# ESR steel designed for hot working

Eliminato: ¶
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Edition December 2008

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## General characteristics

EskyLos® 2344 is chrome-molybdenum-vanadium alloyed steel designed for the manufacture of dies, moulds, punches and other components subjected to high working temperatures.

The best features of this steel are:

- high resistance to thermal shock and to hot cracking
- good mechanical characteristics in hot condition
- good toughness in hot condition
- constant hardness throughout the production cycle
- excellent machinability.

EskyLos® 2344 is obtained through a special 'super clean' production 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 segregative level.

EskyLos® 2344 is normally supplied 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® 2344 can reach a hardness of 50 HRc without affecting the toughness.

In order to improve further the mechanical characteristics of the surface, EskyLos® 2344 can be coated with PVD or PA/CVD methods. Alternatively it can be hardened through flame hardening, induction tempering or subjected to nitriding. This allows a hardness value of about 58 HRc to be reached. The hardness of the nitrided layer is about 900-1000 $HV_{0,2\ kg}$.

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

If required, it is possible to carry out welding operations with TIG or MMA methods on dies made of EskyLos® 2344

## Chemical analysis

| ESKYLOS 2344 | | Alloying % | |
|---|---|---|---|
| C | 0,37 ÷ 0,42 | Cr | 5,00 ÷ 5,50 |
| Si | 0,85 ÷ 1,20 | Mo | 1,20 ÷ 1,70 |
| Mn | 0,20 ÷ 0,50 | V | 0,85 ÷ 1,20 |

Table for comparison of international classification

**W. Nr. 1.2344**

**EN ISO X40CrMoV5-1**

**AISI-SAE H13**

Lucchini RS's tool steels have been researched and formulated to optimize the performance of the materials.
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® 2344 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.



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DIN X40CrMoV5-1¶
AFNOR Z40CDV5¶
AISI H13¶
UNI X40CrMoV5 1 1 KU

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## Physical and mechanical properties

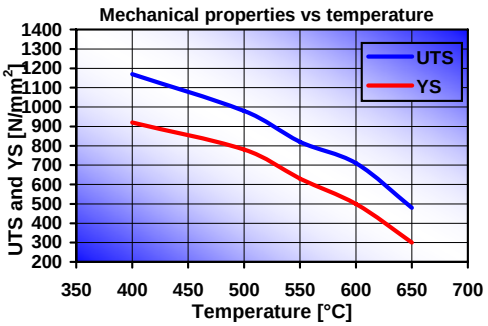
*Main physical properties*

| ESKYLOS 2344 | at 20°C | at 400°C | at 600°C |
|---|---|---|---|
| **Modulus of elasticity [kN/mm$^2$]** | 210 | 179 | 168 |
| **Coefficient of thermal expansion from 20 °C at [10$^{-6}$/K]** | - | 11,9 | 13,0 |
| **Thermal conductivity [W/mK]** | 26,0 | 29,1 | 32,0 |

*Main mechanical properties*

| ESKYLOS 2344 | at 400°C | at 500°C | at 600°C |
|---|---|---|---|
| Ultimate Tensile strength (**UTS**) [N/mm$^2$] | 1.170 | 980 | 710 |
| Yield stress (**YS**) [N/mm$^2$] | 920 | 780 | 500 |

These are average values obtained on a sample which has been hardened at 1020 °C, quenched in oil and tempered at 630 °C to achieve a hardness of 44 HRc.




## Heat treatments

EskyLos® 2344 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 |

**Eliminato:** 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 |

**Eliminato:** 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.



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| | |
|---|---|
| **First pre-heating temperature** | **400 °C** |
| **Heating** | Max 150 °C/h |
| **Soaking time** | 60 min every 25 mm thickness or when (Ts-Tc) < 90 °C |

| | |
|---|---|
| **Second pre-heating temperature** | **600 °C** |
| **Heating** | Max 150 °C/h |
| **Soaking time** | 45 min every 25 mm thickness or when (Ts-Tc) < 90 °C |

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

| | |
|---|---|
| **Austenitising temperature** | **1020°C** |
| **Heating** | > 150°C/h |
| **Soaking time** | t = ( x + 39 ) / 2 or 30 min from when (Ts-Tc) < 15 °C |
| **Cooling** | Air, vacuum cooling, salt bath, oil |

## *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.

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 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 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]

## *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]

**Eliminato: Hardness after oil quenching** ... [1]

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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:

$$t''' = 0{,}8\,x + 180$$

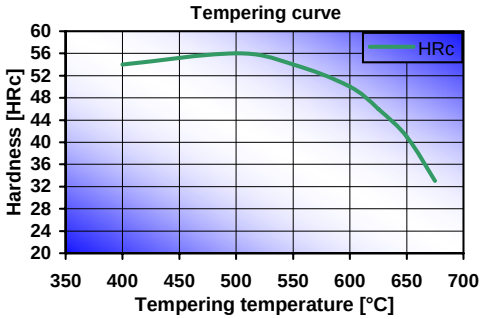
t''' = soaking time [min]

x = thickness [mm]

| | |
|---|---|
| **First tempering temperature** | **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 1020 °C. The diagram shows values obtained after the second temper.

## *Variation in dimensions during heat treatment*

During the heat treatment of Eskylos® 2344 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.

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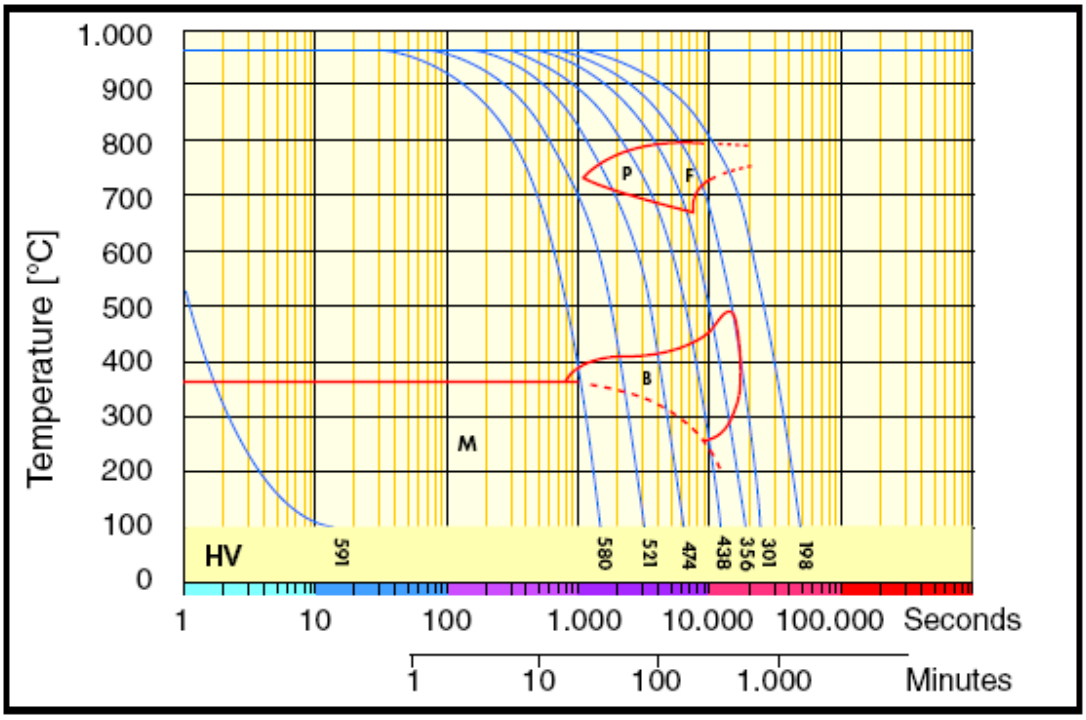
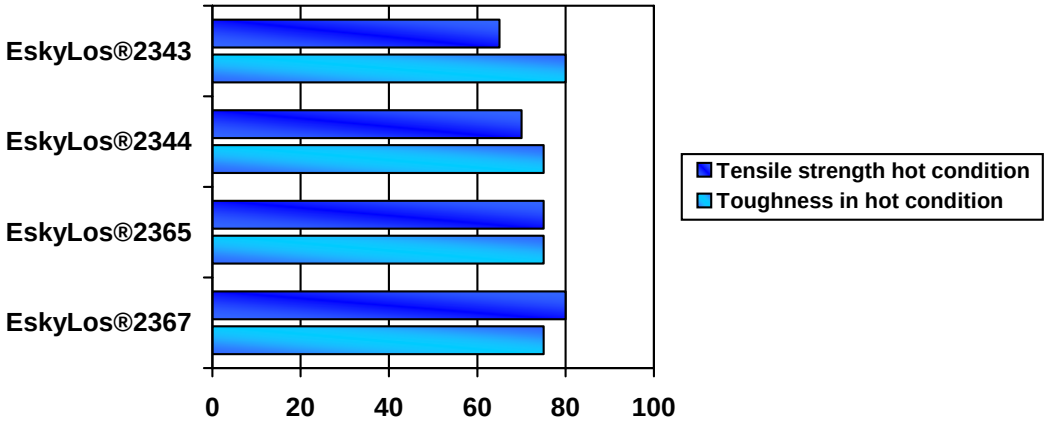
## CCT Curve




## Critical points

| | | | |
|---|---|---|---|
| Ac1 | 870°C | Ms | 360°C |
| Ac3 | 940°C | Mf | 220°C |

## Comparison of properties of different hot work tool steels



# The advantages of the ESR technology

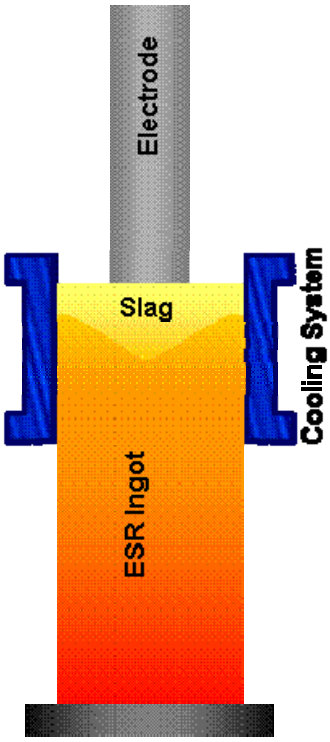
The ESR (Electro-Slag-Melting) manufacturing technology offers the following advantages:

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

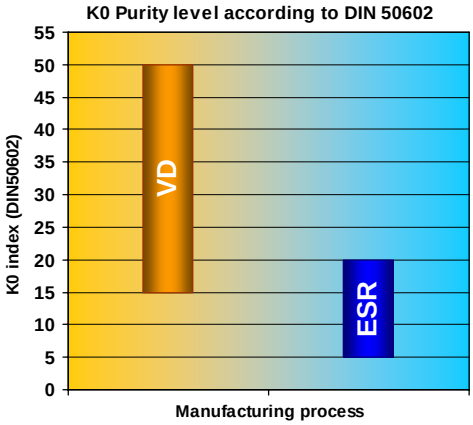
The ESR process is based on ingot remelting, through a traditional VD (vacuum degassing) process, using a particular copper ingot mould that contains basic slag.

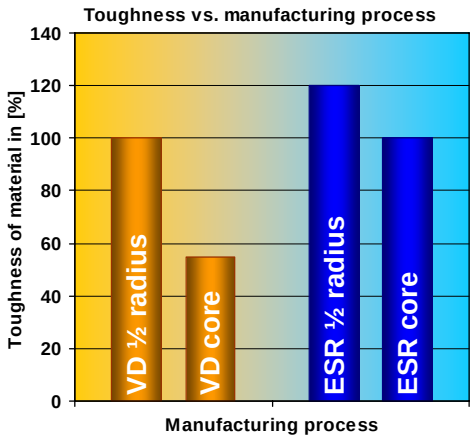
The ingot is remelted in a way that the liquid metal passes through the slag, which acts as a filter and retains the inclusions.

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® 2344 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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## Welding

Welding of Eskylos® 2344 can give good results if the recommended procedure is followed. Being steel with high carbon equivalent content, Eskylos® 2344 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** | 50 °C lower than the tempering temperature previously applied | |

For further information, please refer to the brochure.

## Electrical Discharge Machining (EDM)

Eskylos® 2344 can be machined by EDM to obtain complex shape. Afterwards it is advisable to stress relieving the material.

## Chrome Plating

Eskylos® 2344 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® 2344 is suitable for photo-engraving to obtain various patterns. For further information, please refer to the brochure.

## Polishing

Due to the ESR (Electro-Slag-Remelting) manufacturing process, Eskylos® 2344 has excellent suitability to polishing. For further information, please refer to the brochure.


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**Eliminato: 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*¶
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¶
Interruzione di sezione (continua)
... [2]
**Eliminato:** ¶
**Formattato**
**Formattato:** Spazioprima 12 pt
**Eliminato:** ¶
**Formattato:** Giustificato, Spazioprima 12 pt
**Eliminato:** 650 °C or
**Formattato:** Tipo di carattere: Non Grassetto
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Pagina 4: [1] EliminatoFAcerbis 26/11/2008 10.55.00

| | |
|---|---|
| **Hardness after oil quenching** | 54 ÷ 55 HRc |

Pagina 8: [2] EliminatoFAcerbis 25/11/2008 18.40.00

## 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 |

Interruzione di sezione (continua)

*Milling*

| | | | |
|---|---|---|---|
| | **Rough machining** | | |
| **Type of insert** | **P25-P35 non 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 |

interruzione pagina

Interruzione di sezion

*Drilling*

| | | |
|---|---|---|
| **Type of insert** | **tip with interchangeable inserts** | |
| **$V_c$ cutting speed [m/min]** | 190 ÷ 220 | |
| **$f_n$ feed per turn [mm/turn]** | 0,05 ÷ 0,15 | |

Interruzione di sezione (continua)

Interruzione di sezione (continua)

(*) not advisable

| ESKY LOS 2344 | | |
|---|---|---|
| **Type of machining** | **Drilling** | **Milling** |
| ***n*: number of turns of mandrel** | $\frac{V_c * 1000}{\pi * D_c}$ | $\frac{V_c * 1000}{\pi * D_c}$ |
| ***V<sub>f</sub>*: feed speed [m/min]** | $V_f = f_z * n$ | $V_f = f_z * n * z_n$ |
| ***f<sub>n</sub>*: feed per turn [mm/turn]** | - | $f_n = \frac{V_f}{n}$ |
| **Note** | $D_c$: Milling cutter or tip diameter [mm]<br>$V_c$: cutting speed [m/min]<br>$f_z$: feed [mm] | $f_n$: feed per turn [mm/turn]<br>$z_n$: No. of milling cutter inserts |

Interruzione di sezione (pagina successiva)

*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 |
| **N/mm$^2$** | 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 | -- | -- | -- | -- | -- |
| **N/mm$^2$** | 1.250 | 1.200 | 1.150 | 1.100 | 1.050 | 1.000 | 950 | 900 | 850 | 800 | 750 | 700 | 650 |

interruzione pagina