«COMPACT GRAPHITE IRON'S REAL TIME MANUFACTURING CONTROL BY THERMAL ANALYSIS»

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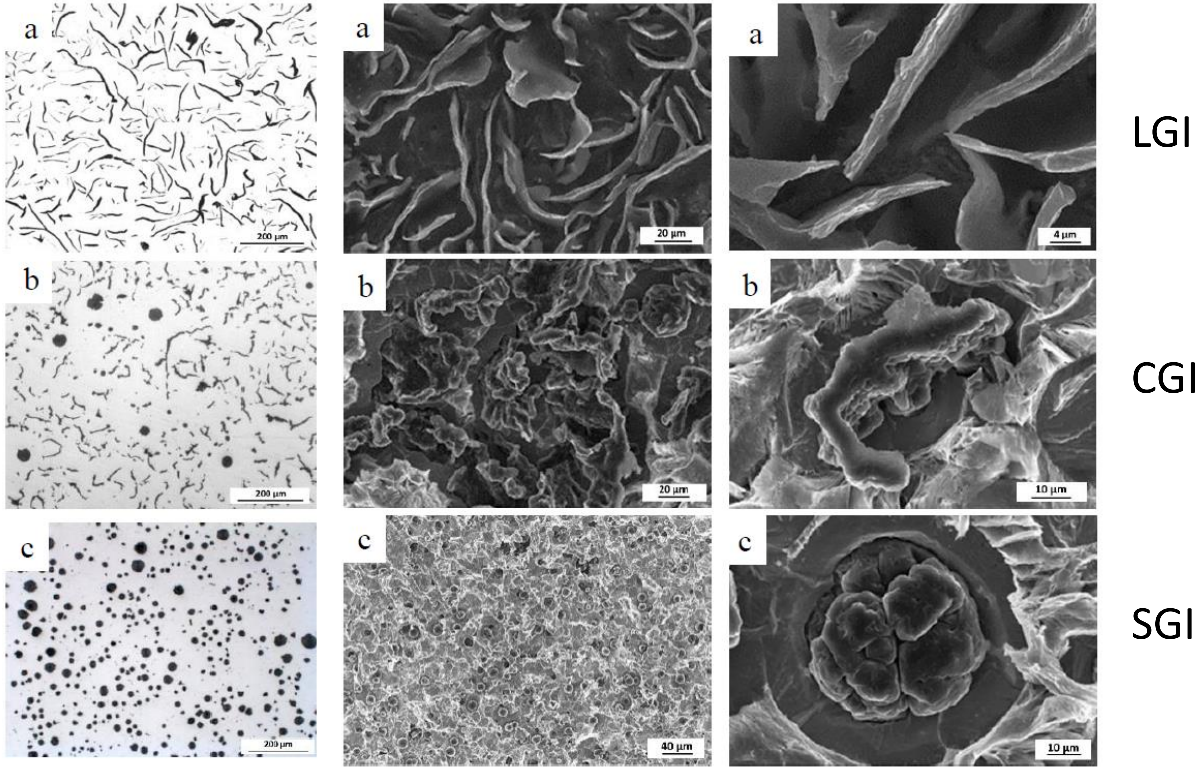
1 INTRODUCTION



VARIABLES AFFECTING CGI OBTENTION

- ✓ Spheroidizing elements amount
- ✓ Cooling rate
- ✓ Chemical composition
- ✓ Inoculation level

2 OBJECTIVES

The aim of this work is, to present how it is possible to forecast the nodularity index in real time, with only one tool that enables the consideration of all the variables that affect the graphite morphology in one test.

The study was made using thermal analysis curves, so that the process parameters can be adjusted to obtain the desired CGI.

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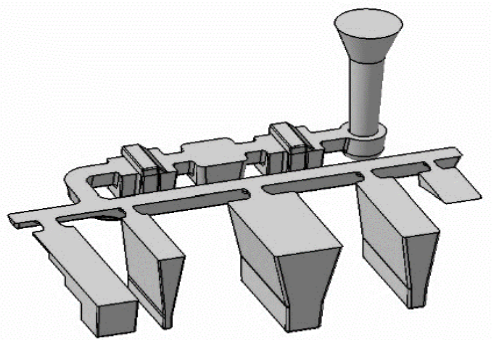
3 EXPERIMENTAL PROCEDURE

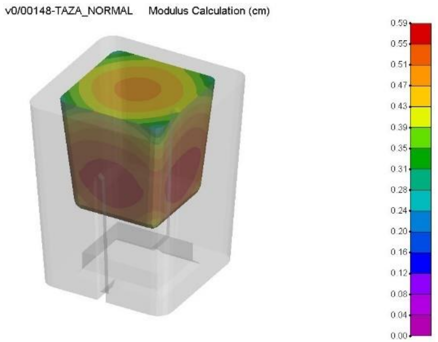
MANUFACTURING CONDITIONS

- ✓ Medium frequency induction furnace
- ✓ Metallic charge: 100% low alloy ductile iron returns (+ graphite + FeSi75)
- ✓ FeSiMg used for spheroidization treatment content(6.3 % Mg; 1.01 % Ca; 0.47 % Al and 0.87 % Rare Earth)
- ✓ Sandwich spheroidization treatment (FeSiMg 0,35-0,70 wt.%)



SAMPLING

- ✓ In order to analyze the influence of thermal moduli in nodularity index, thermal analysis cups and keel blocks Y1, Y2 and Y3 (as per EN 1563) were poured.
- ✓ Thermal modulus (TM) of samples was calculated by means of simulation software QuickCAST®. The results were of 0.70 cm for the Y1, 1.11 cm for the Y2, 1.75 cm for the Y3 block and 0.60 cm for the thermal cup.



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3 EXPERIMENTAL PROCEDURE

MANUFACTURING CONDITIONS

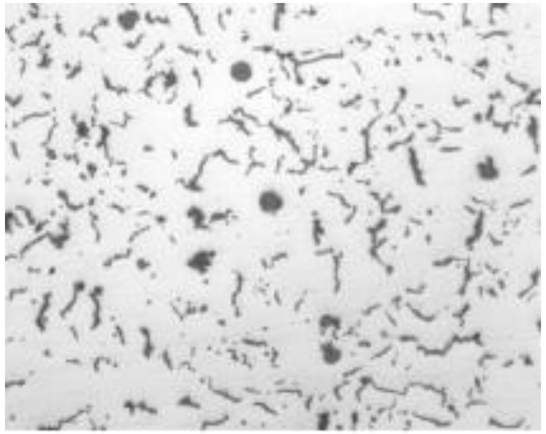
- ✓ Inoculation:
  - Thermal cups: 0,01-0,20 wt.%
  - Y samples mould: 0,05-0,20wt%
- ✓ Chemical composition was in the ranges of the table behind:

C	Si	S	Mg	Ti	P	Mn
3.44-3.86	2.00-2.84	0.002-0.023	0.009-0.033	<0.015	0.010-0.026	0.14-0.19

The silicon content was changed from one batch to another, and then carbon content adjusted to obtain in all the batches, the same carbon equivalent.

SAMPLING

- ✓ The thermal analysis tests were performed in three thermal analysis cups, a plain cubic one, a cubic one with Sulphur addition and a cubic one with tellurium addition and their solidification curves registered and analyzed by Thermolan® software.
- ✓ Thermal center of the thermal cups and the lower zone of Y blocks was prepared for metallographic inspection. Nodularity index was measured by means of image analysis software, using 10 fields of each sample at 100 magnifications.



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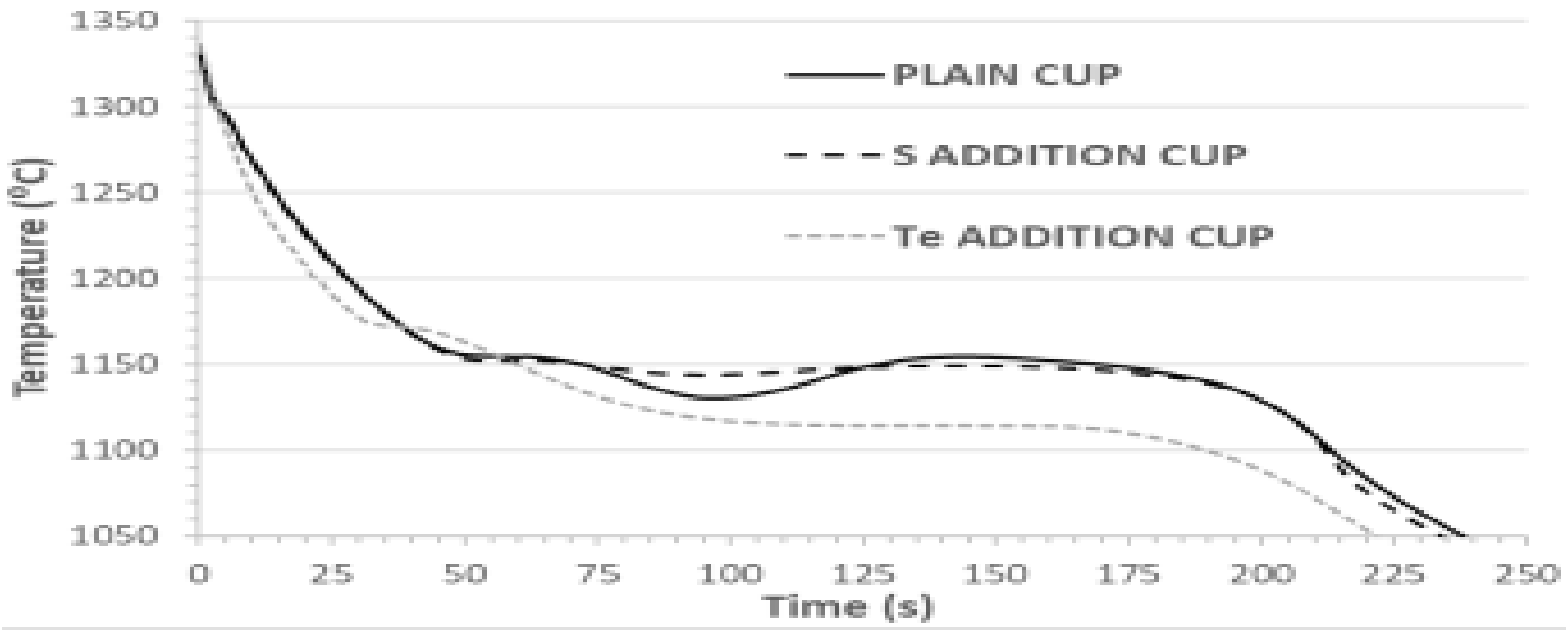
4 RESULTS AND DISCUSSION

THERMAL ANALYZED RESULTS



- **<u>The Plain cup</u>** is the reflection of the melt that is going to be poured in the moulds (inoculated or not inoculated).

- **<u>The cup with the Sulphur</u>** addition, illustrates the form that a lamellar iron with the same chemical composition would have (inoculated or not inoculated).
- **<u>The cup with the Tellurium</u>** addition, depending on the free magnesium is going to be a white or a graphitic curve.

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4 RESULTS AND DISCUSSION

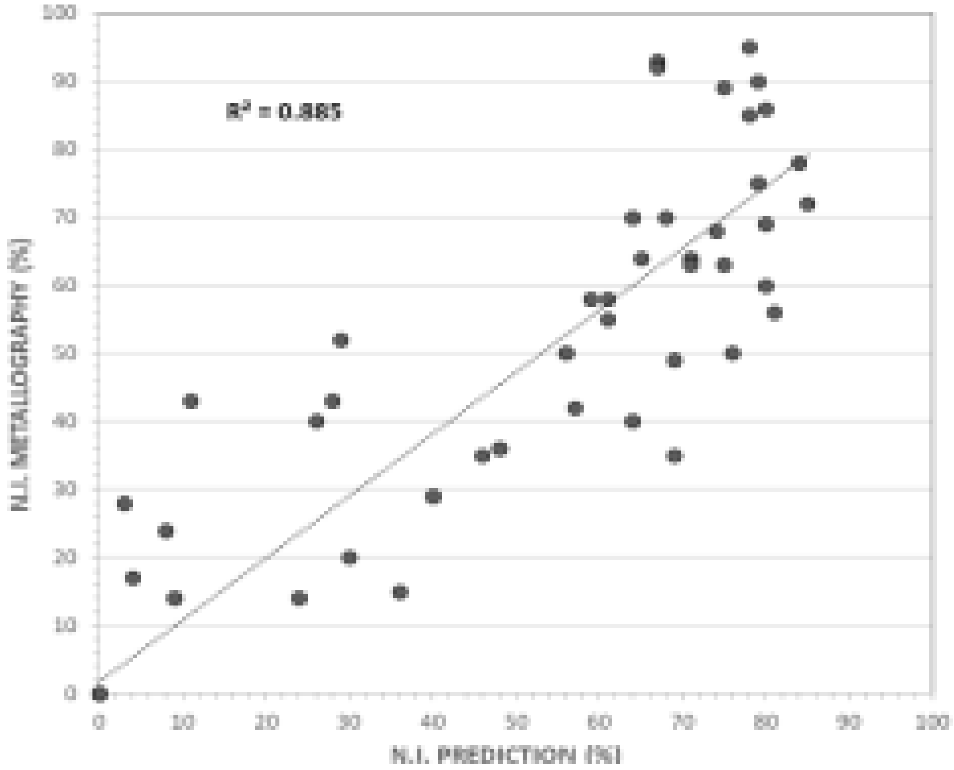
✓ A prediction of the nodularity index is given, following the next equations:

- **If the tellurium cup is white, then equation [1]:**

N.I. (%) $= C_0 + C_1 \times T_{emin\ PLAIN} + C_2 \times T_{emax\ PLAIN} + C_3 \times T_{sol\ PLAIN} + C_4 \times T_{emin\ S} + C_5 \times T_{emin\ TE} + C_6 \times (T_{emax\ PLAIN} - T_{emax\ S}) + C7 \times (SLOPE_{MAX\ Temin\ PLAIN\text{-}Temax\ PLAIN}) + C8 \times (SLOPE_{MAX\ Temin\ S\text{-}Temax\ S}) + C9 \times (SLOPE_{MAX\ Temin\ TE\text{-}Temax\ TE}) + C10 \times (t_{Temin\ S}) + C11 \times (t_{Tliq\ TE})$ [1]

- **If the tellurium cup is graphitic, then equation [2]:**

N.I. (%) $= C_{12} + C_{13} \times T_{emin\ PLAIN} + C_{14} \times T_{emax\ PLAIN} + C_{15} \times T_{emin\ S} + C_{16} \times T_{emax\ S} + C_{17} \times T_{emin\ TE} + C_{18} \times T_{emax\ TE} + C_{19} \times (SLOPE_{MAX\ Temin\ PLAIN\text{-}Temax\ PLAIN}) + C_{20} \times (SLOPE_{MAX\ Temin\ S\text{-}Temax\ S}) + C_{21} \times (SLOPE_{MAX\ Temin\ TE\text{-}Temax\ TE})$ [2]



Labeling:

"PLAIN", "S" and "TE" indicate the different thermal analysis cups.
T_{emin}, T_{emax} and T_{sol} are eutectic minimum and maximum and solidus temperatures.
$SLOPE_{MAX\ Temin\text{-}Temax}$ refers to the maximum slope in between T_{emin} and T_{emax}.
t_{Temin} and t_{Tliq} indicate time up to eutectic minimum and liquidus temperatures from 1250ºC.

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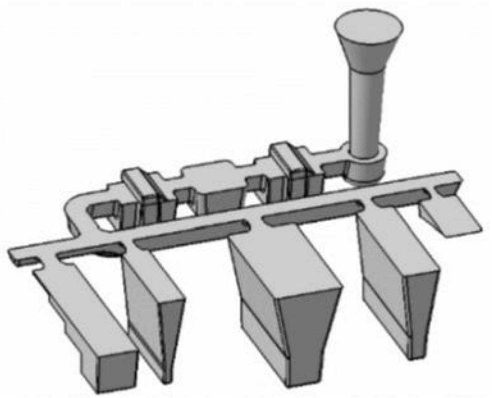
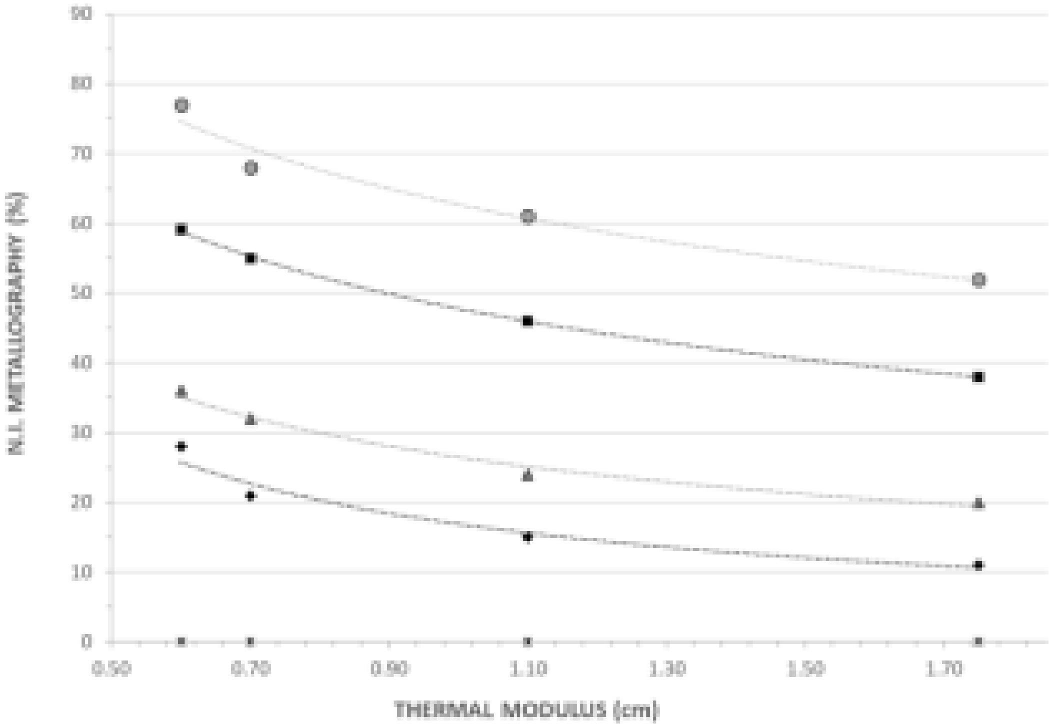
4 RESULTS AND DISCUSSION

Regarding the extrapolation of the thermal analysis cups results to the different sections of a given casting, in figure is shown the relationship between the studied thermal moduli (0.60-0.70-1.11 and 1.75 cm).





These results were obtained considering the same melt and inoculation conditions for all the samples. In total, 24 trials were analyzed, but as the tendency was similar in all of them, for the sake of clarity, only 5 are shown.

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4 RESULTS AND DISCUSSION

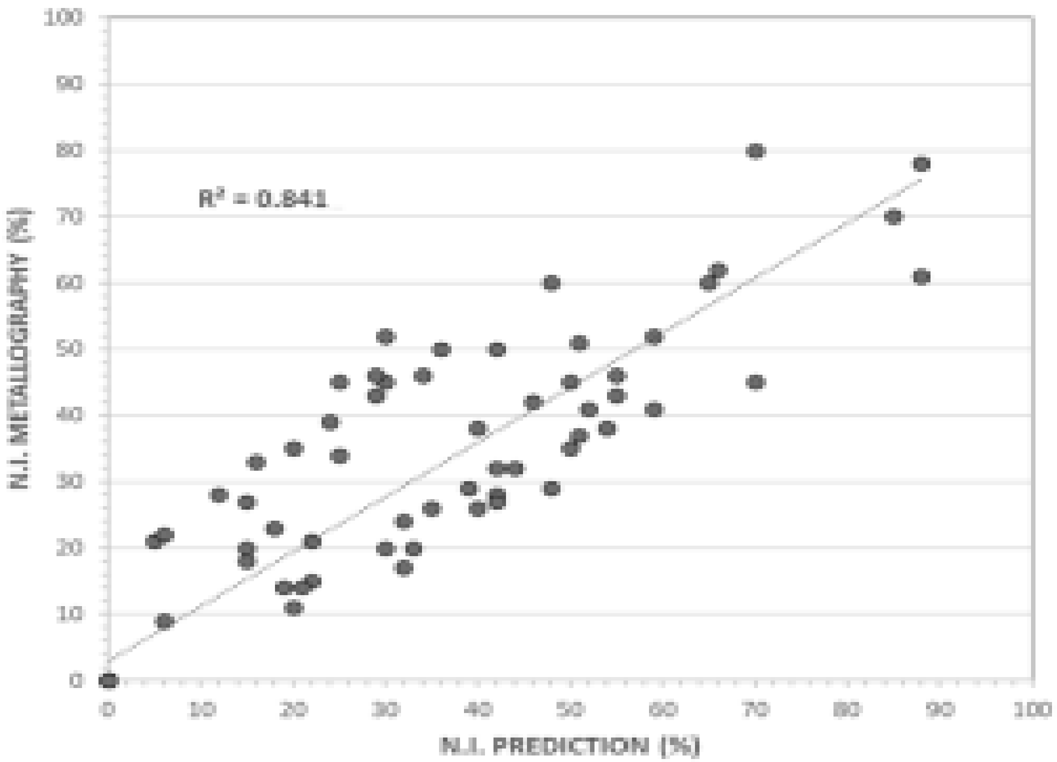
Equation [3] was used to extrapolate the results from the thermal analysis cups to other thermal moduli.

The exception would be, when the nodularity index of the thermal cup is 0 %, that is, the cup is lamellar iron, then all the higher thermal moduli, would also be lamellar (N.I. = 0%).

$$N.I._{TM}\ (\%) = C_{22} \times N.I._{TA} + C_{23} \times TM^{C24} \quad [3]$$

Being the subscripted labels:
"TM" and "TA" the corresponding data of the thermal modulus that is being studied and the data of the thermal analysis cup respectively.

TM corresponds to the thermal modulus of the area of the casting that is being analyzed.



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5 CONCLUSIONS

- A predictive tool was presented to forecast the nodularity index for compact graphite iron production based on thermal analysis techniques.

- The methodology does not need any external input and using three solidification curves, is sensitive enough to take into consideration the different process variables that affect the graphite shape, like spheroidization treatment, inoculation etc.

- The nodularity index prediction is performed on a first step for a thermal analysis standard cup and afterwards, applying the thermal modulus concept, the results can be extrapolated to the different areas of a casting. In both cases, the prediction and the metallographic analysis present a good correlation.

- Considering this predictive system as a process control for compact graphite iron production, results can be obtained in less than 3 minutes and thus take the necessary corrective actions before pouring to guarantee that the graphite morphology is going to be the desired one.

GO/NO GO TEST DEFINING IF THE MELT IS OK/NOT OK FOR CGI PRODUCTION:

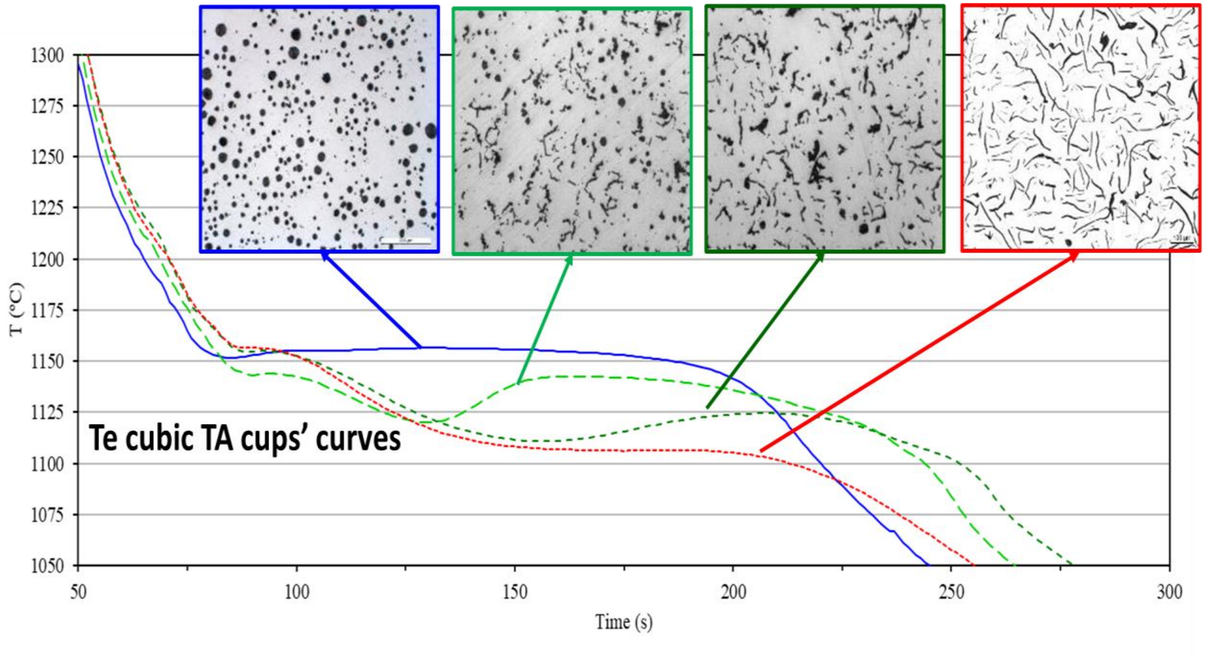
(Only one Tellurium cup required)

THREE DIFFERENT OUTPUTS:

1- GREY IRON. NOT OK. CHANCE TO CORRECT ADDING Mg.

2- MELT OK FOR CGI PRODUCTION. POUR THE MOLDS.

3- TOO HIGH NODULARITY. NOT OK. TOO MUCH Mg.



Free Mg % = f(Temin, Recalescence)

«MECHANICAL PROPERTIES OPTIMIZATION OF AS-CAST AUSFERRITIC DUCTILE IRON AS A FUNCTION OF SECTION SIZE AND HOLDING TIME»

Thank you for your attention

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