HIGH PERFORMANCE INSULATION IN THE STEEL INDUSTRY [1]

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Abstract

In today's modern steel making plants the ladle and other equipments (in special ladles and torpedo) are no longer used simply as metal transfer equipments. The combination of a secondary metallurgical processing and the use of continuous casting have contributed to longer residence times and higher temperatures in the process. These developments have led to the use of more sophisticated refractory materials in order to cope with the more stringent mechanical and chemical conditions that now exist. However, the higher thermal conductivity of such "better quality" refractories means that there is a heat loss penalty resulting from their use. The aim of this study is to demonstrate the benefit of high performance insulation (microporous materials) in the steel industry: ladles, tundish, torpedo, etc. Studies consist in theoretical thermal calculations and practical measurements on refractory lining with and without insulation and its influence on the different parameters affected: Metal shell temperatures, Heat flow through the lining, etc. The results are showing the benefit for the steel industries using microporous insulation.

Key words: Insulation; Ladle; Equipamento; Microporous.

ISOLAMENTO TÉRMICO DE ALTA PERFORMANCE NAS INDÚSTRIAS DE AÇO

Resumo

Nos dias de hoje modernas indústrias de aço, panelas e outros equipamentos (especialmente panelas e carros torpedos) não são mais usados simplesmente como equipamento de transferência de metal. A combinação de processo de metalurgia secundária e o uso de lingotamento contínuo têm contribuído para aumentar os tempos de residência e temperaturas mais altas. Estes desenvolvimentos têm direcionado para o uso de materiais refratários mais sofisticados a fim de resistir às condições químicas e mecânicas mais agressivas que agora apresentam. Entretanto uma condutividade térmica maior de um refratário de "melhor qualidade" significa que há uma maior perda de calor resultante de seu uso. O objetivo desse estudo é demonstrar a vantagem do isolamento térmico (material microporoso) nas siderúrgicas: panelas, tundishes, carros torpedo etc. O estudo consiste em um cálculo térmico teórico e medidas práticas nos revestimentos refratários com ou sem isolamento térmico e sua influência em diferentes parâmetros afetados: temperatura da carcaça, fluxo de calor em todo o revestimento etc. Os resultados mostram o beneficio para as indústrias de aço utilizando o isolamento microporoso.

Palavras-chave: Isolamento; Panela; Equipamento; Microporoso

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INTRODUCTION

In today's modern steel making plants the ladles and other equipments (torpedo ladles) are no longer used simply as metal transfer. The combination of a secondary metallurgical processing and the use of continuous casting have contributed to much longer residence times and higher temperatures in the process. At the same time energy is a more important question in the cost of such process. These developments have led to the use of more sophisticated refractory materials in order to cope with the stronger mechanical and chemical conditions that now exist. The higher thermal conductivity of such refractories is means that there is a heat losses penalty resulting from their use.

Heat lost from the steel during processing must be re-added by electric arc or oxygen heating, which adds cost to the steel and can be destructive to refractories.

This paper discusses methods to minimize heat transfer. It also documents heat loss savings at several shops that use microporous insulation to minimize heat loss from different equipments.

BASICS OF HEAT TRANSFER MECHANISMS

Heat transfers from hot regions to cold regions whenever there is a difference in temperature. The rate at which heat flows depends on many factors such as the difference in temperature from hot face to cold face, the thermal conductivity of the barrier, the heat capacity of the barrier, the thickness of the barrier, and convection currents at the cold face.

There are three basic mechanisms for heat transfer: Conduction, Convection, and Radiation. All three mechanisms work simultaneously, combining to produce the overall heat transfer effect. The thermal conductivity of a material is a physical property that describes its ability to transfer heat.

Conduction

Conduction in a solid, a liquid, or a gas is the movement of heat through a material by the transfer of kinetic energy between atoms and molecules. Steady state unidirectional heat flux is defined by the Fourier Law and is given by the equation:

$$q = -k \, dT/dx$$

q = heat flux in W/m^2
k = thermal conductivity in W/m.K
dT = temperature difference in K
dx = distance across section in m

Solids are the most effective conductors of heat. Although the atoms in a solid have fixed positions, they constantly vibrate and interact with their neighbors. In hot areas the atoms *vibrate more strongly, so the interactions tend to pass energy to cooler regions resulting in heat* flow. Some solids conduct heat much better than others, depending on the way the atoms are bonded together. Metals are much more conductive than other solids such as refractories.

Convection

Convection in a gas or a liquid is the bulk movement of fluid caused by the tendency for hot areas to rise due to their lower density. The rate of cooling of an object is proportional to the difference in temperature between the object and its surroundings and is described in Newton's Law of Cooling:

$$\mathbf{q = h_c (t_s - t_f)}$$

q = heat flux in W/m^2
$\mathbf{h}_c$ = convection heat transfer coefficient in $W/m^2.K$
$\mathbf{t_s}$ = temperature of hot surface in K
$\mathbf{t_f}$ = temperature of fluid in K

The convection heat transfer coefficient $\mathbf{h_c}$ depends on the surface geometry, the fluid motion, the viscosity of the fluid, and several other properties.

Radiation

Radiation is the dissemination of electromagnetic energy from a source. This does not require an intervening medium and occurs most efficiently through a vacuum. Radiant heat losses from a surface increase rapidly with temperature as defined by the Stefan-Boltzmann equation:

$$\mathbf{q = \varepsilon\, o\, (T^4_{surface} - T^4_{surroundings})}$$

q = radiative heat flux in W/m^2
ε = emissivity of the surface (between 0 and 1)
o = Stefan-Boltzmann constant in W/m^2K^4
$\mathbf{T_{surface}}$ = temperature of object in K
$\mathbf{T_{surroundings}}$ = temperature of surroundings in K

<u>Infrared radiation is the principal mode of heat loss at temperatures above 100°C.</u>

USE OF INSULATION MATERIALS IS AN OBVIOUS SOLUTION

Traditional insulation materials (calcium silicate, mineral or ceramic fibers, vermiculite, etc...) with weak mechanical properties or high thermal conductivity are limited in its application in refractory linings. Insulation for this application must be very efficient at high temperature and very strong in mechanical compression giving good stability in refractory lining construction.

ADVANTAGES OF MICROPOROUS INSULATION

Heat transfer is controlled by using an insulating material that has a low intrinsic thermal conductivity. The best insulating material acts as a barrier to all three mechanisms of heat transfer.

Conduction

Microporous insulation is formed largely from amorphous silica particle with a low intrinsic thermal conductivity. It is 90% void space and uses very fine particles, 5-25 nanometers, to increase the path length of solid conduction across the material.
Insulation with a large percentage of void space must also minimize heat conduction by gases. This can be done by ensuring that a maximum number of collisions a gas molecule undergoes within the insulation are with solid surfaces instead of with other gas molecules.

Convection

Gaseous convection is easily eliminated as a heat transfer mechanism through all common insulation materials by making the average void space in the structure small enough those convection currents cannot form. Microporous insulation has extremely small voids and no convection heat loss.

Radiation

The microporous insulation used for this paper contains a thermally stable metal oxide opacifier of a controlled particle size distribution. The particle diameter is sized to be about the same as the wavelength of the incident radiation. So the opacifier particles scatter infrared radiation that would pass through other insulating materials and so reduces the transmission of heat by radiation to the lowest possible level.

Generally speaking thermal conductivity in microporous material is three or four times less than conventional insulation materials.

INSULATION EFFECT ON THE REFRACTORY LINING

Refractory brick normally work under a very high thermal stress due to the slope temperature gradient between hot and cold faces. It causes a mechanical stress following working cycles, increasing and decreasing temperatures. By the insulation effect of this lining cold face temperature is higher and slope thermal gradient reduction is evident.
To prevent refractory life reduction when insolate a refractory lining is very important a correct thermal calculation to get the correct heat flow reduction through the bricks. A right insulation thickness don’t affect to refractory life.

THERMAL CALCULATION PRINTOUT
(Sheet 1)
CONFIDENTIAL

CUSTOMER'S NAME : [redacted]
ENQUIRY NUMBER : LADLE INSULATION
DATE : 04/10/2002

VERTICAL WALL

EMISSIVITY	0.80
AMBIENT TEMPERATURE	25'C
CONVECTION CORRECTION	0%

SUMMARY OF RESULTS FOR STEADY STATE CONDITIONS

HOT FACE TEMP.	1600'C
COLD FACE TEMP.	267'C
HEAT FLOW	5545 Watt/m2
HEAT STORAGE	955985 kJ/m2
THERMAL RESISTANCE	0.240 m2'C/Watt

MATERIAL		THICKNESS mm	SLICES
LAYER 1	DOLOMITE	187	1
LAYER 2	DID. RUBINAL MN	15	1
LAYER 3	AL2O3 62%	45	1
LAYER 4	MICROTHERM SUPER G/HY PANEL	5	1

LAYER SPECIFICATIONS

		LAYER 1	LAYER 2	LAYER 3	LAYER 4
UPPER TEMP	'C	1600	1198	1179	1028
LOWER TEMP	'C	1198	1179	1028	267
MAX TEMP	'C	1800	1700	1680	1000
HEAT STORAGE	kJ/m2	780034.1	52989.1	121983.7	977.8
THERM'RESIST	m2'C/Watt	0.0726	0.0033	0.0272	0.1373
CONDUCTIVITY	Watt/m'C	2.58	4.54	1.65	0.04
DENSITY	kg/m3	2900	2900	2400	300
SPECIF'HEAT	J/kg'C	1047	1047	1047	1047
SLICE WIDTH	mm				

STEEL LADLE SHELL TEMPERATURES

Visiting many melt shops, many steel ladle shell temperatures were measured for ladles with many different working lining and backup lining refractory configurations. To simplify reporting they are grouped into three main categories for comparison of shell temperatures of ladles with and without microporous insulation against the inside of their steel shells.

Ladle shell temperatures were measured in six shops with monolithic backup linings and graphed in Figure 1. The first shop using microporous insulation processes steel in their ladles with a ladle metallurgical furnace (LMF) and a vacuum arc degasser (VAD). The upper barrel is their hottest ladle shell zone. The second shop using microporous insulation processes steel in their ladles with an LMF, so the slagline is their hottest ladle shell zone. The other four shops had no insulation in their ladles and their ladle shell temperatures were clearly hotter than the shops with microporous insulated ladles.

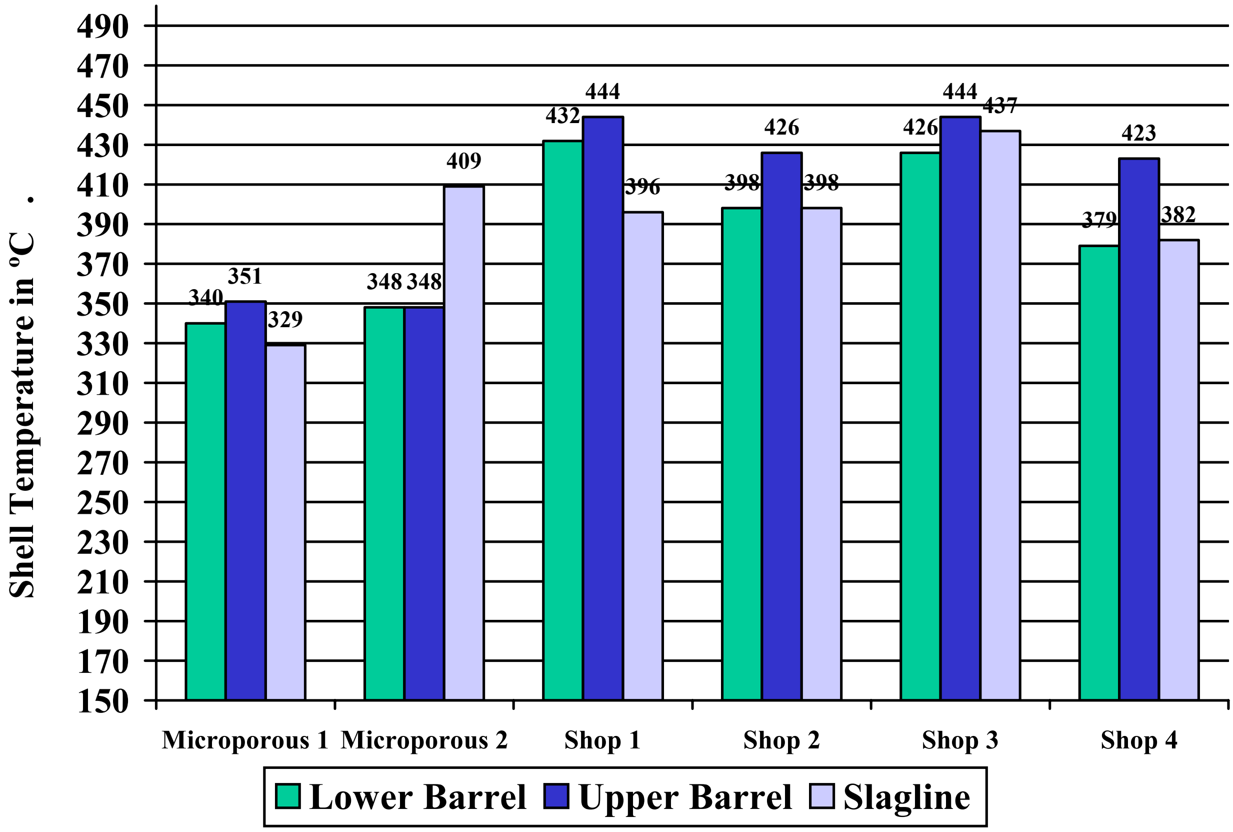

Figure 1. Maximum Shell Temperatures of Ladles with Monolithic Backup Linings

Ladle shell temperatures were measured in six shops with alumina and basic brick backup linings and graphed in Figure 2. The shop using microporous insulation processes steel in their ladles with an LMF and a room degasser. The slagline is their hottest ladle shell zone. The other five shops had no insulation in their ladles and their ladle shell temperatures were clearly hotter than the shop with microporous insulated ladles.

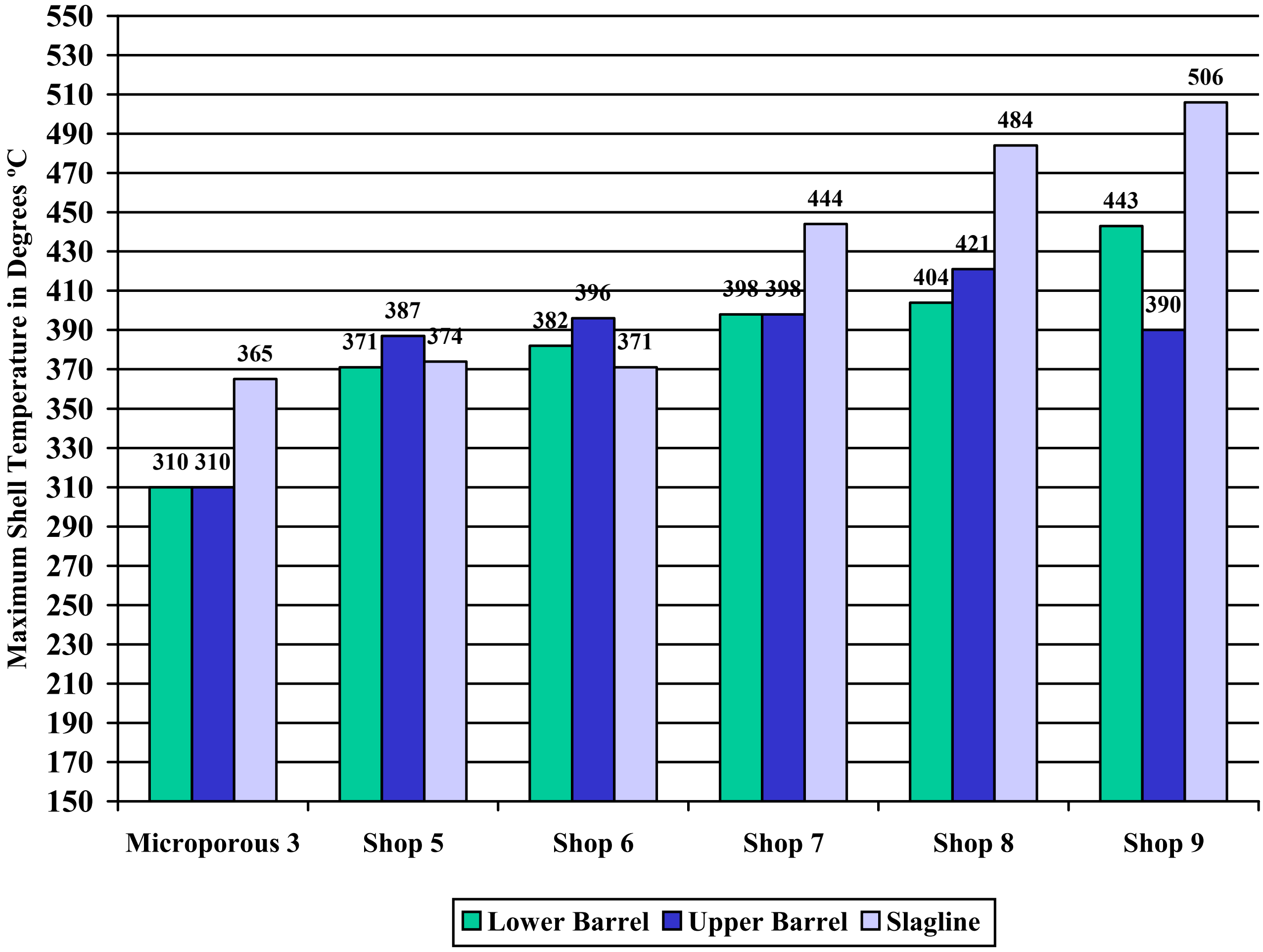

Figure 2. Maximum Shell Temperatures of Ladles with Alumina and Basic Brick Backup Linings

We can obtain the same performance in different equipments where high temperatures and refractory materials are involved.
Some examples:

- **Blast furnace: Hot air pipes / expansion joints / Nozzle**
- **Torpedo Ladles**
- **Converters**
- **RH Degassing**
- **Continuous casting Ladles / Tundish**

CONCLUSIONS

1. Microporous Insulation has excellent resistance to heat transfer due to Conduction and Convection.
2. Opacifier additions give Microporous Insulation excellent resistance to heat transfer due to InfraRed Radiation.
3. No other product resists heat transfer better at elevated temperatures than Microporous Insulation with Opacifiers.

4. Proven shell temperature reduction by Microporous Insulation with Opacifiers in steel ladles and other equipments were measured.

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