COMUNICAÇÃO TÉCNICA

N° 180022

FERA II: AC 3: alloy development for gray cast iron coating

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FeB+C Ferramentarias Brasileiras Mais Competitivas

FERA II

FERRAMENTAS MANUFATURADAS ADITIVAMENTE

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CONFIDENTIAL

General objective

FeB+C

Development of a new alloy for deposition over a gray cast iron substrate with a thickness of 1 mm, aiming at the application on stamping tools for class A surface finishing

Constraints and boundary conditions:

FeB+C

- The alloy must be processed by DED-LB (processability aspects)

- The alloy must meet the properties required by the application

- The alloy should be suitable for post-processes (machining, nitriding, etc.)

- An interlayer material should not be used

Processability aspects

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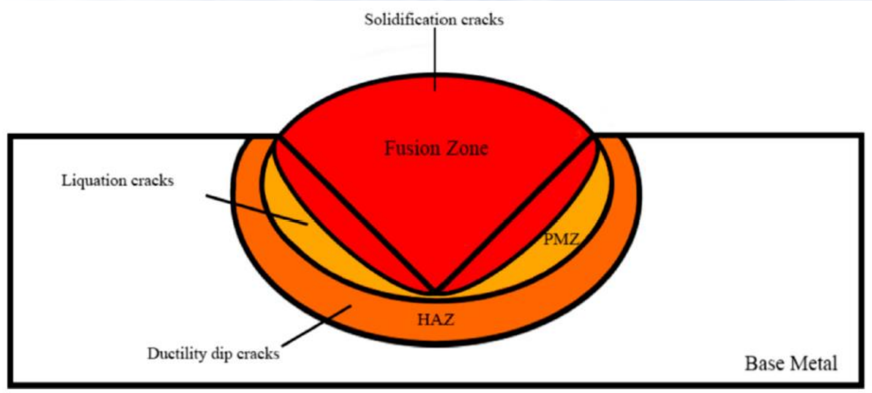
The most important defects that hinder the processability are cracks (cold and hot)



Regions:

- **Deposition region (cold or hot crack)**
- **Dilution region (cold or hot crack)**
- PMZ: partially melted zone (cold crack; liquation crack)
- HAZ: heat-affected zone (cold crack)
- Substrate (cold crack)

A .Wall, M. J. Benoit, A review of existing solidification crack tests and analysis of their transferability to additive manufacturing, Journal of Materials Processing Tech. 320 (2023) 118090

Steps to deal with the challenge

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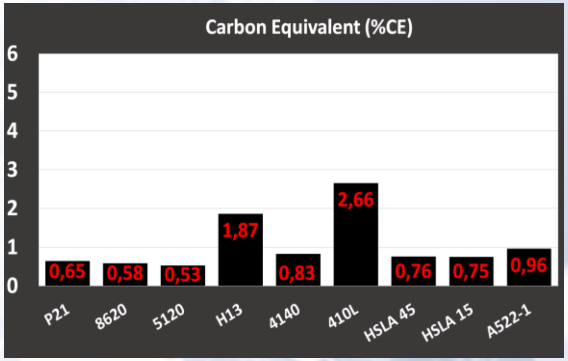
- Literature review about the materials and strategies to coat cast iron using DED-LB.

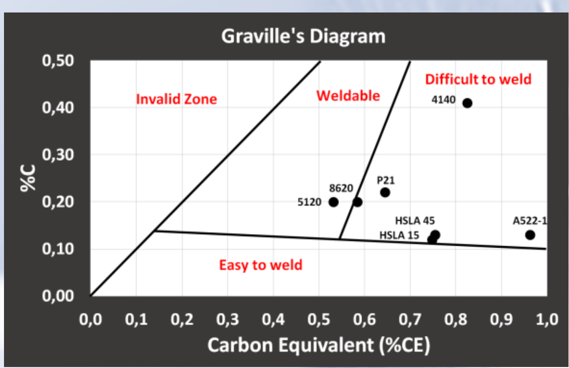
- Comparison of the alloys using several parameters, some of them calculated using thermodynamics simulations (Thermo-Calc), considering the phenomena related to the defects (cold and hot cracks).

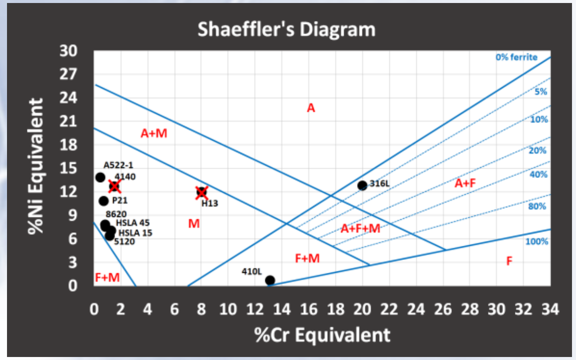
Alloys comparison

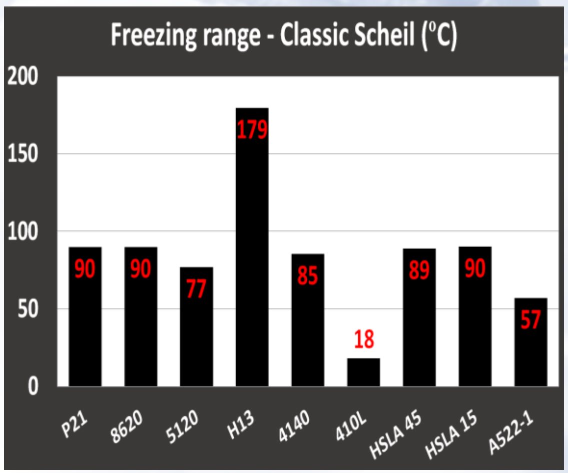
FeB+C

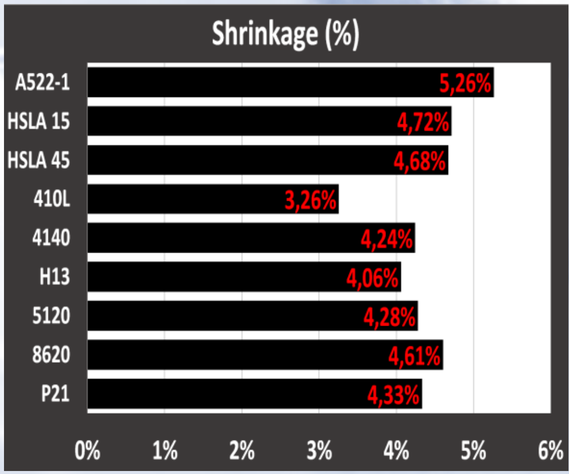
Deposition region

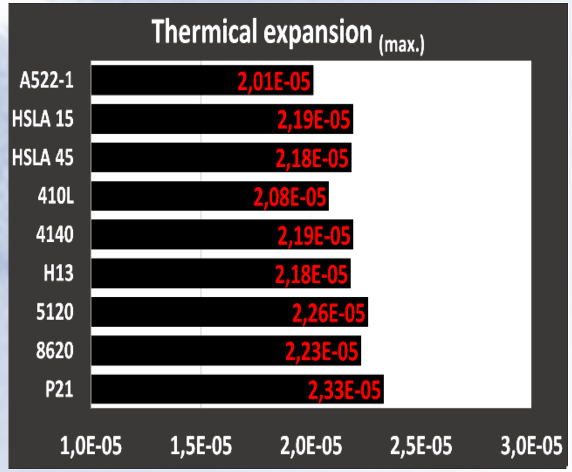








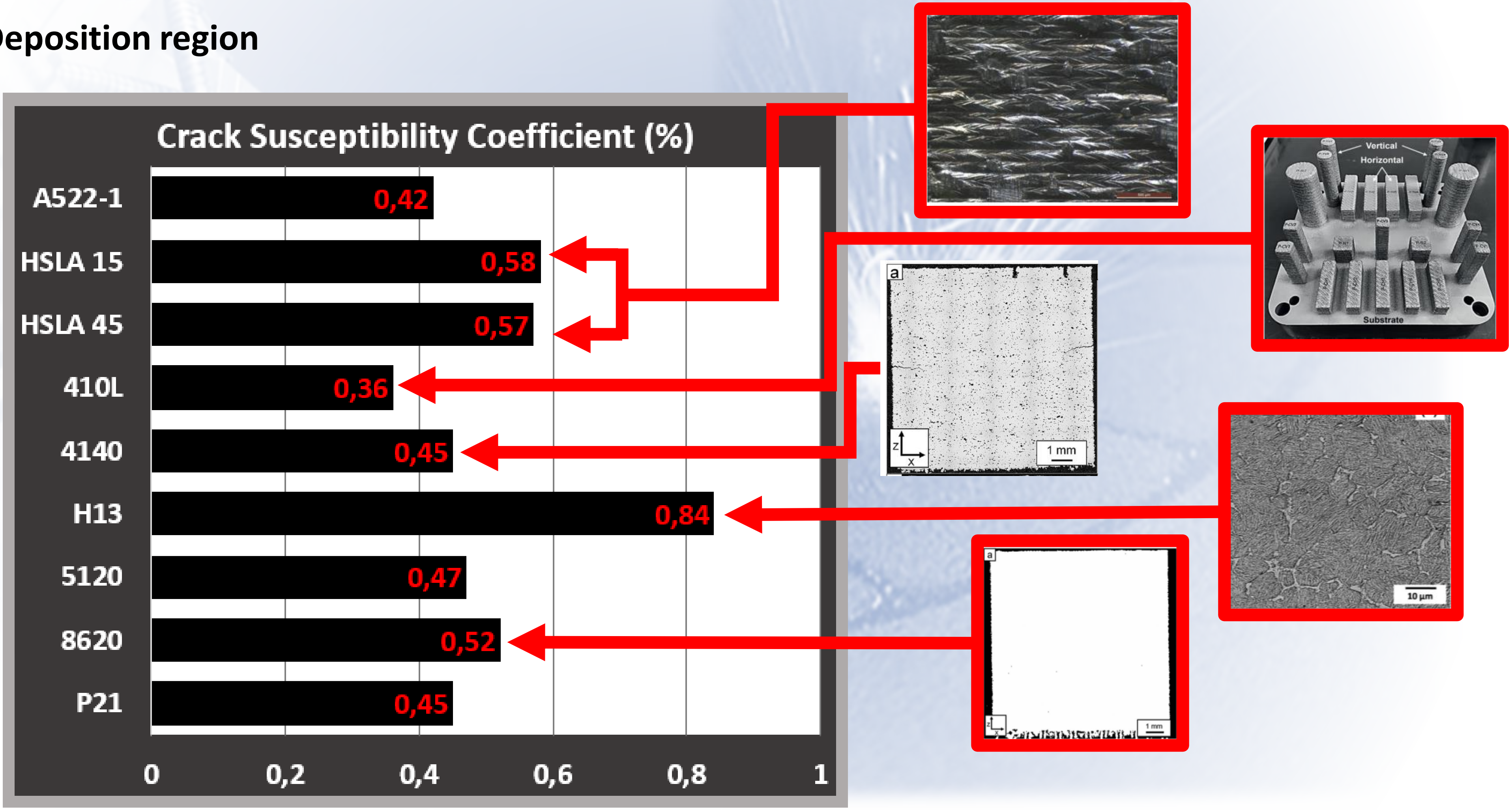




Alloys comparison

FeB+C

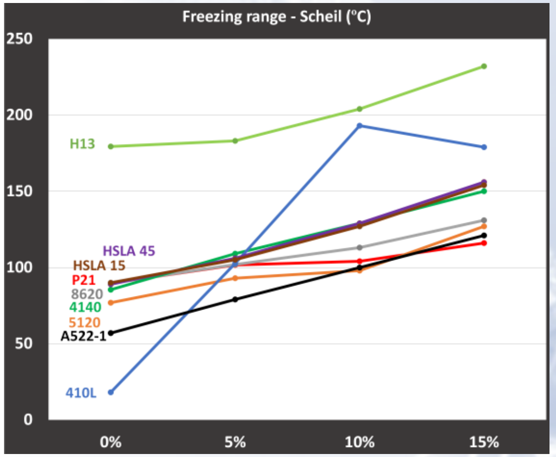
Deposition region

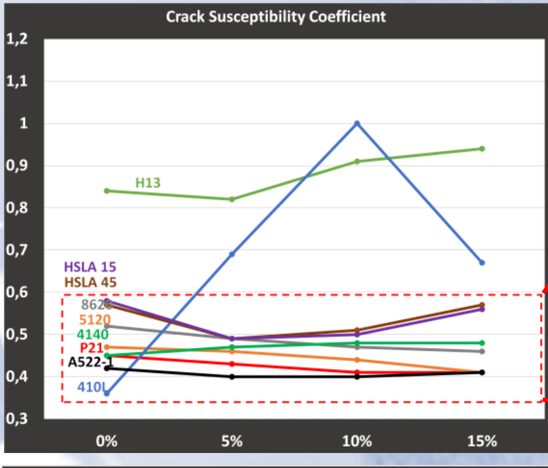


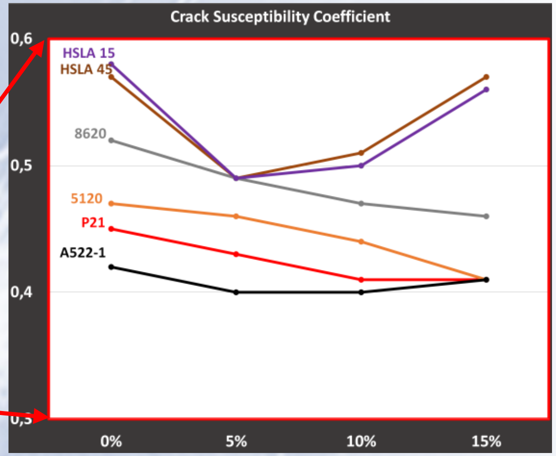
Alloys comparison

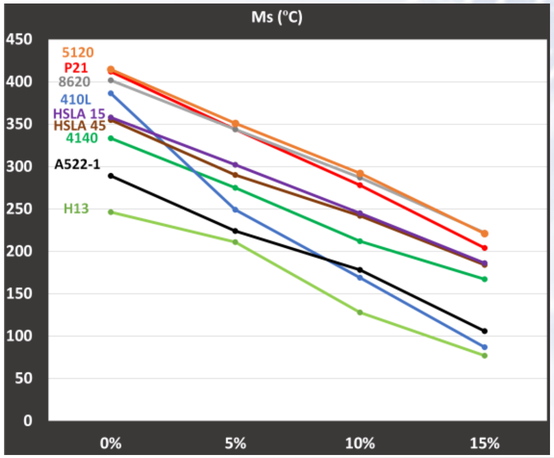
FeB+C

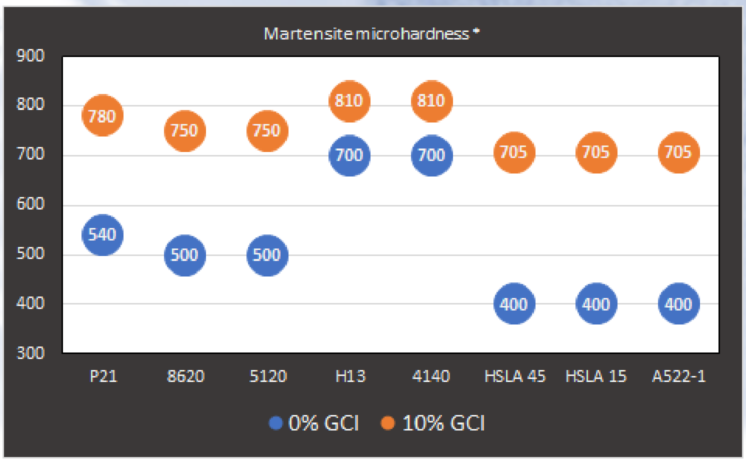
Dilution region











* Krauss, George. "Martensite in steel: strength and structure." Materials science and engineering: A 273 (1999): 40-57.

ASTM 522 type I: Casting

FeB+C

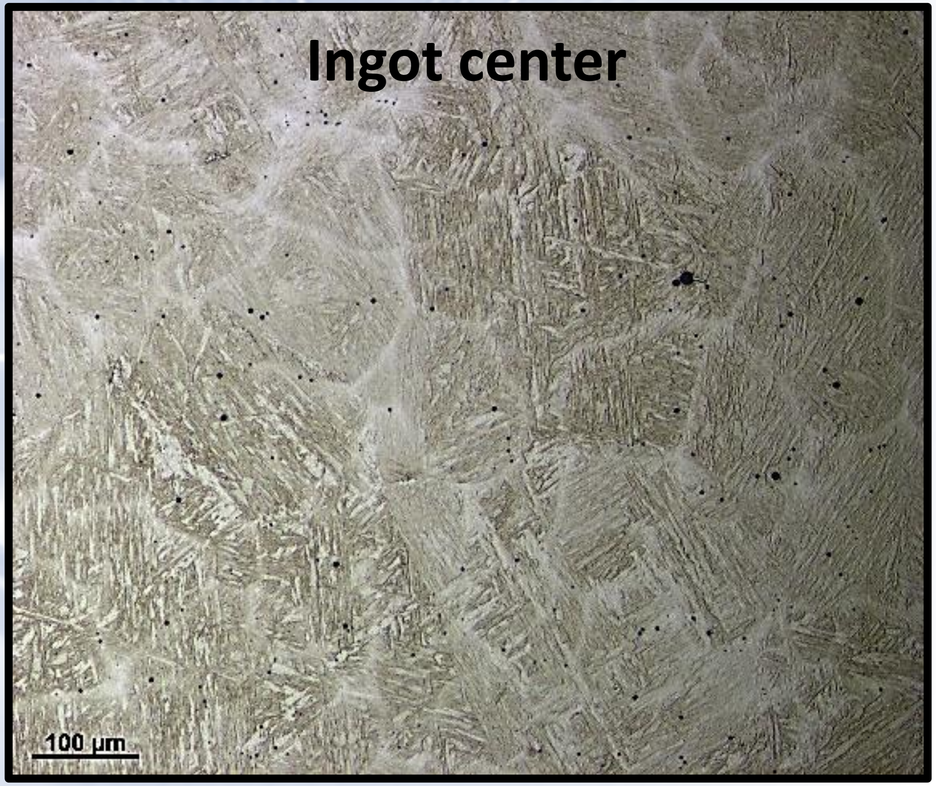
Casting conditions and results

Raw material calculation

Mass (g)	%	Raw material
2294	9,1	Metallic nickel
374	1,5	Metallic manganese
22420	88,9	Base steel
28	0,11	Graphite
94	0,37	Metallic silicon
25210	100	ASTM A522 Type 1

****37,5g of aluminum was added for deoxidation**

Alloy chemical composition (wt.%)					
C	**Si**	Mn	P	S	Al
0,13	**0,02**	0,99	0,001	0,02	0,01
Ni	**Nb**	**Cr**			
8,70	**0,008**	**0,04**			



ASTM 522 type I: Atomization

FeB+C

Atomization

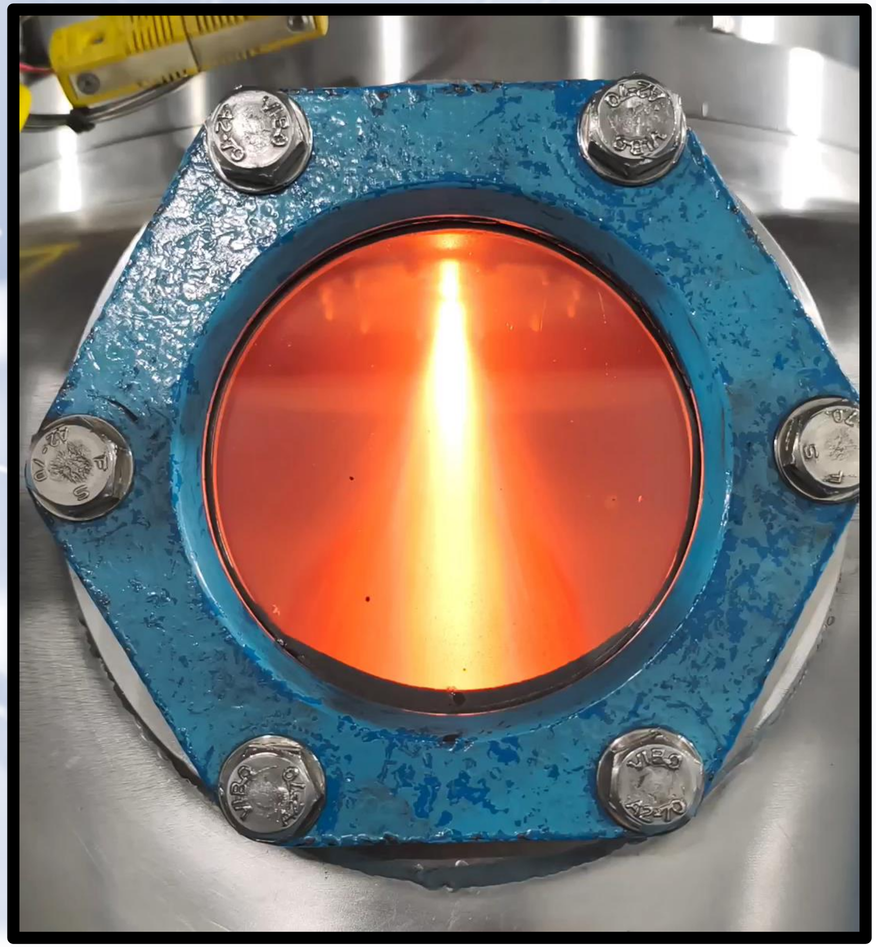
Chemical composition correction during the melting into the atomizer

Mass (g)	**% mass**	**Material**
2862,8	100,00	
2841	99,24	ASTM A522 Type 1
15	0,52	Metallic nickel
6,8	0,24	Metallic silicon

Atomization parameters	
Atomization temperature	1600 °C
Tip diameter	2,5 mm
Chamber pressure	0,25 bar
Atomization pressure	35 bar

Final chemical composition (wt.%)

C	**Si**	Mn	P	S	Cu
0,095	**0,22**	0,824	0,005	0,003	0,005
Ni	Nb	Cr			
9,5	0,008	0,013			



ASTM 522 type I: Atomization

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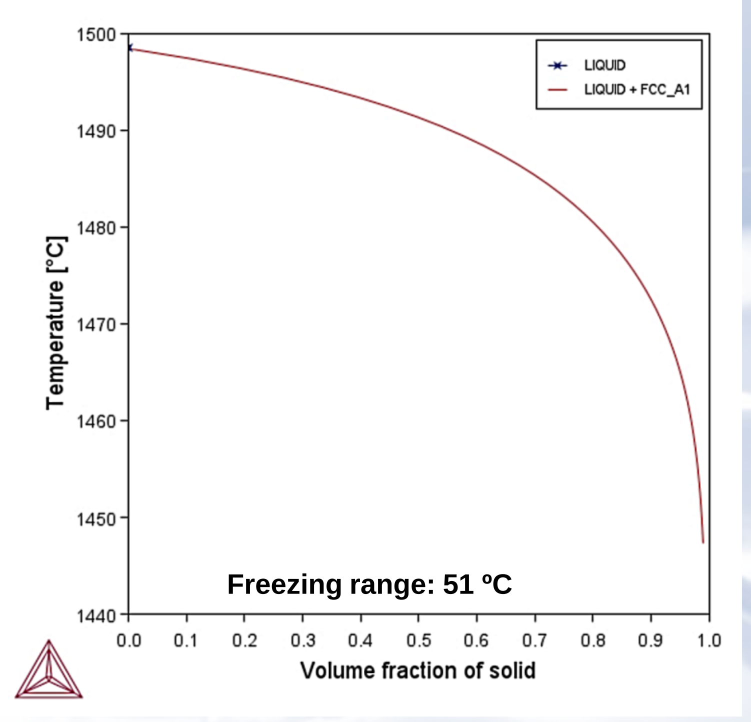
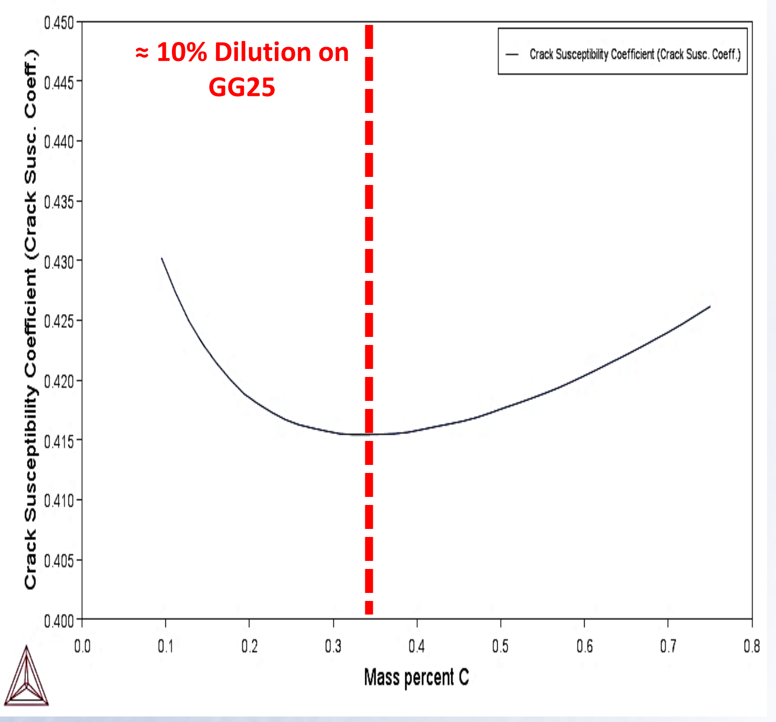
Thermo-Calc simulation results





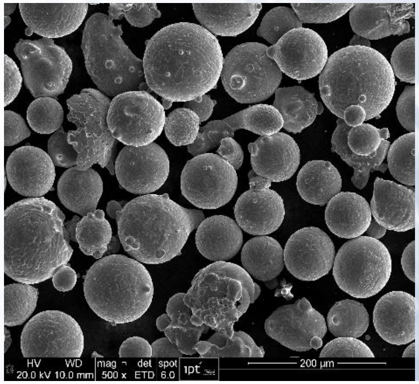
- **The alloy solidifies 100% as austenite**
- **Low freezing range indicates solidification without hot cracks**

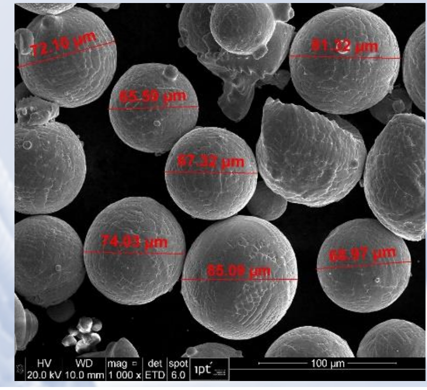
- **It was considered only carbon dilution: 0% to 20% in grey cast iron GG25.**

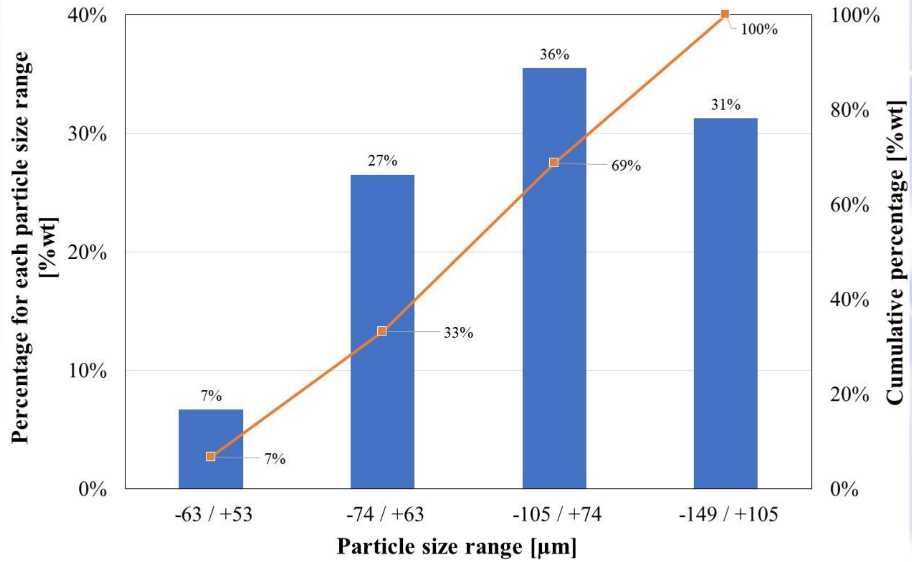
ASTM 522 type I: Atomization

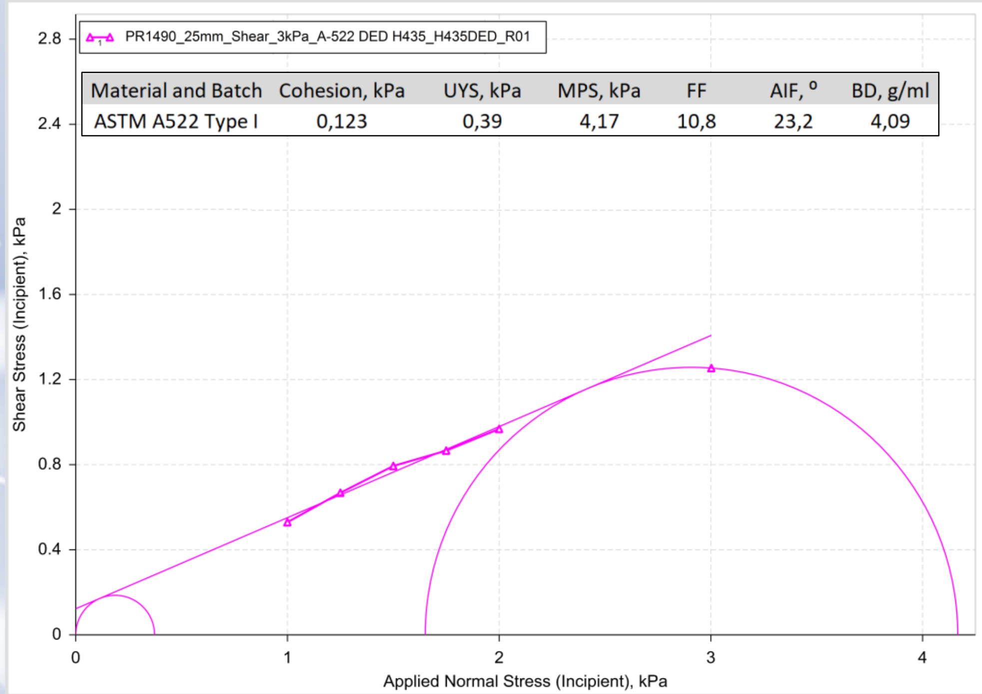
FeB+C

Powder characterization DED (+53 / -149 µm)









Material and Batch	Cohesion, kPa	UYS, kPa	MPS, kPa	FF	AIF, °	BD, g/ml
ASTM A522 Type I	0,123	0,39	4,17	10,8	23,2	4,09

Funnel Hall Flow test = 17s

Atomization yield for DED PSD = 58,9%

ASTM 522 type I: Laser remelting test

FeB+C

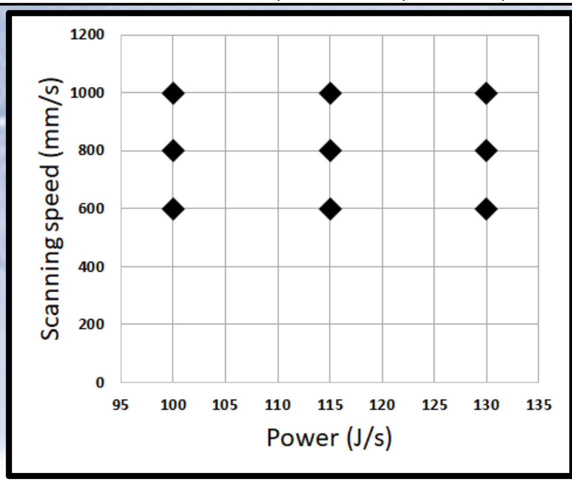
Surface preparation

Steps:

1) Cut a 100 mm section of the billet with the cut-off saw.
2) Mill the ingot creating two parallel faces.
3) Clean the surface with acetone.

Experiment planning – Single tracks

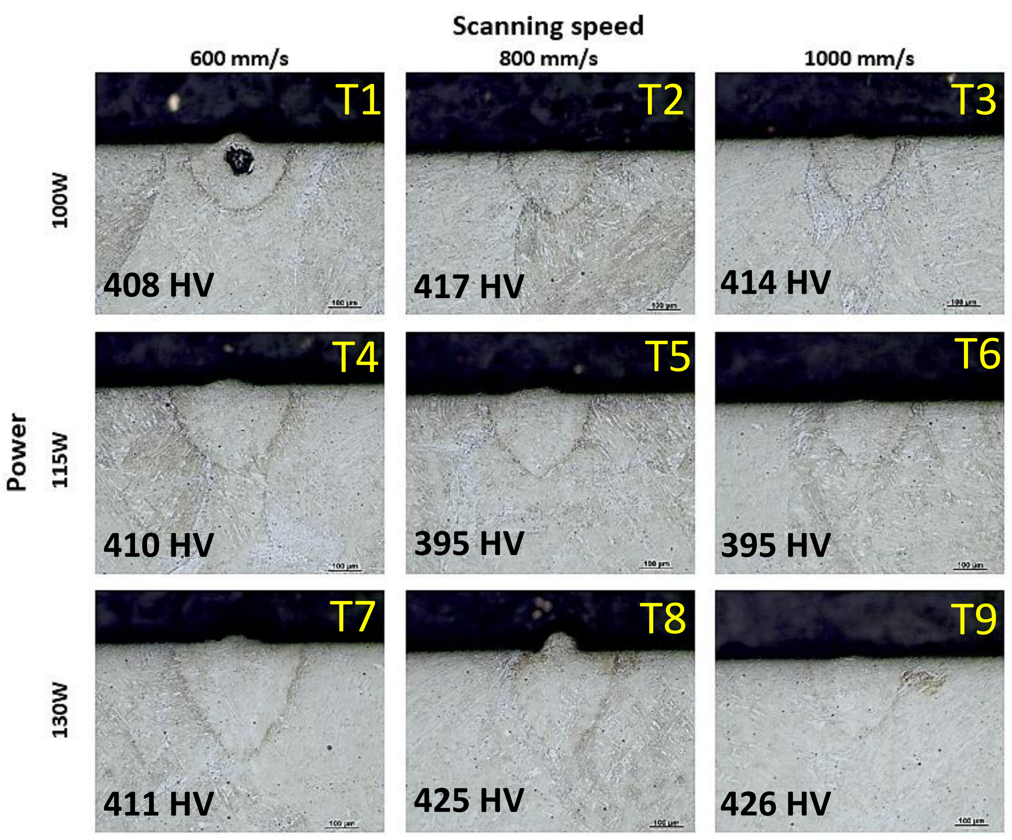
Track	P J/s	v mm/s	El J/mm	Ev J/mm³	Ea J/mm²
1	100	600	0,167	79,4	3,54 x 10^{-4}
2	100	800	0,125	59,5	3,54 x 10^{-4}
3	100	1000	0,100	47,6	3,54 x 10^{-4}
4	115	600	0,192	91,3	4,07 x 10^{-4}
5	115	800	0,144	68,5	4,07 x 10^{-4}
6	115	1000	0,115	54,8	4,07 x 10^{-4}
7	130	600	0,217	103,2	4,60 x 10^{-4}
8	130	800	0,163	77,4	4,60 x 10^{-4}
9	130	1000	0,130	61,9	4,60 x 10^{-4}

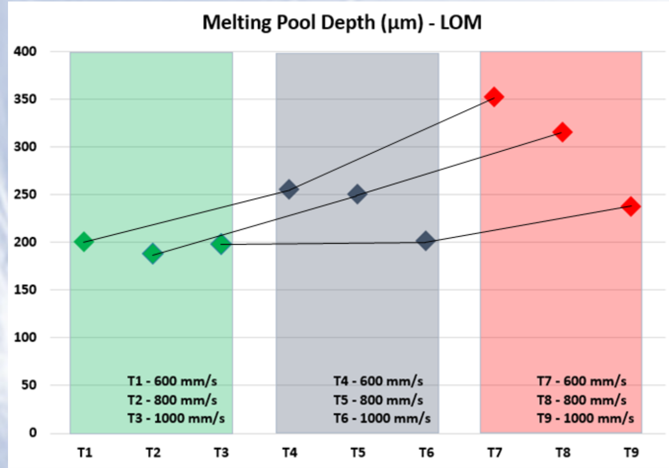


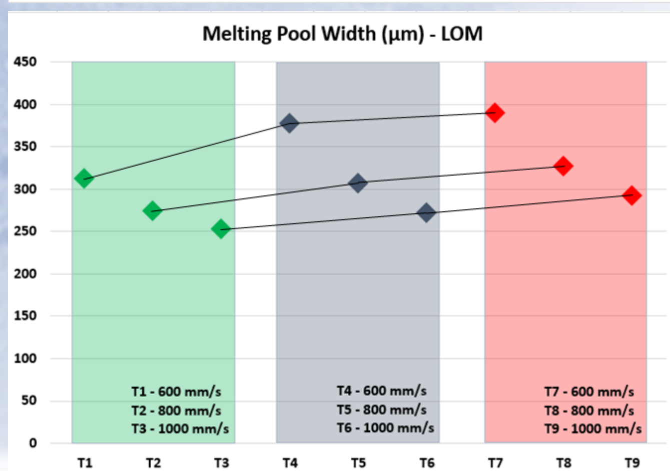
ASTM 522 type I: Laser remelting test

FeB+C

Microstructure characterization / Microhardness test







Ingot microhardeness: ≈400 HV

Conclusions

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1) Alloy ASTM A522 Type I as-cast exhibits a predominantly martensitic microstructure.

2) Alloy ASTM A522 Type I was successfully atomized, producing a powder with spherical particles.

3) The resulting ASTM A522 Type I powder presents characteristics suitable for processing by additive manufacturing techniques.

4) No cracks were observed in the laser remelting tests with alloy ASTM A522 Type I.

GCI group - Quick wins initiative

FeB+C

GCI

GCI
+ carbon content reduction at surface by HT in furnace

LABMAT

GCI
+ carbon content reduction
+ new alloys deposition

HSLA
PHSS
A522 Type I

Initial proposal:
M.Sc Andrei Marx
M.Sc. Moysés Lima