

Oxygen Activity Measurements in Cast Iron

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Research and application development

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- former Flemish Foundry Institute, now Materials Research Center
- 10 years experience in active Oxygen measurement in cast iron

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Presentation Overview

- **History and use of oxygen activity sensor**
- **Explanation of how sensor functions**
- **Overview of research**
- **Results**
- **Conclusions**
- **Applications for oxygen activity sensor**



Origins of Oxygen Activity Sensor

— 1972 : High Oxygen Steel

- Oxygen determination from 50ppm to 1,000ppm

— 1980 : Low Oxygen Steel

- Oxygen determination from 1ppm to 1,000ppm

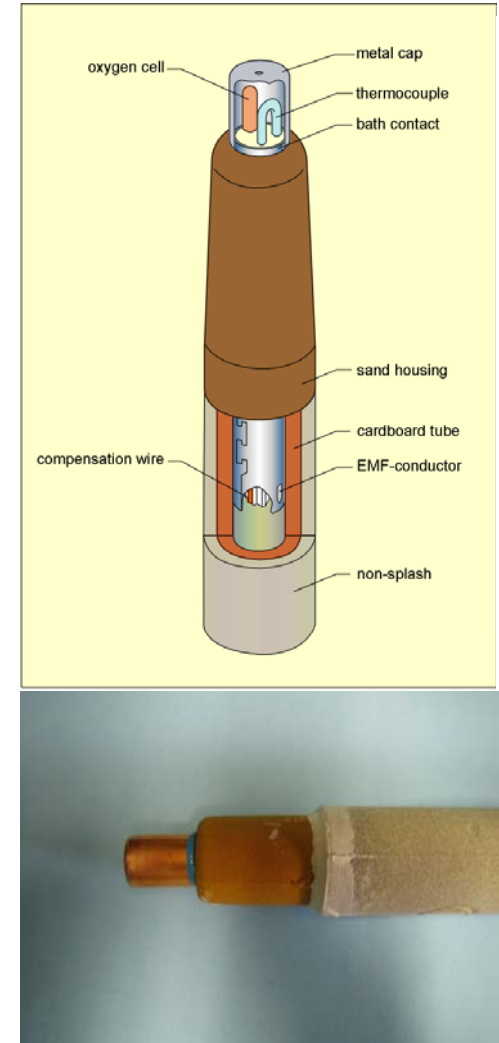
1995 : First Foundry Application

- Oxygen determination to 0.01 ppm
- Poor reproducibility at lower T and high Mg

2005 : Latest Foundry Sensor

- Oxygen determination to 0.001 ppm level (=1 ppb)
- Very reproducible
- Plasma sprayed coating on oxygen cell

ppb = parts per billion = 0,001ppm = 0,0000001%



Using the sensor

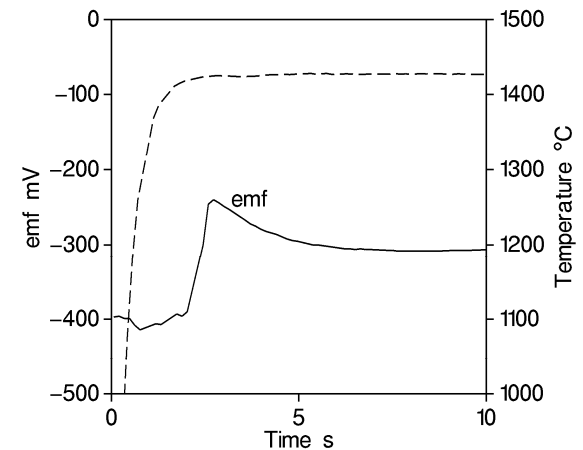


1. Disposable sensor is attached to the end of a pole
2. Plunged into melt
3. Test takes approximately 10-12 seconds
4. Identical to using an immersion thermocouple

Calculation of Oxygen Activity

— Sensor measures 2 signals:

- **Temperature:**
 - by the built-in thermocouple
- **EMF (ElectroMotive Force):**
 - in mV
 - by the built-in electro-chemical Oxygen cell (O-cell)



— According to the law of Nernst the free oxygen activity can be calculated:

$$\log a(O) = 8.62 - [13580 - 10.08(E + 24)] / T$$



a_O = oxygen activity in ppm
 E = electric potential in mV
 T = temperature in K



Oxygen Activity (a_{O}) \neq Total Oxygen Content

Oxygen Activity:

- **Dissolved oxygen in the melt.**

Total Oxygen:

- **All the oxygen in the melt, in any state.**

Goal of Research

Establish a useful relation between oxygen activity and various properties of ductile iron.

Oxygen Activity



- Yield/Tensile Strength
- Hardness
- Elongation
- Ferrite content
- Nodularity



Experimental Procedure

- Add Mg to a melt (500 lb)
- Hold the melt at temperature (2,550 – 2,624°F)
- Measure oxygen activity every 3 minutes
- Gather chemistry samples every 1 minute
- Pour Y-blocks (Keel block) every 4 minutes
 - Mechanical properties
 - Graphite morphology + ferrite/pearlite

Follow transition from ductile iron to compacted graphite cast iron



Test Procedure

— Oxygen Activity

— Microstructure

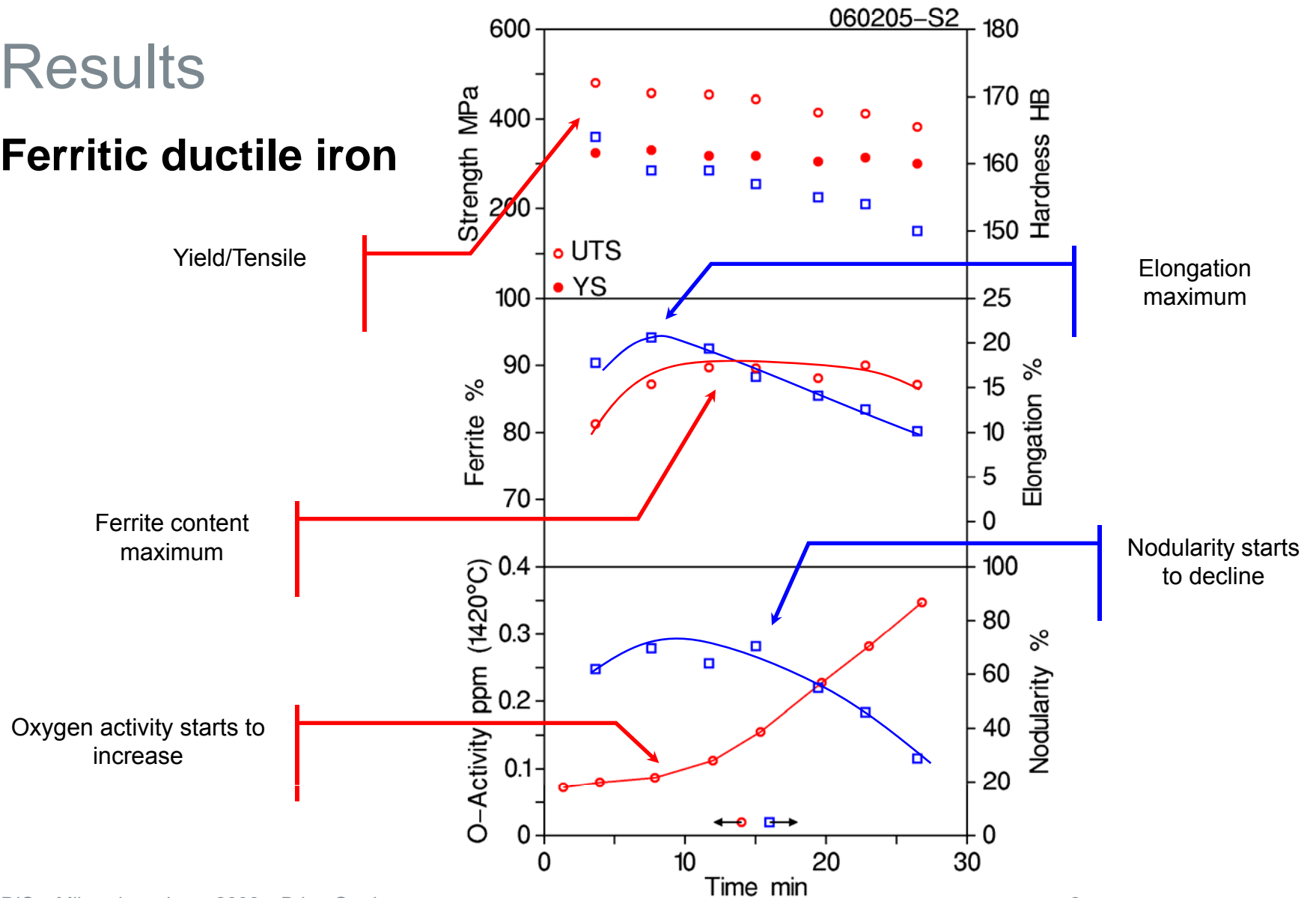
- **Nodularity (MamVision)....length/thickness ratio**
- **Ferrite/Pearlite ratio (MamVision)**

— Mechanical properties

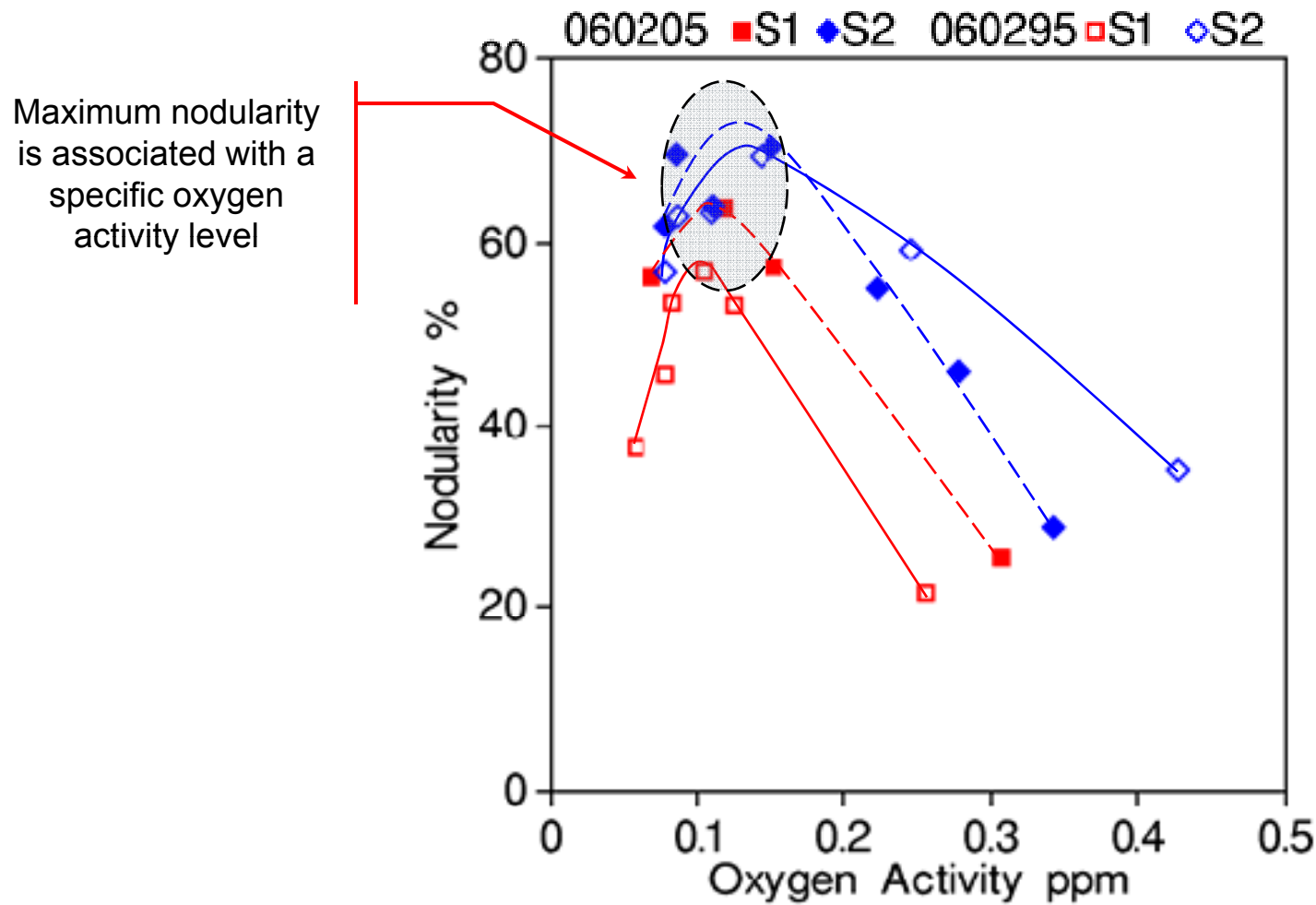
- **Ultimate Tensile Strength UTS**
- **Yield Strength**
- **Elongation**
- **Brinell hardness-HB**

Results

Ferritic ductile iron

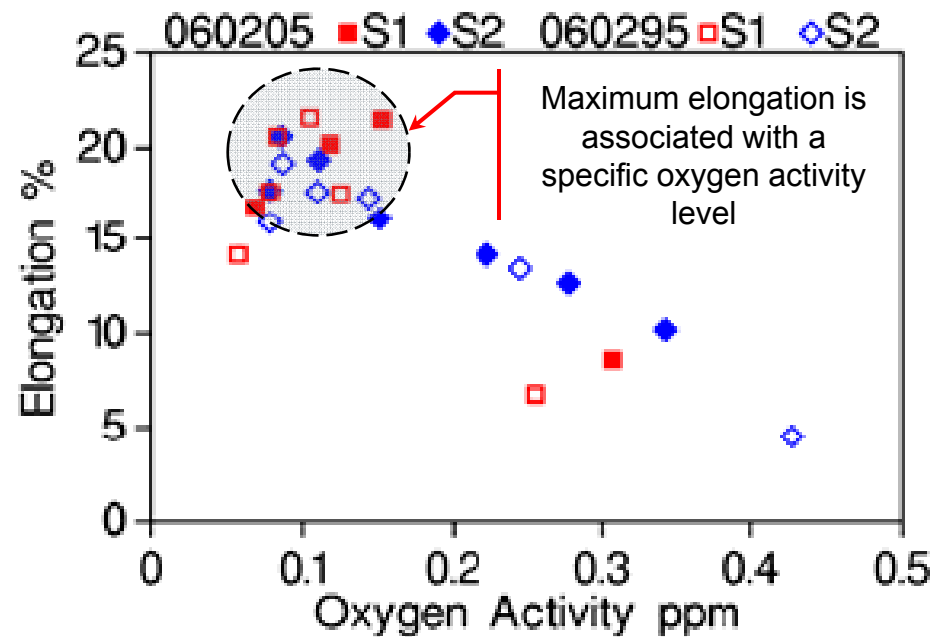
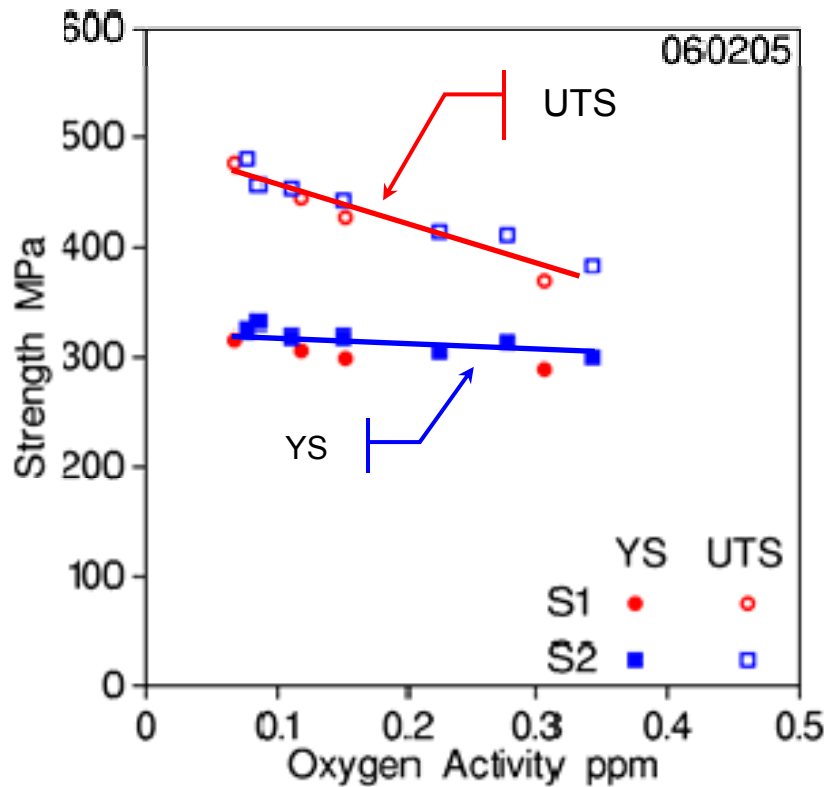


Ferritic ductile iron: Nodularity vs Oxygen Activity



Ferritic ductile iron:

Strength and Elongation vs Oxygen Activity





Conclusions

1. During all experiments, stable and reproducible oxygen activities were obtained.
2. Optimal mechanical properties were obtained for a well-defined oxygen activity range. This is the result of high ferrite content and high nodularity occurring simultaneously.
3. The change of properties during magnesium fade is well known. However, measuring the oxygen activity gives the ability to accurately track these changes during production.



Applications for this technology

Producers of large ferritic/pearlitic DI castings

- Wind energy industry....big in Europe

Biggest response came from CGI producers

- 8 foundries currently using/evaluating technology
- 6 of them are for use in CGI production
 - Engine blocks for low emission diesel engines



For More Information

- **Ductile Iron Society**

- **2008 Symposium on Ductile Cast Iron. October in Las Vegas.**

- **Dr. Mampaey & coauthors will be presenting**

- **All information on SGI**
- **More on CGI**



Questions