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EFFECT OF PRE-CONDITIONING ON GREY CAST IRON METAL

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ABSTRACT:

Holding metal for longer duration is one of the undesirables in a foundry as it affects optimization of energy – a metric for cost economics. However situations such as Monday Morning Iron, mould line breakdowns, delayed tooling changes often arise that may lead to holding metal longer than necessary. Another undesirable is the super-heating of metal to compensate for local constraints such as poor ladle preheating, long pouring lines etc. These have an adverse effect on the molten metal by reducing the propensity of molten metal towards nucleation.

The scope of the current work is to quantify the effect of Pre-conditioning on held-metal before inoculation. It also goes to highlight the effect of a pre-conditioner in rejuvenating the metal before the final inoculation and pouring. Comparative study was conducted for the non-preconditioned and Pre-conditioned metal on the basis of the Mechanical, Micro-structural and Thermal Properties. There was found to be a significant improvement in the response to the inoculation of held metal after Pre-conditioning.

INTRODUCTION:

The phenomenon of Carbon precipitation in Cast iron is dependent upon the choice of raw-materials, pre-treatment, inoculation and solidification (cooling) behaviour. Pre-conditioning here refers to the treatment of metal before the process of inoculation. Pre-conditioning finds more importance in cases of variable charge quality, superheated iron and long hold periods for molten metal.

To understand and validate the role of pre-conditioning, SNAM Alloys Pvt. Ltd., R&D Center conducted an experiment keeping the other melting parameters under control.

EXPERIMENTAL PROCEDURE:

For the experiment, Grey Cast Iron was produced by melting raw materials comprising of 25% Pig Iron, 15% Steel Scrap and Balance as foundry returns. Calcined Petroleum Coke, Ferro-Silicon, Iron Sulphide and Ferro-Manganese were added to adjust the Chemistry. The melting was done with the target metal chemistry corresponding to grade ISO – 250.

The melting was carried out in an Induction Furnace by following the same process route for effective comparison. The temperature was maintained at 1450 deg. C in the furnace and also

while tapping. The metal handling vessels (Pouring ladle, Hand shank, Pouring cups etc.) were adequately pre-heated to retain the heat content of the molten metal.

The metal was held in molten state for different holding durations to check for the impact. The melt was inoculated with SNAM Ziman (0.5 – 2 mm) at addition of 0.25% in the hand shank. The melt was pre-conditioned using SNAM X-Bacal (2 – 6 mm) at an addition rate of 0.15% in the furnace before tapping. Four trials were conducted for the experiment:

1. The metal was held in molten state uncovered for 30 minutes in the furnace and was tapped, inoculated with SNAM Ziman and poured into castings for analysis.
2. The metal was held in molten state uncovered for 30 minutes in the furnace, Pre-conditioner (SNAM X-Bacal) was added in the furnace and this pre-conditioned metal was tapped, inoculated with SNAM Ziman & poured into castings for analysis.
3. The metal was held in molten state uncovered for 60 minutes in the furnace and was tapped, inoculated with SNAM Ziman and poured into castings for analysis.
4. The metal was held in molten state uncovered for 60 minutes in the furnace, Pre-conditioner (SNAM X-Bacal) was added in the furnace and this pre-conditioned metal was tapped, inoculated with SNAM Ziman & poured into castings for analysis.

<u>Sequence followed during the Experiments:</u>

1. Metal was charged and melted in the Induction Furnace by following the standard charging pattern.
2. At the completion of melting, Spectro-coin was inspected using OES spectrometer for Chemistry adjustment and necessary additions made, if required.
3. Chill mould was poured to check for Chill depth.
4. Thermal Analysis Cup was poured for inspection of Thermal properties using NovaCast ATAS.
5. Metal was held for 30/60 minutes in the Induction Furnace at 1400 deg. C.

6. Spectro-coin, Chill wedge and Thermal analysis cup was poured to check for the change in the composition & other properties.

7. A part of Melt was taken in the Hand Shank, inoculated with SNAM Ziman (0.25%), and poured into Spectro-coin, Chill wedge, Thermal Analysis cup, Step-block moulds and Round Tensile bars for analysis.

8. The balance melt in the Furnace was pre-conditioned using SNAM X-Bacal (0.15%) and this metal was used for pouring the Spectro-coin, Chill wedge and thermal analysis cup.

9. This pre-conditioned metal was taken into hand shank, inoculated with SNAM Ziman (0.25%) and poured into Spectro-coin, Chill wedge, Thermal Analysis cup, Step-block moulds and Round Tensile bars for analysis.

10. The samples poured were tested for further analysis and comparison.

Coins for Spectroscopy analysis were cast in a copper mould and were tested in the Optical Emission Spectrometer.

The chill wedge samples were cast and the chill depth was analysed by breaking it from the center and observing the white zone.

The cast samples were poured into a step-block mould having different section thicknesses (10mm, 20mm, 40mm), considering the section sensitivity of cast iron, for microscopic and hardness analysis.

Round bar samples (Φ 30 mm) were poured to check for the tensile strength of the samples.

RESULTS & DISCUSSION:

Chill Formation:

Chill Depth of samples poured for experiment with metal held for 30 minutes in furnace:

SAMPLE	CHILL DEPTH
Base Sample at 0 minutes	3 mm
Base Sample poured after 30 minutes of holding in the furnace	5 mm
Sample poured from a hand shank where the 30 minutes held-metal was inoculated with SNAM Ziman (0.25%)	1 mm
Sample taken from the furnace where the metal held for 30 minutes was Pre-conditioned with SNAM X-Bacal (0.15%)	2 mm
Sample poured from a hand shank where the Pre-conditioned metal was inoculated with SNAM Ziman (0.25%)	0 mm

Chill Depth of samples poured for experiment with metal held for 60 minutes in furnace:

SAMPLE	CHILL DEPTH
Base Sample at 0 minutes	4 mm
Base Sample poured after 60 minutes of holding in the furnace	6 mm
Sample poured from a hand shank where the 60 minutes held-metal was inoculated with SNAM Ziman (0.25%)	2 mm
Sample taken from the furnace where the metal held for 60 minutes was Pre-conditioned with SNAM X-Bacal (0.15%)	3 mm
Sample poured from a hand shank where the Pre-conditioned metal was inoculated with SNAM Ziman (0.25%)	0 mm

There was a reduction in the chill formation with the addition of inoculant and the best result was obtained when the melt was pre-conditioned with SNAM X-Bacal and then inoculated with SNAM Ziman.

Thermal Analysis:

The important parameters of the Thermal analysis are mentioned below. The cooling curves generated are given in the Appendix.

Experiment with the holding time of 30 minutes:

SAMPLE	TL	TE low	TE high	TS	R	GRF1	GRF2	S1	MQ
Base Sample at 0 minutes	1152	1141.8	1145.7	1100.5	3.9	57	83	27	60
Base Sample poured after 30 minutes of holding in the furnace	1159.3	1141.8	1146.13	1099.2	4.3	51	86	33	53
Sample poured from a hand shank where the 30 minutes held-metal was inoculated with SNAM Ziman (0.25%)	1157.1	1145.6	1148.2	1103.6	2.6	63	77	30	79
Sample taken from the furnace where the metal held for 30 minutes was Pre-conditioned with SNAM X-Bacal (0.15%)	1156.3	1143.4	1146.2	1102.7	2.8	60	80	33	77
Sample poured from a hand shank where the Pre-conditioned metal was inoculated with SNAM Ziman (0.25%)	1154.9	1146.9	1149.1	1106.7	2.2	66	73	33	81

Experiment with Holding time of 60 minutes:

SAMPLE	TL	TE low	TE high	TS	R	GRF1	GRF2	S1	MQ
Base Sample at 0 minutes	1165.9	1142.8	1147	1102.6	4.2	61	78	33	74
Base Sample poured after 60 minutes of holding in the furnace	1187	1138	1143	1090.8	5	51	76	40	60
Sample poured from a hand shank where the 60 minutes held-metal was inoculated with SNAM Ziman (0.25%)	1176.6	1143.1	1146.5	1103.2	3.4	64	71	42	79
Sample taken from the furnace where the metal held for 60 minutes was Pre-conditioned with SNAM X-Bacal (0.15%)	1181.4	1140	1144.2	1094.4	4.2	60	90	42	75
Sample poured from a hand shank where the Pre-conditioned metal was inoculated with SNAM Ziman (0.25%)	1164.5	1145.7	1148.7	1109	3	68	68	43	83

The analysis shows a marked improvement in the thermal parameters predicting improved eutectic solidification and lower under-cooling with the addition of Pre-conditioner and inoculant.

Micro-Structure Analysis

The analysis was carried out using a Carl Zeiss Inverted microscope. The flake analysis was carried out on 100x micro graphs using the software dhs image database.

For Experiments with 30 minutes of Holding:

SAMPLE	PARAMETER	10 mm	20 mm	40 mm
Inoculated with SNAM Ziman (0.25%)	Micro-graph			
	Graphite Distribution	D: 70% ; E: 30%	A:72% ; B: 28%	A: 81% ; B: 19%
	Size Class	5	4	4
	Flake Length	7 mm	14 mm	14 mm
Pre-conditioned with SNAM X-Bacal (0.15%) & Inoculated with SNAM Ziman (0.25%)	Micro-graph			
	Graphite Distribution	A: 84% ; B: 16%	A: 91% ; B: 9%	A: 88% ; B: 12%
	Size Class	4	4	4
	Flake Length	14 mm	14 mm	14 mm

The metallographic results indicate that the metal held for 30 minutes in the furnace responds better to Inoculation when Pre-conditioned before pouring. Improved Graphite distribution and larger flake length can be observed after pre-conditioning before the subsequent inoculation.

For Experiments with 60 minutes of Holding:

SAMPLE	PARAMETER	10 mm	20 mm	40 mm
Inoculated with SNAM Ziman (0.25%)	Micro-graph			
	Graphite Distribution	D: 59% ; E: 41%	A:67% ; B: 33%	A: 77% ; B: 23%
	Size Class	6	5	4
	Flake Length	3.5 mm	7 mm	14 mm
Pre-conditioned with SNAM X-Bacal (0.15%) & Inoculated with SNAM Ziman (0.25%)	Micro-graph			
	Graphite Distribution	A: 79% ; B: 21%	A: 83% ; B: 17%	A: 86% ; B: 14%
	Size Class	4	4	3
	Flake Length	14 mm	14 mm	27 mm

The above metallographic results indicate the held metal responds better to Inoculation when Pre-conditioned before pouring. Improved Graphite distribution and larger flake length can be observed after pre-conditioning before the subsequent inoculation.

It can also be observed that holding the metal for longer duration further deteriorates the metallographic properties.

Mechanical Properties Analysis:

Brinell Hardness Testing (BHN) Results:

Holding Time	Sample	10 mm	20 mm	40 mm
30 minutes	Ziman	210 - 221	196 - 203	178 - 182
	X-Bacal + Ziman	201 - 209	191 - 194	169 - 174
60 minutes	Ziman	215 - 219	211 - 220	195 - 199
	X-Bacal + Ziman	212 - 215	209 - 214	187 - 189

Tensile Test Results:

Holding Time	Sample	Tensile Strength
30 minutes	Ziman	257 MPa
	X-Bacal + Ziman	271 MPa
60 minutes	Ziman	249 MPa
	X-Bacal + Ziman	259 MPa

The BHN and Tensile values were found to be within the acceptable range for the given grade of Cast iron. The mechanical properties suggest an improvement in the metal quality and the Castings poured thereafter when Pre-conditioned before inoculation.

CONCLUSION:

Pre-conditioning of held metal is necessary to achieve castings with good Mechanical and Metallurgical properties.

On the basis of the tests carried out on Grey Cast iron and the samples examined for Holding the metal, pre-conditioning and inoculation and the inferences drawn thereafter, the following conclusions can be drawn:

1. Reduction in Carbide formation was observed after Pre-conditioning.

2. From the Thermal Analysis, it is observed that pre-conditioning gives improved Eutectic cooling, graphite precipitation and reduced under-cooling.

3. The nucleating potential of the metal was found to improve after pre-conditioning, as observed from the Micro-analysis and the Cell count.

4. The mechanical properties met the acceptable values for the given grade of Cast Iron with an improved Tensile strength and reduced hardness on pre-conditioning.

REFERENCE:

1. Cast Iron Handbook, The Institute of Indian Foundrymen, (2012).

2. Harvey JN, Noble, GA, Inoculation of Cast irons – An overview, (2007).

3. Grey Cast iron Processing, American Foundry Society, (2000)

APPENDIX 1:1

Charge Mix for the Melts:

Pig Iron: 25%

Steel Scrap: 15%

Coke (CPC): 0.4%

Ferro-Silicon: 0.2%

Iron Sulphide: 0.1%

Ferro Manganese: 0.2%

Foundry Returns: 59%

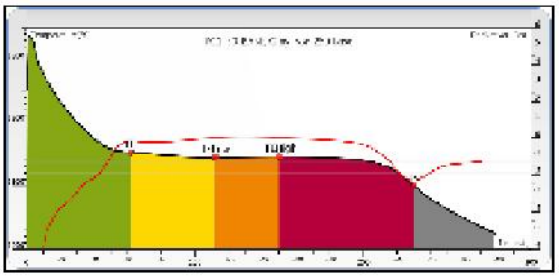
Melt Chemistry:

HOLDING TIME	SAMPLE	C %	Si %	Mn %	S %	P %	Cu %	Cr %
0 minutes	Base	3.51	1.9	0.65	0.1	0.11	0.08	0.19
30 minutes	Ziman (0.25%)	3.37	2.04	0.63	0.09	0.11	0.09	0.19
	X-Bacal (0.15%) + Ziman (0.25%)	3.33	2.09	0.63	0.1	0.1	0.08	0.19
HOLDING TIME	SAMPLE	C %	Si %	Mn %	S %	P %	Cu %	Cr %
0 minutes	Base	3.55	1.88	0.61	0.1	0.11	0.08	0.2
60 minutes	Ziman (0.25%)	3.35	1.99	0.59	0.1	0.11	0.08	0.2
	X-Bacal (0.15%) + Ziman (0.25%)	3.31	2.07	0.6	0.11	0.11	0.08	0.2

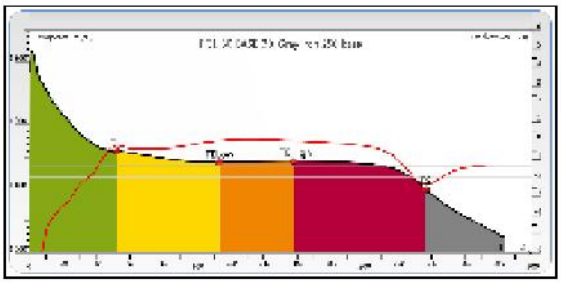
APPENDIX 1:2

Cooling curves generated during the Thermal Analysis for the experiment:

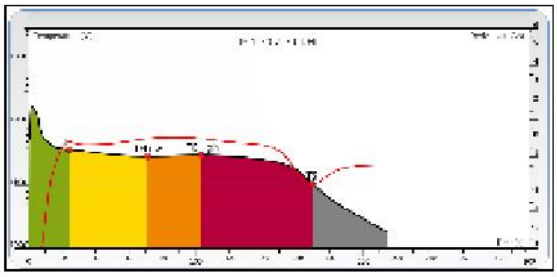
Cooling curves for experiment with 30 minutes of holding:



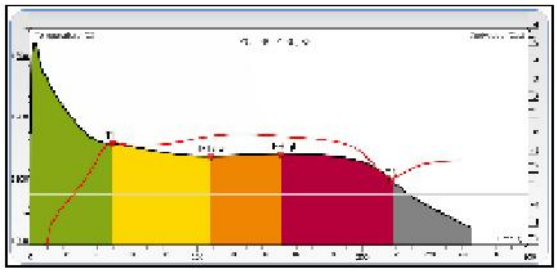
(a) 0 minutes (Base)



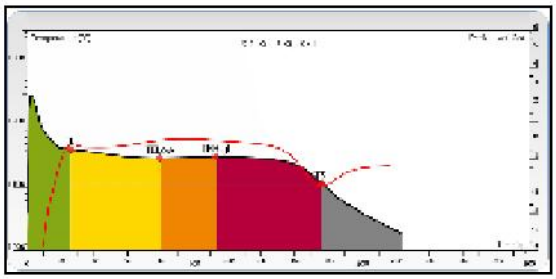
(b) 30 minutes (Base)



(c) 30 minutes (SNAM Ziman - 0.25%)

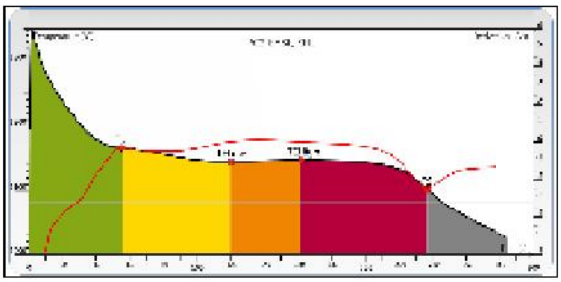


(d) 30 minutes (SNAM X-Bacal - 0.15%)

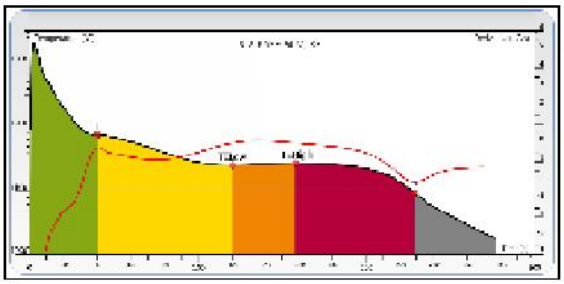


(e) 30 minutes (SNAM X-Bacal – 0.15% + SNAM Ziman - 0.25%)

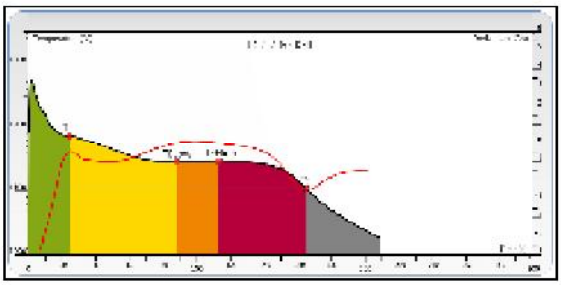
Cooling curves for the experiments with 60 minutes of holding:



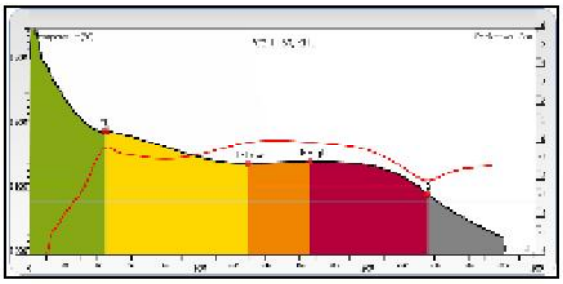
(f) 0 minutes (Base)



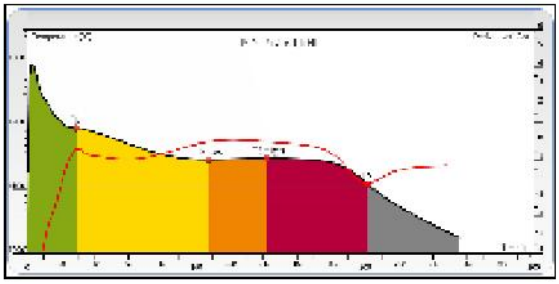
(g) 60 minutes (Base)



(h) 60 minutes (SNAM Ziman - 0.25%)



(I) 60 minutes (SNAM X-Bacal - 0.15%)



(j) 60 minutes (SNAM X-Bacal – 0.15% + SNAM Ziman – 0.25%)