

# **ESKY<sup>®</sup> LOS 4542**

Precipitation Hardening  
martensitic stainless steel  
in ESR quality:  
a innovative approach  
to corrosion resistant  
plastics Industry

## General characteristics

EskyLos<sup>®</sup> 4542 is a stainless steel and it is particularly suitable for the manufacture of dies and moulds subjected to high mechanical stress.

EskyLos<sup>®</sup> 4542 is obtained through a special 'super clean' manufacturing process and by using the ESR (Electro-Slag-Melting) 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<sup>®</sup> 4542 is supplied in the "solution treated" condition with hardness lower than 355 HB in sections up to 500 mm.

If high mechanical properties are required in the pattern and a homogeneous hardness throughout the whole mould is needed, EskyLos<sup>®</sup> 4542 can be further hardened to reach 28 ÷ 40 HRC, 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.

EskyLos<sup>®</sup> 4542 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 and mirror polishability;
- micro-purity;
- resistance to corrosion.

Resistance to corrosion allows the surface characteristics of the mould to be maintained over time.

This means that the die can be stocked with no need for special precautions to be taken and with the certainty of being able to use the mould whenever needed.

The expensive and complicated operations of cleaning and setting up the die are not needed before usage.

Constant development in processing technologies require the use of EskyLos<sup>®</sup> 4542, thanks to its high fatigue and wear resistance, combined with its excellent dimensional stability, extremely low distortions and corrosion resistance.

Thanks to its quasi-isotropic properties of ESR quality, EskyLos<sup>®</sup> 4542 represents one of the most important tough options for highly resistant plastic moulds that need very high pressure strength, excellent resistance to abrasion and corrosion.

The increasing in the use of synthetic and abrasive materials has led manufacturers to use EskyLos<sup>®</sup> 4542 also when suitability for mirror polishing and graining, combined with abrasion and compression resistance, are required.

EskyLos<sup>®</sup> 4542 offers the following advantages:

- excellent machinability;
- excellent suitability for embossing;
- excellent suitability for mirror 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, in case of repair by welding;
- excellent resistance to corrosion.

EskyLos<sup>®</sup> 4542 is 100% ultrasonically inspected, according to the most demanding of NDT standards.

EskyLos<sup>®</sup> 4542 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 EskyLos<sup>®</sup> 4542 grade.

## Chemical analysis

	Range	C [%]	Si [%]	Mn [%]	Cr [%]	Cu [%]	Nb [%]	Ni [%]
<b>ESKY<sup>®</sup> LOS 4542</b> Alloying [% in weight]	min	/	/	/	15,00	3,00	0,15	3,00
	max	0,08	1,00	1,00	17,00	5,00	0,45	5,00

Table for comparison of international classification

<b>W. Nr.</b>	<b>1.4542</b>
<b>DIN</b>	<b>X5CrNiCuNb17-4</b>
<b>AFNOR</b>	<b>X5CrNiCuNb16-4</b>
<b>AISI</b>	<b>17.4PH</b>

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<sup>®</sup> 4542 lends itself to the following applications.

Plastic moulding:

- dies of big/medium size for the automotive industry;
- special dies for the food industry;
- dies for rubber moulding;
- dies for compression stamping (SMC, BMC);
- die bolsters for plastic die casting;

Extrusion:

- matrices and gauges for PVC;
- various components for extrusion.

## Physical and mechanical properties

*Main physical properties*

<b>ESKY<sup>®</sup> LOS 4542</b>	20°C	250°C	500°C
Modulus of elasticity [GPa] (1GPa=1000 MPa)	210	198	180
Coefficient of thermal expansion from 20 °C at [10 <sup>-6</sup> /K]	19,0	19,8	20,5

## Heat treatments

### 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 <b>200 °C</b> , 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.

### Precipitation Hardening

Precipitation Hardening steel grades as EskyLos® 4542 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 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.

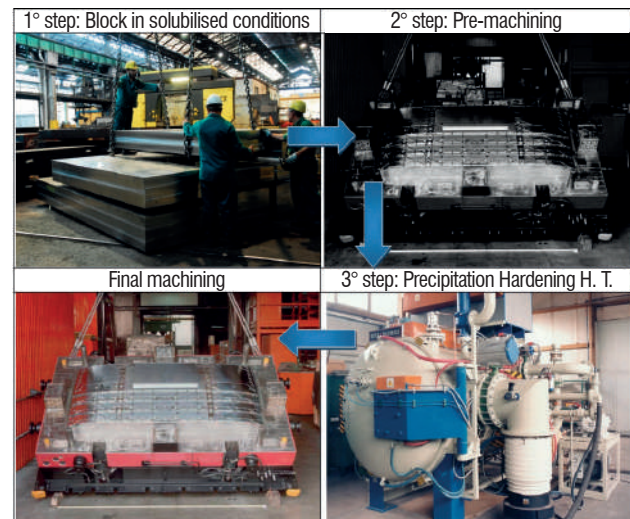
This means that there are few worries about unexpected cracks and damages induced by heat treatments of the mould; hence, dimensional and shape variations are certainly less than on 'traditional' steels but, in any cases, they are present and have to be taken in proper consideration on the manufacturing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

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, EskyLos® 4542 can be also used in solubilised conditions or in pre-hardened conditions: in those cases, the working cycle is the same of Pre-Hardened steel grades.



EskyLos® 4542 is supplied in solubilised condition:

Solubilisation T = 1.040°C; Hardness < 38HRc.

In the event that it is necessary to obtain different hardness levels with different YS/UTS ratios, a precipitation hardening heat treatment on the material according to the following work parameters is recommended.

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

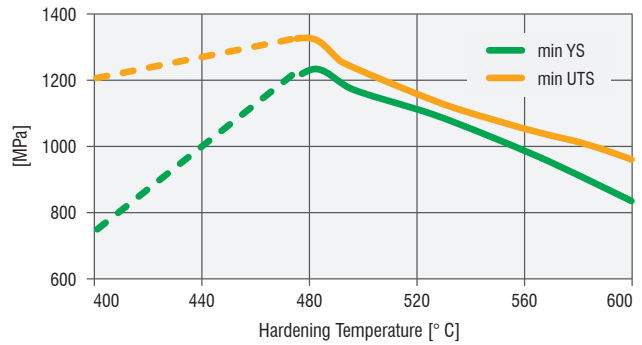
The attached data are for illustration purposes only; they can be modified with different heat treatment facility, time-temperatures parameters and thickness of the die.

In summary, KeyLos® 4542 can reach wide margin of modulation of the Hardness (between 30 and 40 HRC) and of the correspondents mechanical properties, obtained by means of aging in the interval of temperature 480°C - 600°C (H900 - H1100).

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

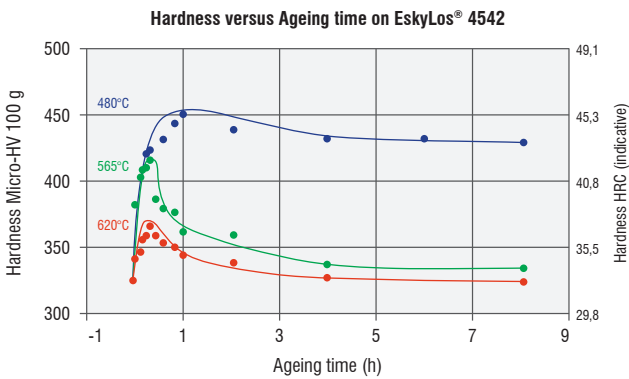
Precipitation Hardening Temperature		Min YS	Min UTS	Min Hardness
[°F]	[°C]	[MPa]	[MPa]	[HRc]
H900	485	1.170	1.310	40
H925	495	1.070	1.170	38
H1.025	550	1.000	1.070	35
H1.075	580	860	1.000	32
H1.100	595	795	965	31
H1.150	620	725	930	28

Thickness of the die [mm]	100	150	200	250
Suggested time for Precipitation Hardening heat treatment	2h	3h	4h	5h



YS and UTS versus Precipitation Hardening temperature for EskyLos® 4542; soaking time are calculated after the achievement of the aimed temperature in the core of the section, according to the suggested table.

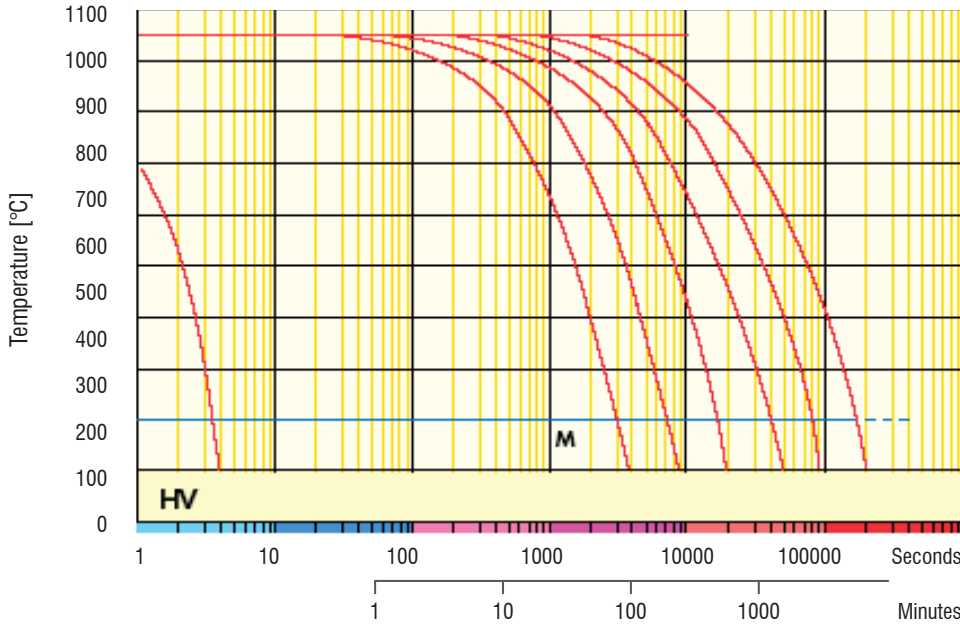
The attached data are for illustration purposes only; they can be modified with different heat treatment facility, time-temperatures parameters and thickness of the die.



EskyLos® 4542 behaves in different way, when time-temperature parameter change; suggested time parameters are designed with the aim to reach the horizontal asymptotic trend of the curve.

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 ESKYLOS<sup>®</sup> 4542



The microstructure of KeyLos<sup>®</sup> 4542 as delivered by Lucchini RS, in solubilised conditions, detected about 20 mm under surface, consists of a tempered martensite with dispersed carbides.



## Quick comparison guide among the different grades

The following table shows a quick comparison among the most important characteristics of the annealed grades normally applied in plastic moulding and the precipitation hardening grades, with or without corrosion resistance.

Lucchini RS Mould steel Family for plastics Industry								
Special features and delivered conditions	Annealed Corrosion Resistant					Precipitation Hardening		
	KEYLOS					ESKYLOS	ESKYLOS	
	2083	2084	2085	2316	2316S	2083	4542	2001
HB in surface in Annealed condition	< 220	< 220	< 220	< 220	< 220	< 220	< 355	310 - 350
HB in surface Pre-hardened or Hardened after machining	400 - 450	400 - 450	400 - 450	400 - 450	400 - 450	400 - 450	300 - 400	350 - 450
Maximum thickness [mm]	500	500	500	500	500	500	500	500
Hardness and Wear Resistance	4	4	4	4	4	4	2	3
Degree of Through Hardening in the section	3	2	2	2	2	3	4	3
Toughness	2	1	1	2	1	2	2	2
Machinability after Annealing	2	3	3	2	3	2	2	3
Machinability after Hardening	1	2	2	1	2	1	1	1
Etch-Grainability	2	1	1	2	1	4	4	4
Polishability	2	1	1	2	1	3	3	3
Repair by Welding	1	0	0	1	0	1	2	1
Thermal Conductivity	1	1	1	1	1	1	1	1
Corrosion Resistance	2	2	2	2	2	2	1	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.

## 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 EskyLos® 4542, a Precipitation Hardening stainless steel grade.

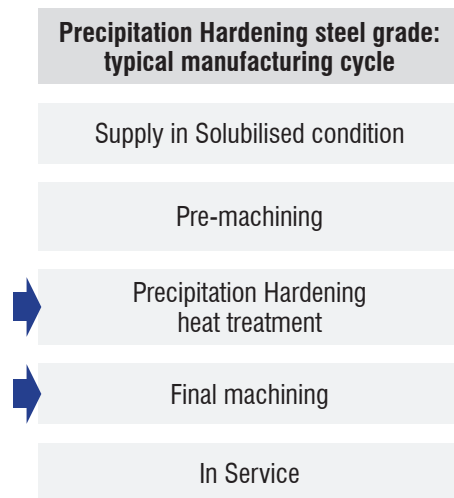
EskyLos® 4542 gives all the advantages of pre-hardened steels, without the restrictions that they present when high mechanical properties are required.

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, EskyLos® 4542 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 EskyLos® 4542 can be restored through solubilisation.

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



## The advantages of the ESR technology

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

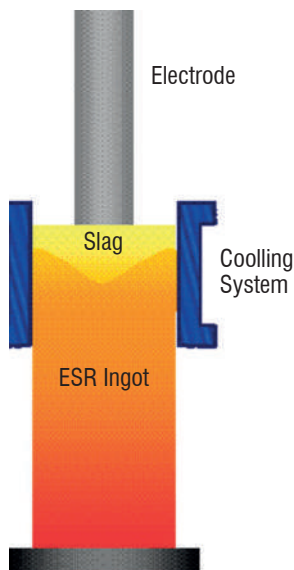
- increase of material toughness;
- high micro-cleanness level;
- total isotropy of the material;
- very low segregation level.

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.

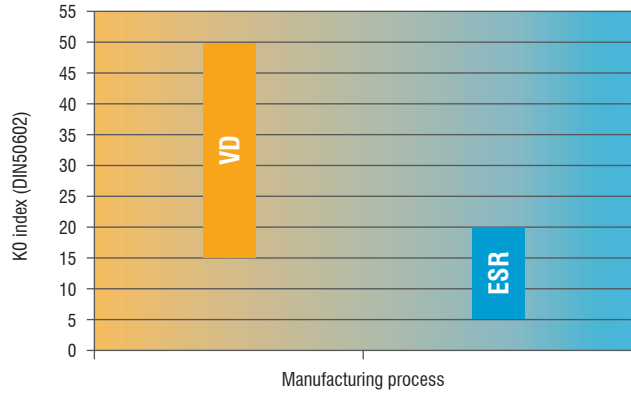
The ingot is remelted in a way that the liquid metal passes through the slag, which acts as a filter and retains the inclusions.

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

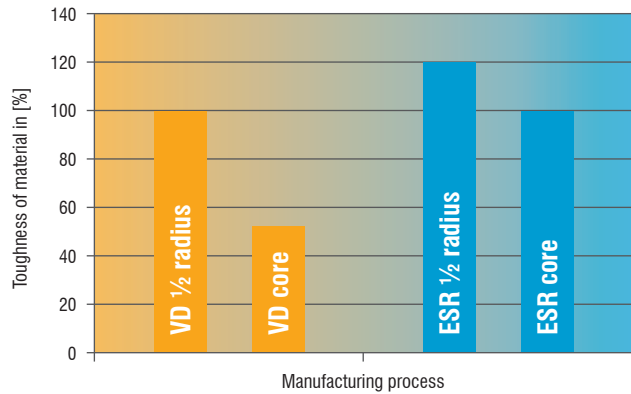
The result is homogeneous and isotropic steel.



**KO Purity level according to DIN 50602**



**Toughness vs. manufacturing process**



Thanks to the ESR process, EskyLos<sup>®</sup> 4542 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.

### Turning

Type of insert	Rough machining		Finish machining	
	P20-P40 coated	HSS	P10-P20 coated	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 EskyLos<sup>®</sup> 4542 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 treat the piece again and age harden it a second time.*

## Electrical Discharge Machining (EDM)

EskyLos<sup>®</sup> 4542 can be machined by EDM to obtain complex shape.

Afterwards it is advisable to stress relieving the material.

## Photo-engraving

EskyLos<sup>®</sup> 4542, as a result of the modern processes utilised and of the low Sulphur content, can be photo incised to obtain designs of various types.

## Polishing

Due to the ESR (Electro-Slag-Remelting) manufacturing process, EskyLos<sup>®</sup> 4542 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.