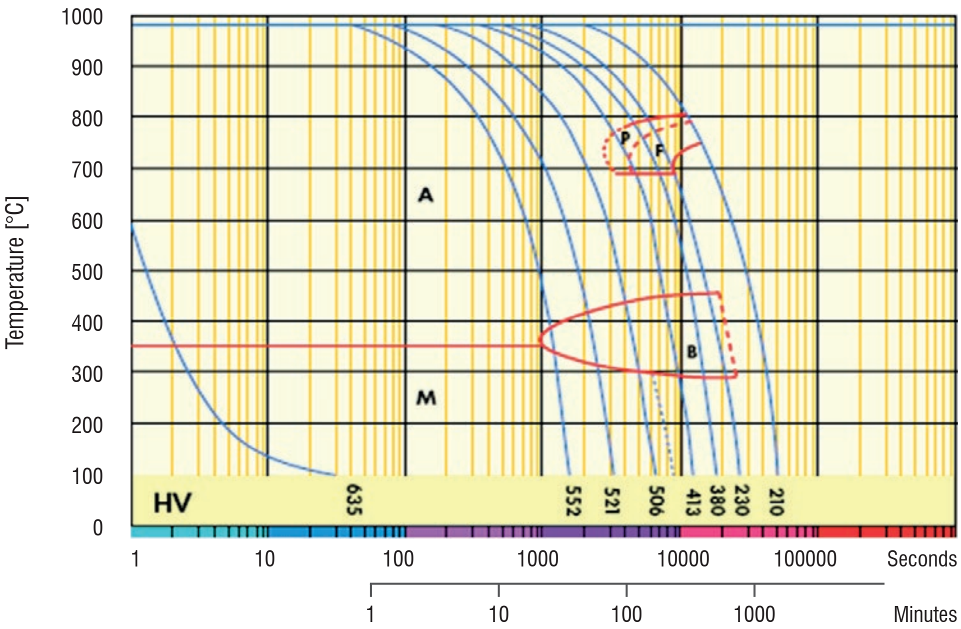
Remarks

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.

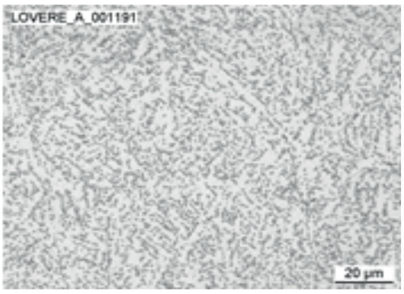
We strongly recommend to send your dies to one of the heat treatment companies officially approved by Lucchini RS.

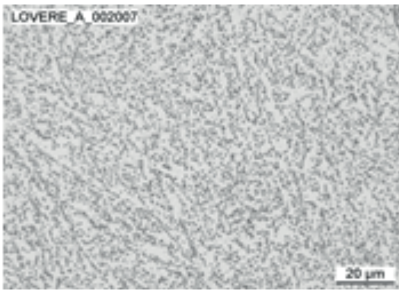
For more information don't hesitate to ask to our local Distributor – Service Center or to our Sales Department. In case of different needs of heat treatment (like salt bath) please contact our technical staff of Metallurgy & Laboratories Department

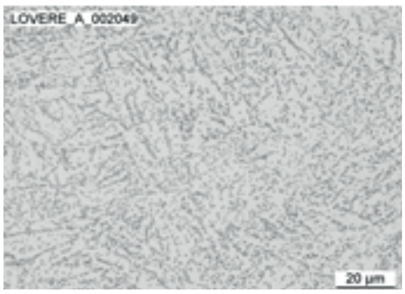
CCT Curve



Annealed microstructure of Eskylos® 2343 HDC







Example of Annealed microstructure of Eskylos® 2343 HDC examined at 500X, after polishing and etched with 4% Nital: essentially ferritic matrix with an homogeneous distribution of spheroidized carbides, free of excessive banding.

The advantages of the ESR technology

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

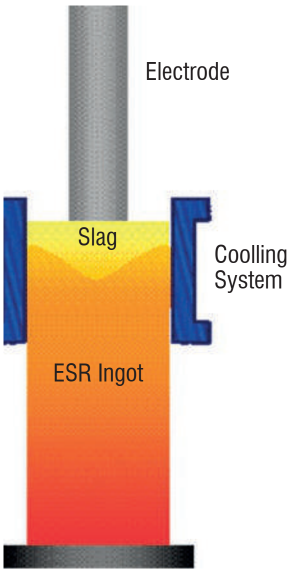
- high micro-cleanliness level;
- very low segregation level.
- Very high isotropy of the material;
- increase of material toughness;

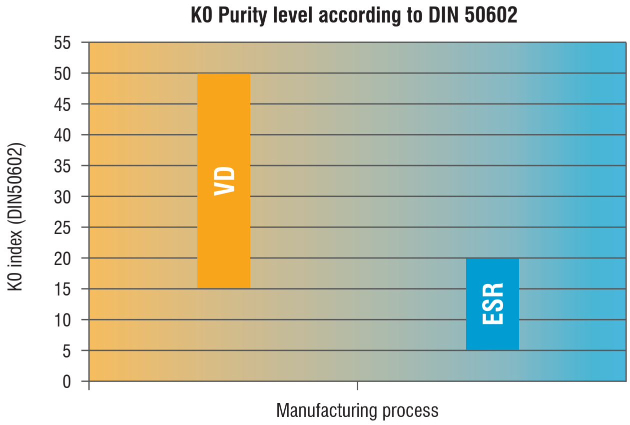
The ESR process is based on the re-melting of a conventional EAF+LF+VOD ingot, using a particular copper ingot mould that contains basic slag.

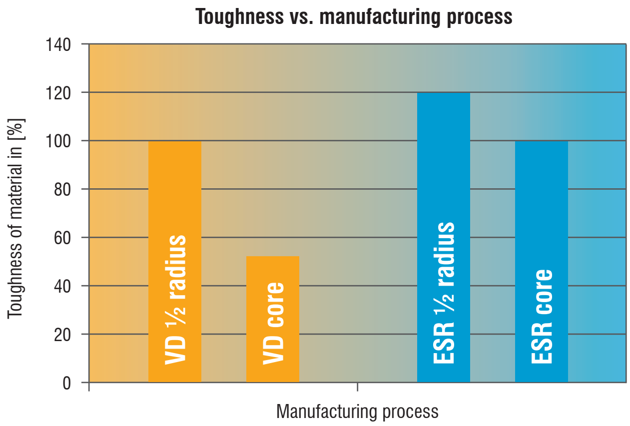
The conventional ingot ("Electrode") is re-melted by going the liquid steel through the slag, which acts as a filter and retains the inclusions.

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

The result is a new homogeneous and isotropic ESR steel ingot.







Guidance for machining

The following parameters are just indicative and must be adjusted to the particular application and to the machining equipment that is going to be used. The data refer to the material in the annealed condition with 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 EskyLos® 2343 HDC can give good results if it is carried out according to the here under recommended procedure. As steel with high Carbon Equivalent content, EskyLos® 2343 HDC is very sensitive to cracking.
We recommend to carry 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 at 850 °C, cooling in the furnace up to 600 °C at a rate of 20 °C/h, afterward 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 used	

Electrical Discharge Machining (EDM)

EskyLos® 2343 HDC can be machined by EDM to achieve complicated shape.

Afterwards it is advisable to carry out stress relieving.

Chrome Plating

EskyLos® 2343 HDC can be Chrome plated in order to enhance the mechanical characteristics on the surface.

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

Photo-engraving

Thanks to the Super Clean steel manufacturing procedure, followed by the Electro Slag Re-melting and thanks to the low Sulphur content, EskyLos® 2343 HDC is suitable for photo-engraving to obtain the most complicated patterns.

Polishing

Thanks to the ESR process, EskyLos® 2343 HDC is particularly suitable for optical 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.