

# Use of thermal analysis in iron casting: MAIN APPLICATIONS

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*Thermal analysis: an accessible, high value tool for process control in iron casting*

AZTERLAN Metallurgy Research Centre ([www.azterlan.es](http://www.azterlan.es)) is presenting, over a series of three articles, the fundamental principles of this widely used technique for process control in foundries.

Following the first article, which outlined the basic operating principles of the technique, this second contribution focuses on key applications that have been successfully implemented in highly competitive foundries.

A third and final article will provide a more advanced perspective on in-line quality control, combining thermal analysis with simulation of filling and feeding systems.

## INTRODUCTION

In today's highly demanding industrial environment, where quality excellence and cost reduction are essential to remain competitive in global markets, process control tools have become critical.

Thermal analysis has established itself as a reliable and widely adopted tool for metallurgical control in the production of graphite cast irons.

In the previous article (published in the April/May 2026 issue of *Foundry Trade Journal*), the theoretical foundations of thermal analysis systems were presented, highlighting their potential for process optimisation.

This article focuses on practical applications of thermal analysis, presenting case studies where implementation has led to measurable improvements in both process stability and final product quality.

## INSTRUMENTATION

All thermal analysis systems are based on recording and analysing the cooling curve of molten metal during solidification and subsequent cooling.

In practice, molten metal is poured into a standard pre-coated sand cup equipped with a thermocouple. The signal is transferred to a data acquisition unit, providing temperature readings over time. This enables the evolution of temperature [°C] versus time [s] to be tracked, capturing key transformations such as liquid-to-solid, eutectic and solid-state (eutectoid) transformations.

A typical example of such curves is shown in fig.1.

Different types of commercial cups are used depending on the application.

The recorded data are automatically processed, and key parameters are displayed according to the selected configuration. The use of numerical outputs removes subjectivity from result interpretation.

## IMPLEMENTATION OF THERMAL ANALYSIS IN PRODUCTION FACILITIES: LAY-OUTS

Thermal analysis is commonly used on melting platforms, mainly to determine carbon and silicon levels in molten metal, as discussed later. It also plays an important role in the pouring area, where it is used to assess the metallurgical quality of the metal prior to casting.

As a result, a wide range of equipment layouts can be found in industrial environments (fig.4), from simple configurations to more advanced setups where a single unit controls multiple moulding lines, including wireless data transfer and remote result visualisation in decision making areas (fig.5).

## MAIN APPLICATIONS

### Chemical composition estimation (GJL – GJS – GJV)

Transformation temperatures are directly related to chemical composition, allowing carbon and silicon contents to be calculated from the cooling curve based on the metastable model. For this purpose, cups with Te addition are used for grey iron (GJL), and cups with Te and Mg neutraliser are used for ductile and compacted graphite irons (GJS and GJV).

The uncertainty in carbon measurement using Thermolan®, for example, is below 0.05 per cent (k=2), comparable to combustion techniques. In addition, results are available within seconds, offering a clear advantage in production environments.

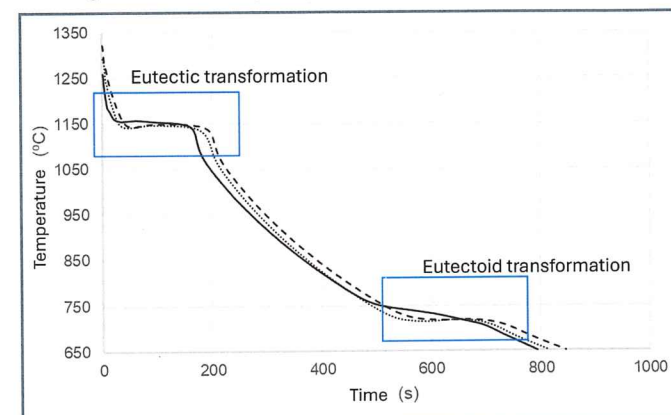


Fig.1 Solidification and cooling curves recorded using thermal analysis cups

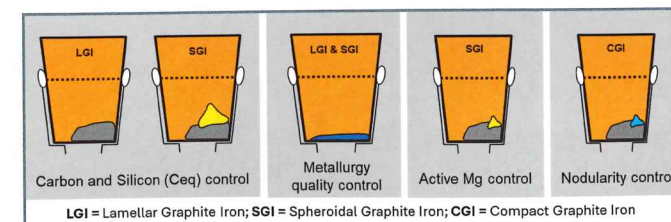


Fig.2 Types of commercial cups used for thermal analysis, depending on the application



Fig.3 Typical application of a thermal analysis system on the melting platform, with on-site results visualisation

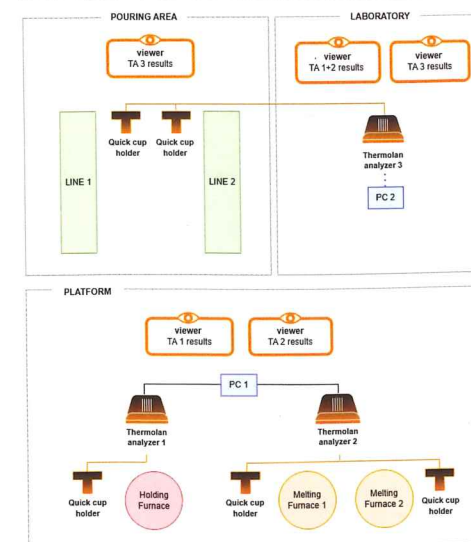


Fig.4 Layout of the implementation of thermal analysis in the melting and pouring areas of a plant with multiple production lines. Implementation of data visualisation displays at key decision making points



Fig.5 Thermal analysis results display (Thermolan®) integrated with other plant control parameters for process management and decision making

Recent developments have focused on extending the controllable range of carbon and silicon, as shown in fig.6.

### Active magnesium control (GJS)

Total magnesium content does not guarantee adequate nodularity. Part of the magnesium can react with sulphur, oxygen or other elements, leading to a fading (or loss) of magnesium activity.

For this reason, foundries are primarily interested in active magnesium, defined as the fraction effectively available in the molten metal after treatment.

Thermal analysis systems can determine whether the metal meets the minimum active Mg threshold required to ensure proper nodularisation.

This application is based on proprietary control cups capable of identifying not only threshold limits but also active Mg ranges.

### Metallurgical quality control (GJL – GJS)

Metallurgical quality control ensures that melting and treatment processes are sufficient to achieve the required mechanical and functional properties. Monitoring the metal prior to pouring provides valuable information for process control.

The recording of the solidification curve makes it possible to parameterise the nucleation potential of the metal, as well as to predict the tendency for carbide formation and microshrinkage. Some thermal analysis systems are capable of predicting the nodule count and the self-feeding capacity of the metal in GJS. In GJL, it is also possible to predict the percentage of A-type graphite or various numerical factors related to metallurgical quality.

Results obtained from thermal analysis cups can be extrapolated to different areas of castings, enabling earlier decision making and cost optimisation through adjustment of ladle additions based on dynamic pre-inoculation concepts.

The results of a complete test for GJS, including composition

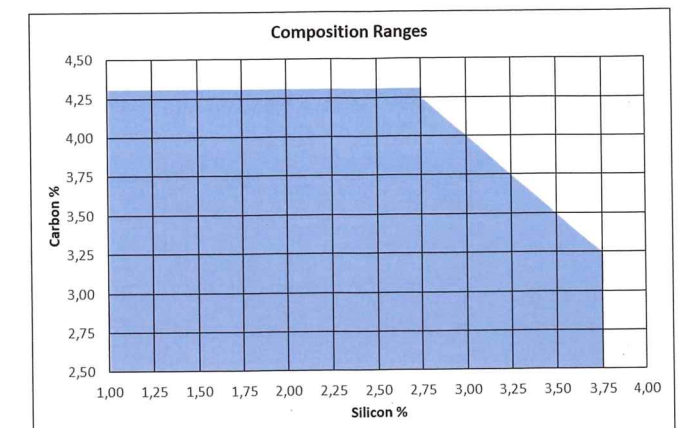


Fig.6 Extended control range for C and Si using Thermolan®



Fig.7 Example results for metallurgical quality control (GJS)



Fig.8 Results for metallurgical quality control of GJV, including extrapolation of results to specific areas of the component

control, active Mg threshold and metallurgical quality assessment of the metal, are shown in fig.7.

### Nodularity Index (NI) control in GJV

Some systems also provide solutions for controlling compacted graphite iron production using a single cup. The cooling curve is used to determine whether the metal falls within the required window for CGI production, reducing the risk of flake graphite formation.

As with other applications, results can be extrapolated to different sections of castings with complex geometries.

## PRACTICAL APPLICATION CASES OF THERMAL ANALYSIS

The integration of thermal analysis into process management enables intelligent, precise and optimised control of molten metal treatment, both in the spheroidisation stage and in conditioning and inoculation processes. It also ensures control of nodularity and overall metallurgical quality.

Case 1: Minimum active Mg control in GJS

Plant overview:

- Production: 14,000 t/year (75 per cent ductile iron, 25 per cent grey iron).
- Two horizontal high pressure moulding lines.
- Two medium frequency induction furnaces (8t).
- Wire feeding nodularisation in 1,000kg ladles.

Initial situation:

Due to the inability to ensure Mg content prior to pouring, the plant applied an average over treatment of 25.3m/t to guarantee a minimum Mg level.

Proposal:

Implementation of a thermal analysis system for early detection of minimum active Mg threshold.

Results:

- 100 per cent detection of insufficiently treated ladles.
- 22 per cent reduction in wire consumption.
- Estimated annual savings: US\$78,000.00 (€66,000.00).

Case 2: GJV production control

Plant overview:

- Production: 36,000 t/year (45 per cent ductile iron, 55 per cent compacted graphite iron).
- Three vertical moulding lines with pressurised pouring.
- Six medium frequency induction furnaces (10t).
- Sandwich nodularisation in 1,800kg ladles.

Initial situation:

No predictive control system was available. Validation relied on chemical analysis with a delay of three treatments, resulting in rejection of four treatments. Average defect rate: 0.1 per cent.

Proposal:

Implementation of a thermal analysis system providing early warning of defective treatments.

Results:

- 100 per cent early detection of defective ladles.
- Elimination of in-process rejection.
- Estimated annual savings: US\$48,000.00 (€41,000.00).

Case 3: Metallurgical quality control in GJS

Plant overview:

- Production: 24,000t/year (100 per cent ductile iron).
- Two vertical moulding lines with pressurised pouring and in-stream inoculation.
- Four medium frequency induction furnaces (12t).
- Sandwich nodularisation in 1,500kg ladles.

Initial situation:

A 0.30 per cent pre-inoculant addition was applied without metallurgical quality control, making its effectiveness unknown.

Proposal:

Implementation of thermal analysis to assess metallurgical quality under different pre-inoculation conditions.

Results:

- Definition of a systematic metallurgical quality control approach.
- 33 per cent reduction in pre-inoculant addition.
- Estimated annual savings: US\$140,000.00 (€120,000.00).

The blue section (left) presents practical case studies based on the implementation of the Thermolan® thermal analysis system, currently used in several foundries worldwide. The examples have been anonymised and the data adapted to preserve the confidentiality of the companies involved. In all cases, the implementation of thermal analysis was part of projects aimed at optimising process stability and the quality of the production metal.

CONCLUSIONS

Process control through thermal analysis tools has become a key requirement for foundries aiming to enhance their competitiveness. These technologies not only enable real-time monitoring of metal behaviour, but also allow deviations to be anticipated and decision making to be optimised at critical stages of the production process.

In this context, the evolution of control systems and the growing relevance of generated data have driven the integration of additional tools capable of complementing traditional thermal analysis. The combination of multiple sources of information — from metallurgical quality to process variables — provides a higher level of context, significantly improving predictive capabilities and moving foundries closer to zero defect manufacturing strategies.

Furthermore, integrating information related to in-plant metal quality with the geometric characteristics of components and the specific conditions of feeding systems enables a deeper understanding of the root causes of defects. This holistic approach facilitates the correlation between process parameters and final results, allowing for more precise adjustment of manufacturing conditions and advancing towards more robust, efficient and sustainable production models.

A forthcoming article will further explore how predictive models, applied to real component designs and feeding systems and supported by representative data on metal quality in production, can be used to optimise mould and tooling design. In addition, the use of these models in combination with real-time data will enable the anticipation of deviations and contribute effectively to defect prevention in manufacturing.



Fig.9 Calculation of the amount of Mg to be added based on data from previous treatments, carried out using AZTERLAN's Dosing Track intelligent system



Fig.10 Calculation of pre-inoculation addition in the nodularisation treatment, performed using AZTERLAN's Dosing Track intelligent system