ESKYLOS® OPTIMO

VALUE IN ISOTROPY

TOP QUALITY ESR STEEL FOR LIGHT ALLOYS DIE CASTING APPLICATIONS

General characteristics

ESKYLOS® OptiMo is the latest evolution proposed by Lucchini RS for the family of low Silicon steel grades, designed for the most demanding High Pressure Light Alloys (Al-Mg) Die Casting moulds. It has been developed starting from the experience of ESKYLOS® 2340 grade, optimizing the Molybdenum (Mo) content and adding special micro-alloying elements such as Tungsten (W) to improve characteristics.

ESKYLOS® OptiMo fully meets NADCA #207 specification concerning the annealed microstructure and banding segregation in the core of the block, the most critical position.

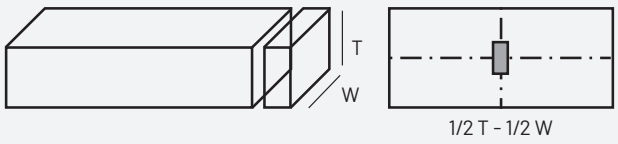
The impact capability testing is performed according to NADCA #207 specification, one of the most important worldwide reference for die-casting application.

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, ESKYLOS® OptiMo is able to achieve extremely high performances.

Delivery conditions

ESKYLOS® OptiMo is supplied in annealed condition and for each single block Lucchini RS guarantees an high level of material quality, based on the control of key quality indicators of annealed steel capability summarized by the Table 1 "Annealed steel capability".

In particular, ESKYLOS® OptiMo is characterized according to the specification NADCA #207, one of the most important worldwide reference for die-casting application, that requires the "Annealed steel capability" assessment by samples' location in the core of the block, the most critical one.

		Sampling location
Micro-cleanliness	According to NADCA #207	
Microstructure	According to NADCA #207	
Banding segregation		
Impact test	≥ 27 (23)J According to NADCA #207 GRADE E	 Samples taken from a corner of the block and heat treated separately for 45 ±1 HRC
Grain size	G≥7 According to NADCA #207	

Tab. 1: annealed steel capability

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Main features

- excellent isotropy;
- high mechanical properties and strength: compared to the steel grade 1.2343 ESR, ESKYLOS® OptiMo combines a better warm rigidity and warm strength with an excellent toughness.
- good hardenability
- good thermal conductivity
- good tempering resistance
- good thermal stability
- good thermal fatigue and hot cracking resistance;
- good fracture toughness in hot condition;
- excellent ductility
- good wear and erosion resistance
- suitable for medium and large dies (up to 2 tons)
- recommended for long run dies for pieces requiring smooth surface (to be coated or paint)
- not recommendable for dies producing small lots neither for non – thermoregulated dies.

Main application

- High pressure Aluminium/Magnesium die casting moulds;
- Moulds for low pressure Aluminium die castings;
- Moulds for Aluminium gravity die castings;

Chemical analysis

	Range	**C** [%]	**Si** [%]	**Mn** [%]	**Cr** [%]	**Mo** [%]	**V** [%]	**S** [%]	**P** [%]
ESKYLOS®OPTIMO Alloying [% in weight]	min	0,32	0,10	0,30	4,80	1,50	0,40	-	-
	max	0,40	0,30	0,50	5,50	2,00	0,70	0,003	0,015

Comparison with international classifications:
NADCA GRADE E

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.

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Physical and mechanical properties

Main physical properties

ESKYLOS®OPTIMO	20°C	400°C	600°C
Young modulus E [MPa]	210	180	140
Coefficient of linear thermal expansion α [10-6/K]	-	12,3	13,1
Thermal conductivity λ [W/mK]	-	31,4	33,2

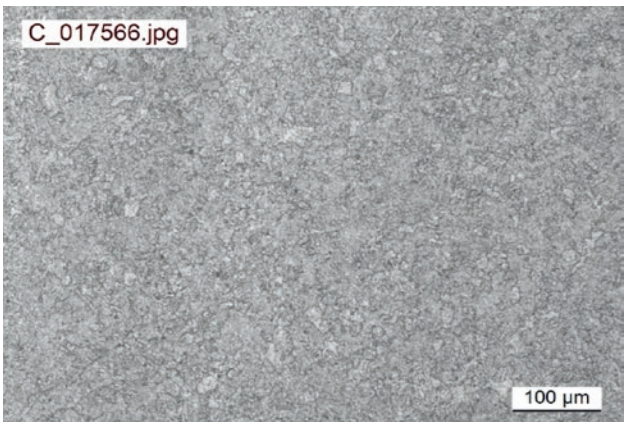
Main mechanical properties

ESKYLOS®OPTIMO	400°C	500°C	600°C
Ultimate tensile strength UTS [MPa]	1190	1050	800
Yield strength YS [MPa]	1000	910	610

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

Microstructure

The main microstructure of ESKYLOS® OptiMo consist of a ferritic matrix with a homogeneous distribution of spheriodized carbides.



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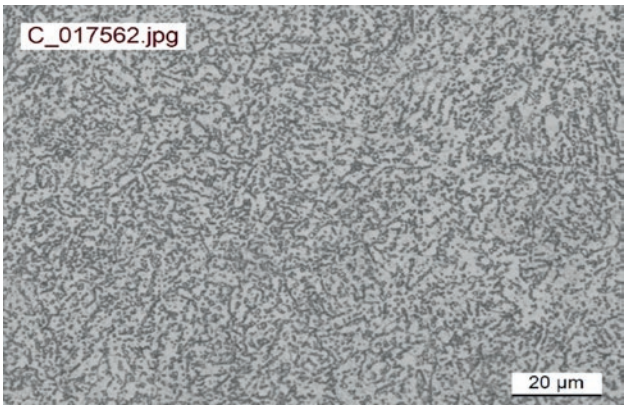
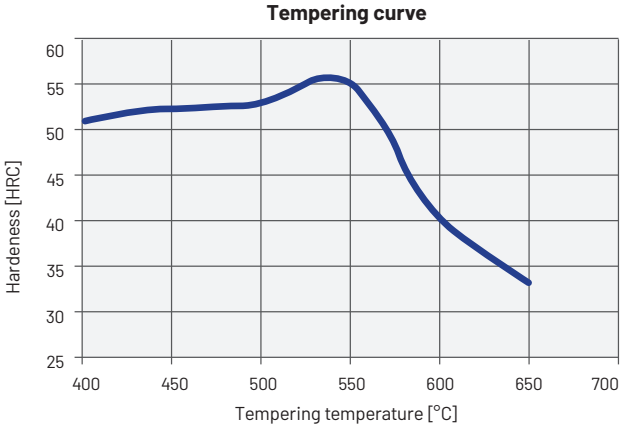


500x

Surface hardness vs tempering temperature

Tempering curve of a sample austenitized at 980°C. The diagram shows values obtained after the second tempering; the first tempering is performed at 550°C.



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Heat treatment

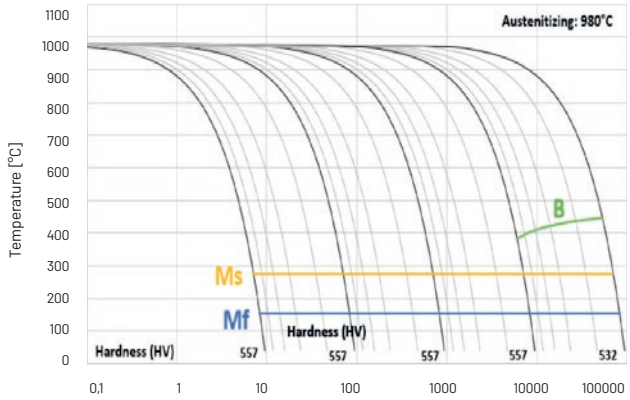
ESKYLOS® OptiMo is supplied in annealed condition with a hardness value below 220 HB.

Heat treatment shall be carried out using the parameters recommended and given below.

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 processing the dies to one of the heat treatment companies officially approved by Lucchini RS.

Continuous cooling transformation curve (CCT)



Soft annealing

Heating	max 50°C/h
Suggested temperature	850 °C
Soaking time	120 min from the temperature's settlement
Cooling	Slow cooling in furnace (20°C/h)

Soft annealing is useful to improve machinability reducing hardness at 220 HB.

Stress relieving

Heating	max 100°C/h
Suggested temperature	Annealed condition: 650°C QT condition: 50°C lower than the last tempering
Soaking time	120 min from the temperature's settlement
Cooling	Slow cooling in furnace (20°C/h)

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.

Heating	Max 150°C/h
First pre-heating temperature	400°C
Soaking time	25 min / 25 mm in thickness or ($T_{SURFACE} - T_{CORE}$) < 90°C

Heating	Max 150°C/h
Second pre-heating temperature	600°C
Soaking time	20 min / 25 mm in thickness or ($T_{SURFACE} - T_{CORE}$) < 90°C

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Heating	Max 150°C/h
Third pre-heating temperature	800°C
Soaking time	20 min / 25 mm in thickness or ($T_{SURFACE}$ – T_{CORE}) < 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 (T_{CORE}) and the Surface temperature ($T_{SURFACE}$) 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 ($T_{SURFACE}$ – T_{CORE}) < 15 °C or on the basis of the following formula:

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

Heating	Max 150°C/h
temperature	980°C
Soaking time	t=(x+39)/2 or 30 min from ($T_{SURFACE}$ – T_{CORE}) < 15°C
Cooling	Air, vacuum cooling, salt bath, polymer

Tempering

It is recommended to set the temperature of the first tempering at 550°C, close to the secondary peak 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.

The soaking time for the third tempering is calculated by the following empirical formula:

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

First tempering temperature	550°C
Soaking time	t' = 0,8 x + 120
Cooling	Still air

Second tempering temperature	Based on mechanical properties required
Soaking time	t'' = 0,8 x + 120
Cooling	Still air

Third tempering temperature	30-50 °C less than the maximum temperature previously used
Soaking time	t''' = 0,8 x + 180
Cooling	Still air

Chrome plating

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ESKYLOS® OptiMo 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.

Nitriding

ESKYLOS® OptiMo is suitable for ionic and gas nitriding. This treatment is very useful for moulds subjected to extremely stressful applications.

The increase of the surface hardness, following nitriding, extends the component life cycle.

Up-to-date nitriding procedures allow to minimize the dimensional variation of the piece.

Other properties can be deeper analysed against specific Customer request: please contact our Metallurgy Department.

Polishing and photo-engraving

ESKYLOS® OptiMo is the suitable material when polishing and photoengraving are needed. Thanks to its integrated manufacturing process, those material manufactured by Lucchini RS are characterized by a high degree of purity.

Polishing for graining: 4 Excellent
Suitability for medium gloss polishing: 4 Excellent
Suitability for mirror polishing: 4 Excellent
Suitability for engraving: 4 Excellent

Rating scale:
4 Excellent – 3 Very good – 2 Good – 1 Normal – 0 Unsuitable

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The advantages of the ESR technology

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

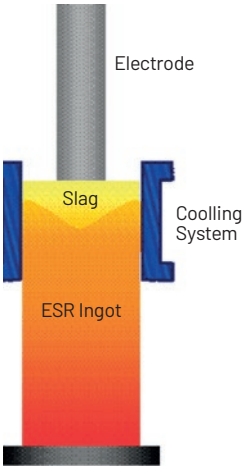
- increase of material toughness;
- high micro-cleanness level;
- total isotropy of the material;
- very low segregation level.

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.

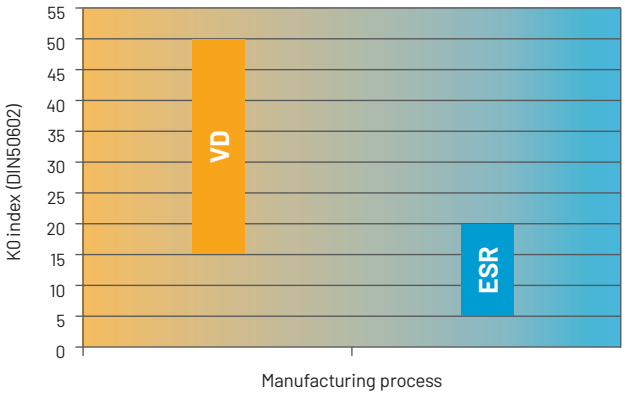
The ingot is remelted in a way that the liquid metal passes through the slag, which acts as a filter and retains the inclusions.

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

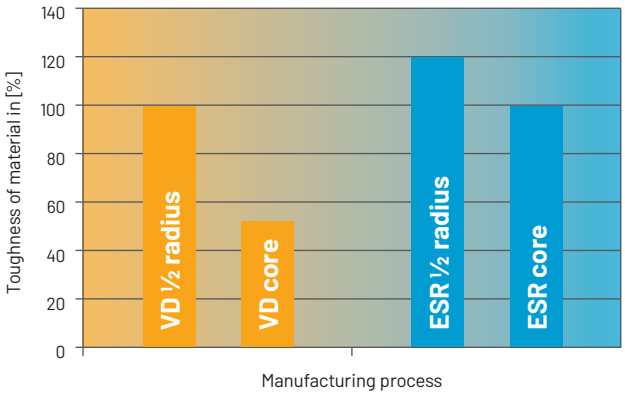
The result is homogeneous and isotropic steel.



K0 Purity level according to DIN 50602



Toughness vs. manufacturing process



Thanks to the ESR process, ESKYLOS® OptiMo 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.

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Guidance for machining

The following parameters are approximate only and must be adjusted to the specific application and machine tool.

Turning

	Rough machining	Finish machining		
Type of insert	P20-P40 coated	HSS	P10-P20 coated	Cermet
V_c cutting speed [m/min]	150 ÷ 190	(*)	190 ÷ 230	260 ÷ 320
a_r cutting depth [mm]	5	(*)	< 1	< 0,5

Milling

	Rough machining		
Type of insert	P25-P35 not coated	P25-P35 coated	HSS
V_c cutting speed [m/min]	120 ÷ 140	160 ÷ 180	(*)
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]	140 ÷ 160	180 ÷ 200	(*)
f_z feed [mm]	0,2 ÷ 0,3	0,2 ÷ 0,3	(*)
a_r cutting depth [mm]	< 2	< 2	(*)

	Finishing		
Type of insert	P10-P20 not coated	P10-P20 coated	Cermet P15
V_c cutting speed [m/min]	200 ÷ 240	250 ÷ 270	300 ÷ 340
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

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Drilling

Type of insert	tip with interchangeable inserts	HSS	brazed tip
V_c cutting speed [m/min]	130 ÷ 160	(*)	90 ÷ 120
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

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Welding

Welding ESKYLOS® OptiMo can give good results if it is carried out using the recommended procedure.

As steel with high Carbon Equivalent content, ESKYLOS® 2343 EVO is very sensitive to cracking.

We recommend to carry out pre-heating and heat treatment after welding.

In order to obtain the best results, we recommend the following procedure:

Material condition	Annealed	
Welding technique	TIG	MMA
Pre-heating at	330 – 380°C	
Recommended Heat treatment	Heating at 850 °C, cooling in furnace up to 600°C at a rate of 20 °C/h, afterward cooling at room temperature	

Material condition	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® OptiMo can be machined by EDM to obtain complex shape. Afterwards we advise to carry out the stress relieving procedure.

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 its tool steel grades, putting eco-effectiveness into practice.

The main adopted steps are:

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

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