MOISTURE INFLUENCE ON PERFORMANCE OF NOZZLE FILLER FOR CONTINUOUS CASTING OF STEEL (1)

Mylene Laurindo Seixas (2)
Anibal de Oliveira Lavinas (3)
Maria Carolina C. Bezerra (4)
Cláudio Antônio Goulart Valadares (5)
Kenich Noma (6)
Masahiro Emi (7)
Hikaru Uchiyama (8)

ABSTRACT
Nozzle filler is a mixture of refractory raw materials and it is used in the nozzle of ladle in Continuous Casting of steel. The main goal is to achieve a higher level of free opening performance, close to 100%, guaranteeing the steel process flow, from ladle to tundish continuously, avoiding the nozzle clogging. This can generate personal accident and lack of productivity, by casting speed reduction, process interruption, and a production of non clean steel, affecting its quality.
The moisture present in the atmosphere and industrial equipments tends to contaminate the product and can present an influence on sintering, causing a non free opening.
The purpose of this paper is to evaluate the moisture content influence on nozzle filler sinter tendency.
A specific test was developed to evaluate the strength of sintering. Samples was sintered at 1400ºC and then, a pressure was applied on the sample by a press machine with a load detector. Then, a maximum load value (kg) that is the breaking value of the sintering sample is measured. Samples with different moisture content were evaluated, in order to define a relationship between the moisture content in nozzle filler and its sintering tendency.

Key Words: Nozzle Filler, Free Opening Ladle, Continuous Casting, Moisture

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(2) Metallurgic Engineer, R&D Engineer of Carboox.
(3) Mechanical Engineer, Technical Assistant Manager of Carboox.
(4) Master in Metallurgical and Materials Engineer, Chemistry Production Engineer, Operational Director of Carboox.
(5) M.Sc, CQE/ASQ, Metallurgic Engineer, Technical Director of Carboox.
(6) Metallurgic Engineer, Technical Group Chief Engineer of Nippon Thermochemical – Japan
(7) Metallurgic Engineer, Technical Director of Nippon Thermochemical – Japan
(8) Metallurgic Engineer, President of Nippon Thermochemical – Japan

1 - INTRODUCTION

Steelmaking plants around the world are focused on production and efficiency increasing. One important factor is the free opening ladle index. The ultimate goal in continuous casting is to achieve index close to 100% free opening. A free opening occurs when steel flows freely from the ladle once the slide gate is opened. A nozzle filler is used to fill up the nozzle and well block positioned on the bottom area of ladle. This nozzle transfers the liquid steel from ladle to tundish. A free opening occur when steel flows freely from the ladle when the slide gate is opened and no sinter excess of nozzle filler occurs, guarantying the process without interruption. The figure 1 shows a diagram of this process.

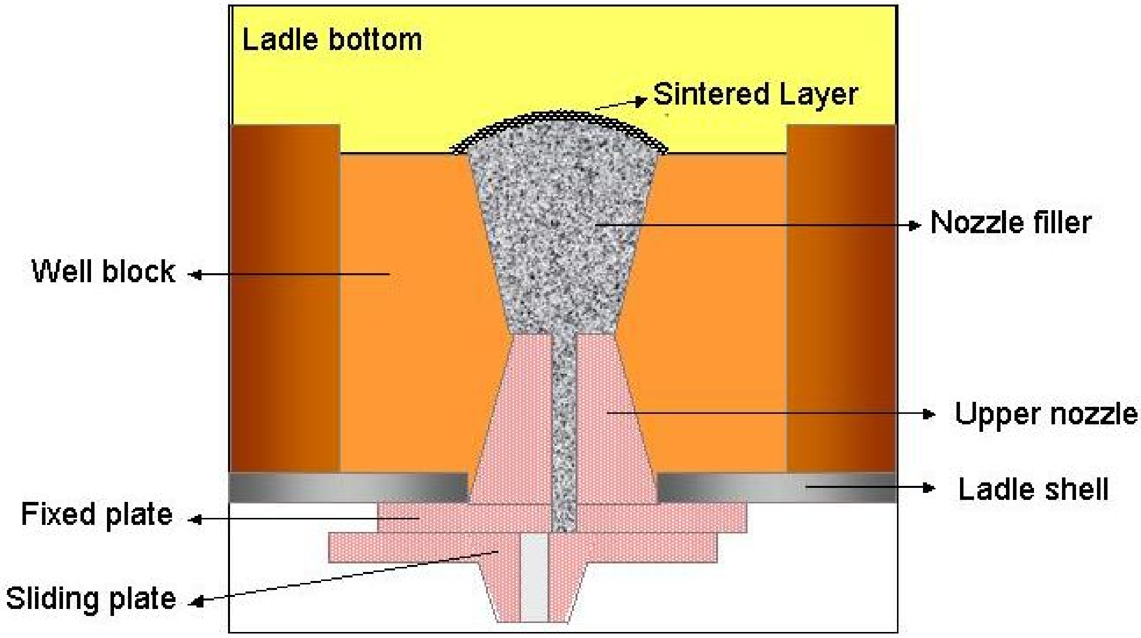


Figure 1: Schematic diagram of sliding gate

During a non-free open, the ladle to tundish shroud must be removed and the pouring stream is established using an oxygen lance [(1)]. This can negatively impact the process due to of main points described below:

- Impact on safety of operators because of potential splashing of liquid steel and exposure to emissions from the lancing operations;
- Impact on steel quality: The steel stream without the nozzle is exposed to atmosphere and re-oxidation of steel can occur, resulting in non-metallic inclusion formation;
- Slag entrapment by the opened steel stream from ladle to tundish. The slag can become trapped in the steel flow and swept in the mould;
- Cast sequence abortion because a low tundish level or freeze of steel. A caster turnaround causes loss of production.

Nozzle filler characteristics to attend each particular process must be developed according to several factors of continuous casting process, such as ladle size and capacity, ladle nozzle dimensions, ladle cycle time, tap-to-ladle open time, steel grade production and steel temperature, in order to achieve the following functions:

- Fill the nozzle cavity to avoid skull formation and steel solidification in the nozzle ensuring easy opening of sliding gate;
- Avoid the presence of slag and other refractory particle inside the nozzle.
- Highly refractory granular product that provides an appropriate sintered layer even with long times in high temperature;

The sintered layer function is to avoid the infiltration and solidification of liquid steel between sand particles and also, avoid dispersion of nozzle filler grains by liquid steel.

The main nozzle fillers characteristics are given by raw materials properties such as grain type (angular or spherical), grain size, crystalline phase present and carbon source[2]. The grain size distribution and particle type has an influence on packing factor that would be appropriate to promote the nozzle filler flowing when the sliding gate is opened. Carbon is added basically by two reasons, in order to inhibit the sinter speed and also lubricate the particles improving the nozzle filler flowing.

Several raw materials can be used to produce nozzle filler. The most common are quartz, chromite sand, zircon sand as refractory agents, graphite, carbon black or coke as carbon source. Some producers can add low amount of melting agents such as sodium or potassium to control the sinter intensity of nozzle filler.

There is another concern by nozzle filler users related to moisture content in the material. It is already known that higher moisture content in nozzle filler, worse is the free opening ratio obtained by the sinter intensity variation. The main purpose of this work is to evaluate the sinter tendency in several samples with different moisture content and to explain the mechanism involved.

2 - Methodology

To evaluate strength of sintering, raw material combination showed in table 1 were mixed and seven samples of nozzle filler of 500g each were prepared by Nippon Thermochemical laboratories.

Table 1: Carboox raw material combination used in the preparation of nozzle filler

Raw Material	Percentage	Quantity
Chromite Sand	69,85%	349,25g
Quartz	30,0%	0,75g
Carbon	0,15%	150,0g

The typical grain size distribution of this mix is showed in the table 2:

Table 2: Grain size distribution - ASTM (% retained weight)

# 20 (850μm)	# 60 (250μm)	< #60 (<250μm)
0,5	77,0	22,5

Water was added to each sample, in order to obtain different moisture values in seven levels, which were: 0,0%, 0,2%, 0,4%, 0,6%, 0,8%, 1,0% and 1,20%.

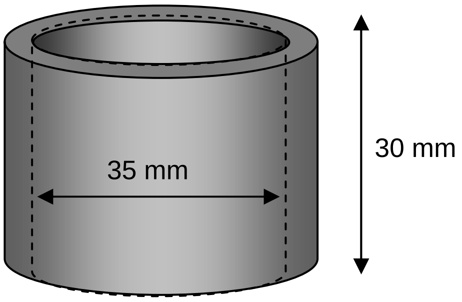
The samples were divided in two groups:

First Group: seven samples of 250g each were evaluated immediately after the mix preparation;

Second Group: seven samples of 250g each were perfectly sealed in plastic bags and evaluated 15 days after the mix preparation;

The mechanism of developed test consists on evaluation of body tests of each sample prepared using a graphite crucible of 35 mm of diameter and 30 mm of height. The crucibles were totally filled with each sample. The whole material were taken into a muffle furnace at 1400ºC where they were kept for one hour. Then, the samples were cooled at room temperature and body tests totally sintered were obtained.

The figure 3 shows the graphite crucible scheme (a) and the sintered body test (b).



(a)

(b)

Figure 3: graphite crucible (a) and sintered body test (b)

Body tests were submitted to compression test, applying pressure to the sample by a press machine with a load detector, whose scheme is showed in figure 4. Then, a maximum load value was measured when the body tests are broken.

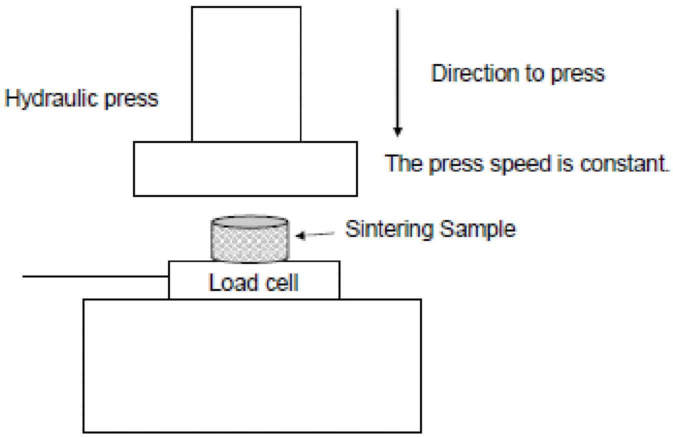


Figure 4: Press machine scheme

Each sample was tested three times by this method and the average of results was used to compare all results.

Through the results of maximum load obtained (kgf) and the sample surface area when the load was applied (cm^2), it was possible to obtain the strength of sintering (kgf/cm^2), according to the equation 1, where the sample surface area was $1.75cm \times 1.75cm \times 3.14 = 9.62cm^2$

Equation 1: Strength of Sintering (kg/cm^2) = Maximum load value (kg) / Sample surface area (cm^2)

3 – Results and Discussion

The table 3 shows the moisture content obtained in each sample (wt%), the maximum load obtained in compressing test (kgf) and the strength of sintering (kgf/cm^2) of first group (a) and second group (b) samples.

Table 3: Maximum load value (kgf) and strength of sintering (kgf/cm2)

First Goup (a)							
Moisture (wt%)	**0,05**	**0,22**	**0,39**	**0,59**	**0,77**	**0,94**	**1,2**
BT1	589	500	427	427	375	276	246
BT2	561	518	465	402	377	318	269
BT3	547	520	433	385	358	314	237
Average (kgf)	566	513	442	405	370	303	251
Strength of Sintering (Kgf/cm^2)	**59**	**53**	**46**	**42**	**38**	**31**	**26**
Second Group (b)							
Moisture (wt%)	**0,04**	**0,19**	**0,36**	**0,55**	**0,74**	**0,89**	**1,15**
BT1	516	479	456	382	337	287	290
BT2	543	436	363	352	351	322	327
BT3	520	453	420	373	329	341	284
Average (kgf)	526	456	413	369	339	317	300
Strength of Sintering (Kgf/cm^2)	**55**	**47**	**43**	**38**	**35**	**33**	**31**

The Figure 5 shows the relationship between moisture content (wt%) and strength of sintering (kgf/cm^2) of first and second group.

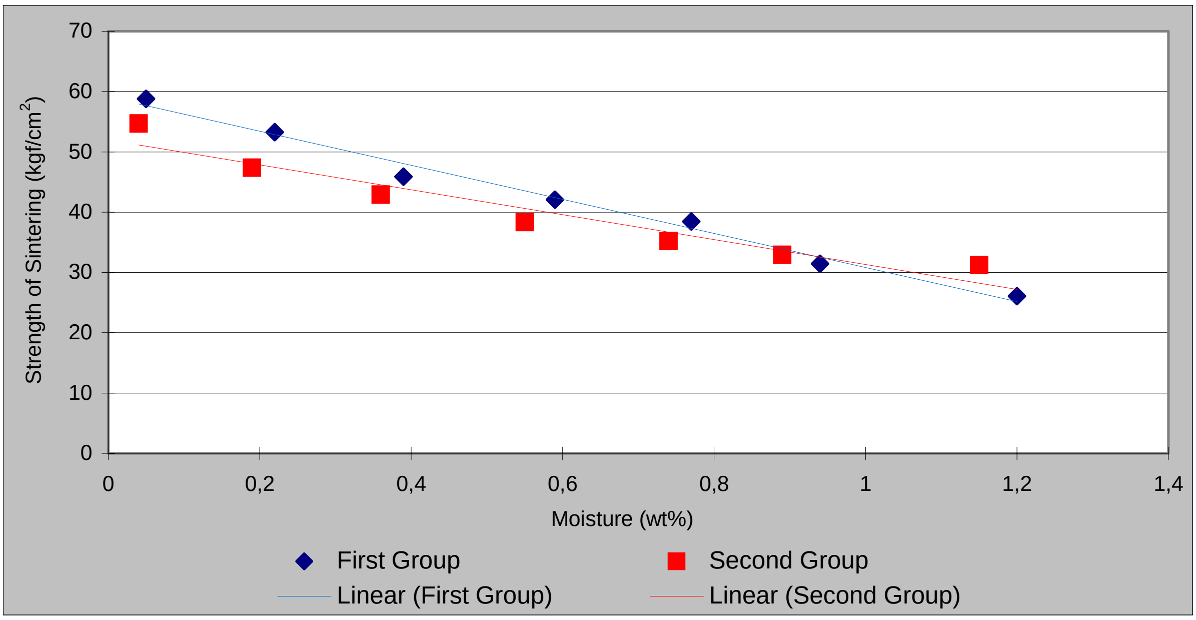


Figure 5: Relationship between sintering intensity and moisture

Through the results obtained, is observed that, when moisture content was increased, the sintered strength decreased. This occurs because the water evaporates, so, the filling density decreases and sintering intensity becomes weak due to steam gas.

The same phenomenon is also expected in real operation.

There are in Japan two general theories to explain the moisture influence in the free opening of ladle:

One of them explains that, once strength of sintering is decreased, loss of the nozzle filler performance is expected. Usually, the sintered layer is formed in the upper part of the well block, as showed in figure 1. When strength of sintering is reduced, nozzle filler particles are partially removed from the well block and the sintered layer is formed in a lower position, as showed in figure 6. If this occurs, the surface area of the sintered layer decreases, because the diameter of the hole becomes small. Therefore, the sintered layer becomes very hard to be destroyed.

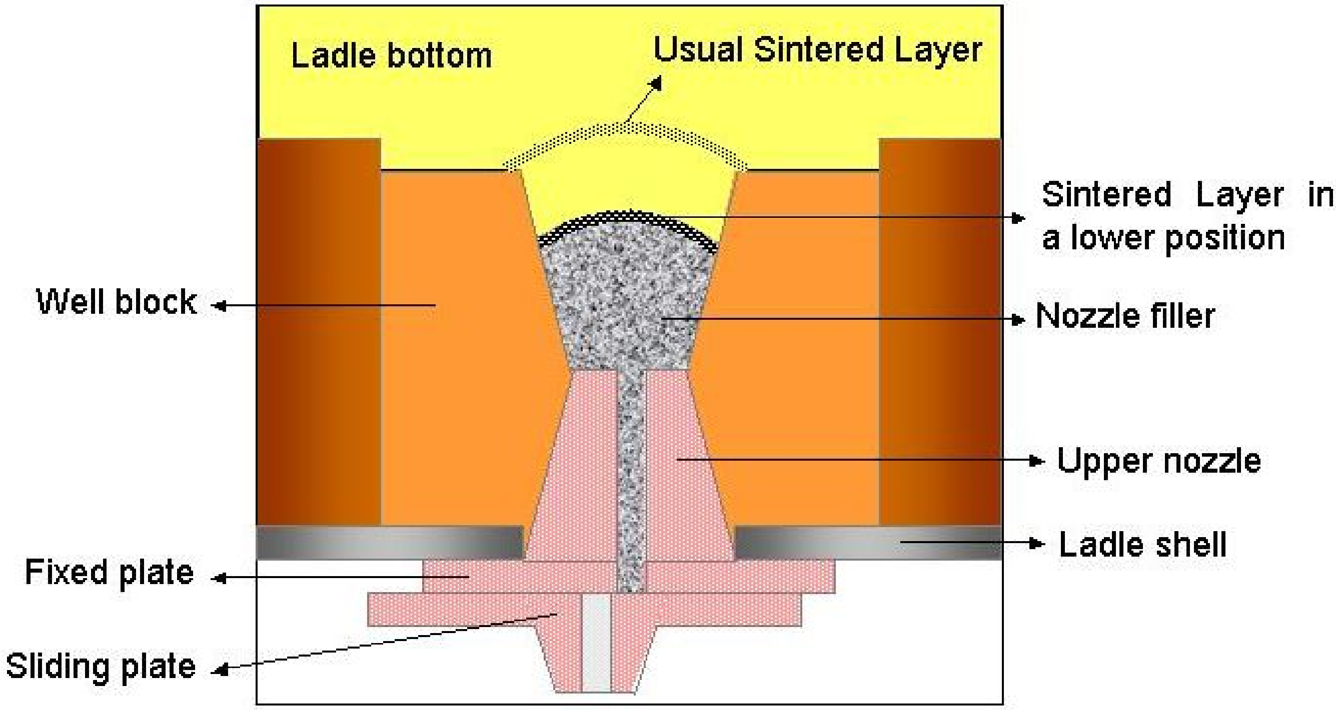


Figure 6: Schematic diagram of sliding gate – sintered layer in a lower position

In other hand, the second theory describes that, once filling density is decreased, molten steel infiltrates the nozzle filler more easily, and so, solidifies in the sintered layer. Therefore, the intensity of a sintering layer increases.

Based on our experience and results described, probably both theories can happen. Nozzle filler volume in the well block is reduced by nozzle filler removing, due to liquid steel washing part of nozzle filler, added by infiltration of liquid steel in the porous generated by steam gas.

4 - Conclusions

Based on results obtained in this work, we can have the following conclusion:

- The experimental method can be considered appropriated to evaluate the influence of moisture in the nozzle filler sintering strength. The obtained results were consistent;
- As higher moisture content in nozzle filler, the strength of sintered layer of a fixed composition of nozzle filler is lower.
- Two theories were presented to justify the loss of free opening rate. One of them related to the lower position of sintered nozzle filler layer, due to particles removal as strength of sintering is reduced. Other is related to the vacancies formation in nozzle filler positioned in the well block by steam gas, reducing the density, promoting the liquid steel infiltration, solidifying sintered layer and increasing its strength.

5 - References

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INFLUÊNCIA DA UMIDADE NO DESEMPENHO DA AREIA REFRATÁRIA PARA ABERTURA DE VÁLVULA GAVETA NO LINGOTAMENTO CONTÍNUO DE AÇOS

Resumo

A areia refratária é utilizada no preenchimento da válvula-gaveta da panela de aço líquido a fim de propiciar a abertura da mesma durante o Lingotamento Contínuo dos Aços. Ela é constituída de uma mistura de material granulado refratário, e o seu papel é fundamental para garantir a continuidade do processo, pois garante o escoamento do aço líquido após a abertura da panela, evitando o risco de obstrução da válvula impedindo a passagem do aço líquido e podendo ocasionar acidente pessoal e perda de produtividade, seja pela redução da velocidade de lingotamento ou pela interrupção do processo de transferência de aço líquido da panela para distribuidor, ocasionando a parada de máquina.

A umidade presente na atmosfera e nos equipamentos industriais tende a contaminar a areia e pode influenciar a sua sinterização, ocasionando, assim, uma não-abertura livre de panela.

O objetivo deste trabalho é avaliar a influência do teor de umidade da areia refratária na tendência à sinterização da mesma. Foi desenvolvido um ensaio específico para avaliar a resistência do corpo sinterizado. O ensaio consiste em aplicar uma pressão de compressão em um corpo de prova sinterizado a 1400ºC através de um equipamento que registra o valor da carga. Então, no momento de ruptura do corpo sinterizado, a carga máxima é registrada. Amostras com diferentes teores de umidade foram avaliadas, a fim de se obter uma relação entre o teor de umidade e a resistência do corpo sinterizado.

Palavras-chave: Areia refratária, abertura livre de panelas, lingotamento contínuo, umidade.