CHEMISTRY IRON

GREY (flake) IRON
CHEMISTRY IRON

NO STANDARD REQUIRES CHEMICAL COMPOSITION

CUSTOMER MOSTLY REQUIRES:
  * TENSILE STRENGTH
  * HARDNESS
CHEMISTRY IRON

TOOLS OF FOUNDRY TO ACHIEVE THE REQUIREMENTS:

1. CHEMICAL COMPOSITION
2. COOLING OF CASTING
3. HEAT TREATMENT
CHEMISTRY IRON

COOLING OF CASTING

DANGEROUS TO PLAY WITH DUE TO:

• RESIDUAL STRESS LEVEL

• LOW CONTROLIBILITY

+ COOLING RATE

+ RESULT DEPENDS ALSO ON CHEMISTRY
CHEMISTRY IRON

HEAT TREATMENT OF CASTING

THIS IS A CORRECTIVE ACTION THAT IS:

- VERY EXPENSIVE
- DEPENDING ON CHEMISTRY
CHEMISTRY IRON

THEREFORE

LET’S FOCUS ON CHEMISTRY
CHEMISTRY IRON

YES BUT......

RESULT IS DEPENDING ON TYPE OF FURNACE!

CUPOLA MELTED IRON IS DIFFERENT FROM ELECTRICAL MELTED IRON!?
CHEMISTRY IRON

CONCERNING WHAT?

1. MECHANICAL PROPERTIES
2. HARDNESS
3. MACHINABILITY
4. CASTABILITY:
   + FLUIDITY
   + POROSITY
CHEMISTRY IRON

IS THIS POSSIBLE?

IS THE IRON EQUAL?
GREY IRON

MECHANICAL PROPERTIES (TENSILE STRENGTH AND HARDNESS) DEPEND ON:

- CHEMICAL COMPOSITION
- WALL THICKNESS
- COOLING
RELATION TENSILE – WALL THICKNESS

TENSILE STRENGTH - WALL THICKNESS

MODULE SECTION

TENSILE STRENGTH MPa

0 0,25 0,5 1,0 2,0 4,0 7,5 15 cm

WALL THICKNESS

5 10 15 20 40 80 150 300 mm

EN-GJL350
EN-GJL300
EN-GJL250
EN-GJL200
EN-GJL150
RELATION TENSILE – WALL THICKNESS
MATERIAL COMPOSITION LIMITS

% C 2,90 – 4,00 %
% Si 1,00 – 3,30 %
% Mn 0,25 – 1,00 %
% P 0,05 – 1,00 %
% S 0,03 – 0,18 %

ALLOYING ELEMENTS

% Ni < 0,20 %
% Cr < 0,10 %
% Mo < 0,20 %
% V < 0,05 %
TENSILE STRENGTH in 30 mm test bar
NON ALLOYED IRON

Rm = 787 MPa – 150 (% C)
– 47 (% Si)
+ 54,9 (% Mn)
+ 219 (% S)

Rm IS TENSILE STRENGTH IN MPa
HARDNESS ON TEST BAR OF 30 mm NON ALLOYED IRON

HARDNESS = 444 HB

− 71,2 (% C)
− 13,9 (% Si)
+ 21,0 (% Mn)
+ 170 (% S)
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<thead>
<tr>
<th>Element</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
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<tr>
<td>C</td>
<td>2.90%</td>
<td>4.00%</td>
</tr>
<tr>
<td>P</td>
<td>0.05%</td>
<td>1.00%</td>
</tr>
<tr>
<td>Si</td>
<td>1.00%</td>
<td>3.30%</td>
</tr>
<tr>
<td>S</td>
<td>0.03%</td>
<td>0.18%</td>
</tr>
<tr>
<td>Mn</td>
<td>0.25%</td>
<td>1.00%</td>
</tr>
<tr>
<td>Cr</td>
<td>0.20%</td>
<td>0.60%</td>
</tr>
<tr>
<td>Cu</td>
<td>0.50%</td>
<td>1.50%</td>
</tr>
<tr>
<td>Mo</td>
<td>0.20%</td>
<td>1.00%</td>
</tr>
<tr>
<td>V</td>
<td>0.10%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Ni</td>
<td>0.60%</td>
<td>1.00%</td>
</tr>
<tr>
<td>Sn</td>
<td>0.04%</td>
<td>0.08%</td>
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TENSILE STRENGTH ALLOYED IRON

\[ R_m = 1120 \text{ MPa} + \frac{2865}{D} \text{ (diameter test bar)} \]

- 150 (% C)
- 422 (% Si)
- 73 (% Mn – 1,7 % S)
- 181 (% Cu)²
- 164 (% Mo)²
+ 95 (% Cr) + 14 (% Ni)
+ 211 (% Cu)
+ 275 (% Mo) + 98 (% Si)²
USE OF FORMULA

RESTRICTIONS

* CALCULATION IS WITHOUT TAKING IN ACCOUNT THE COOLING

* FOUNDRY MUST PRODUCE ALWAYS SIMILAR (MELTING PROCEDURE). WE MUST DEFINE RG and RH
RG = REAL Rm / CALCULATED Rm

COMPARE 10 TO 20 REAL TEST RESULTS WITH THE CALCULATED VALUES.

RG WILL MOSTLY BE WITHIN 0,9 … 1,1
RH = REAL HB / CALCULATED HB

SIMILAR TO TENSILE STRENGTH
CHEMISTRY GREY IRON

LET’S LOOK TO THE ELEMENTS CONCERNED:

- C
- Si
- Mn
- P
- S
CHEMISTRY GREY IRON

CARBON

• DECREASE AS WELL TENSILE AS HARDNESS
• DECREASE LIQUIDUS TEMPERATURE (able to pour thinner sections: fluidity)
• INCREASE MACHINABILITY (chips will break easily)
• DECREASE TENDENCY TO POROSITY (Ceq)
CHEMISTRY GREY IRON

Free graphite

- C content
- Melted metal quality
- Inoculation
- Cooling
CHEMISTRY GREY IRON

GRAPHITE APPEARANCE

<table>
<thead>
<tr>
<th>Ceq</th>
<th>Cooling</th>
<th>Inoculation</th>
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<tr>
<td>A</td>
<td>4,3</td>
<td>slow</td>
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<tr>
<td>B</td>
<td>mixture of A and D</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>&gt; 4,3</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>all</td>
<td>quick</td>
</tr>
<tr>
<td>E</td>
<td>&lt; 4,3</td>
<td></td>
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</tbody>
</table>
CHEMISTRY GREY IRON CARBON

BEST MACHINABILITY IS:
  * HIGH CARBON CONTENT
  * GRAPHITE APPEARANCE “A”

WORST MACHINABILITY
  * LOW CARBON CONTENT
  * GRAPHITE APPEARANCE “D” and “E”
CHEMISTRY GREY IRON

SILICON

• VERY SMALL INCREASE OF TENSILE STRENGTH IF $C_{eq}$ IS EQUAL

• DECREASE WHITE SOLIDIFICATION
CHEMISTRY GREY IRON

SILICON

• NECESSARY FOR INOCULATION (FeSi with or without Al, Ca, Ba…)

• BUT NOT VERY IMPORTANT!
  SULFUR IS MORE IMPORTANT
CHEMISTRY GREY IRON
MANGANESE

INCREASE THE TENSILE STRENGTH AND HARDNESS IF

Mn / S RATIO IS CORRECT!

DANGER FOR SEGREGATION (Hot spots)
CHEMISTRY GREY IRON

SULFUR

- INCREASE TENSILE STRENGTH
- INCREASE HARDNESS
- DECREASE HOT STRENGTH

- IMPORTANT FOR GRAPHITE PRECIPITATION (SHAPE)!
CHEMISTRY GREY IRON

MANGANESE / SULFUR

\[ Mn = 1.7 \times S + a \]
CHEMISTRY GREY IRON

Mn / S RATIO

- $a = 0.10$  highest hardness
  high tensile strength
- $a = 0.10$ to $0.30$  hardness decrease
  tensile: small decrease
- $a = 0.30$  lowest tensile
- $a = 0.30$ to ...  tensile increase till...and then decrease again
- $a = 0.50$  presence of blowholes
CHEMISTRY GREY IRON

Mn / S RATIO

THIS MAKES THE FORMULA LESS VALID IF S-CONTENT CHANGES CONTINUOUSLY!

FORMULAR IS ONLY VALID IF % Mn > 0,25 %
CHEMISTRY GREY IRON

SULPHUR

IMPORTANT FOR INOCULATION!

- $S > 0.06\ %$ TO HAVE AN EFFECT
- $S > 0.15\ %$ GIVES PROBLEMS

BEST CONTENT $S = 0.08 - 0.10\ %$
CHEMISTRY GREY IRON

PHOSPHORUS

• INCREASE FLUIDITY
• INCREASE TENDENCY TO METAL PENETRATION AND FINNING (CASTING SURFACE)
• PROBLEM P-EUTECTICUM
  + DECREASE HOT STRENGTH
  + INCREASE HARDNESS
  + DECREASE MACHINABILITY
CHEMISTRY GREY IRON

DID WE FORGET AN IMPORTANT ELEMENT?
CHEMISTRY IRON

YES

NITROGEN
CHEMISTRY IRON

NITROGEN

INTRODUCED BY CARBON, WHICH CAN BE DIFFERENT FOR ELECTRICAL AND CUPOLA MELTING
CHEMISTRY IRON
NITROGEN

VALID FOR CONTENT OF 50 – 90 ppm

* N < 0,005 % VERY LOW TENSILE STRENGTH

* N 0,005 < … < 0,009 %
  TENSILE INCREASE 6 – 8 MPa / 10 ppm

* N > 0,009 % GAS PROBLEMS
CHEMISTRY IRON

THERE IS A LARGE DIFFERENCE BETWEEN CUPOLA AND ELECTRICAL MELTING DUE TO MAINLY GRAPHITE ADDITION:

DIFFERENCE IN S- AND N-CONTENT
CHEMISTRY IRON

THE FOUNDRY IS IN CHARGE

YOU CAN MASTER YOUR METAL
CHEMISTRY IRON

THEREFORE

• S AND N ARE NO HARMFULL ELEMENTS

• MELT ACCORDING TO STRICT PROCEDURE USING CORRECT MATERIAL

• CHECK ALL ELEMENTS REGULARLY