AOD Mouth Cleaning Results in APERAM South America Using Slagless Clean Up®

Breno Totti Maia[1], Bruno Orlando de Almeida Santos (*in memoria*)[1], Fabrício Silveira Garajau[1], Humberto de Sousa Barcelos[2], Marcelo de Souza Lima Guerra[1], Maurício Ferreira Coelho[2], Otávio Augusto de Cunha Teixeira[2]

[1]Lumar Metals Ltda
Rod. MG 232, km 09, Nº 100, Santana do Paraíso, MG, Brazil, ZIP Code: 35.167-000
Phone: +55(31) 9399 3200
breno.totti@lumarmetals.com.br

[2]APERAM South America
Praça 1º de Maio, Nº 09, Timóteo, MG, Brazil, ZIP Code: 35.180-018
Phone: +55 (31) 9107 7458
Otavio-augusto.teixeira@aperam.com
Slagless Clean Up®
Keywords: Term AOD; Mouth cleaning; Slagless Clean Up

INTRODUCTION

Nowadays the main target in most stainless steel plants is to optimize production costs. APERAM South America works with an AOD-L that started in January 2002, using an old available space around LD 2 facilities, which was shut down during that time. Carbon and electric steels are produced in an MRP-L converter. The AOD-L was installed using systems, compounds and devices that worked in the old LD. The main modifications made were: blow system, tilting, charging and dedusting system. **Figure 1** shows the actual steel plant schedule in APERAM South America[1].

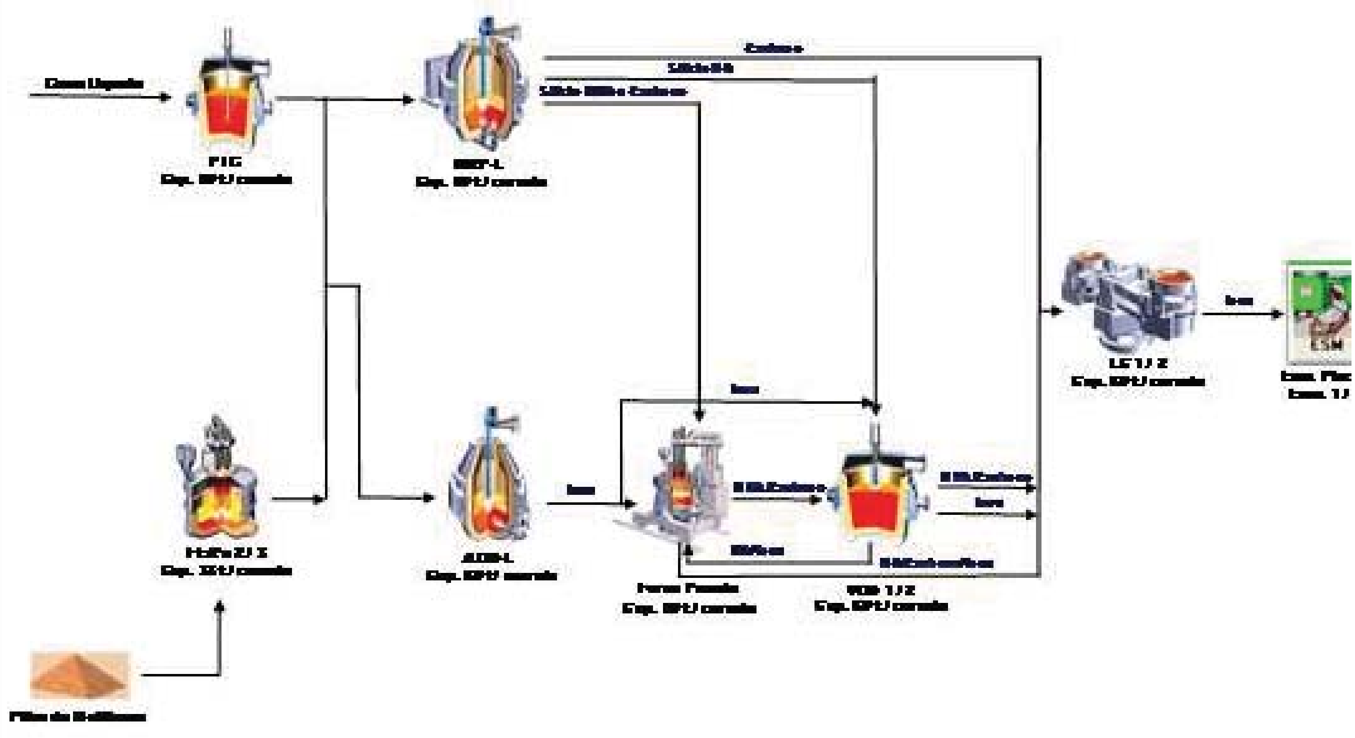


Figure 1 – APERAM schedule production.

Summarized, the AOD process is an excellent technology for primary refining and decarburization of stainless steel due to combination of a top lance oxygen and a mix of gases injected by tuyeres that are located in the lower part of the cylindrical refractory of the AOD, as shown in **Figure 2**.

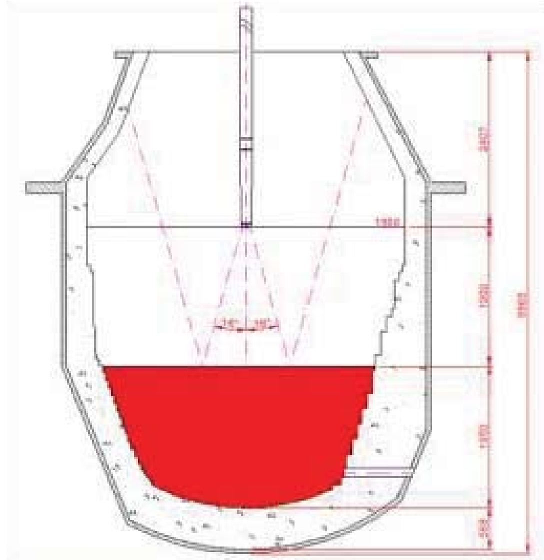


Figure 2 - Lateral view of AOD-L converter.

This condition provides good benefits to the kinetic reactions due to strong bath movement that can be achieved. The tuyeres for AOD-L consist of concentric pipes. Different mixes of oxygen and inert gases are injected through the center pipe for each stage of the blow to control the final carbon and oxygen in the bath. Inert gases are injected through the annular space between the center and outer pipe for tuyere cooling. At the same time ~~a~~ top lance injects oxygen to increase the decarburization rate. After the top blow, the tuyeres continuously work to reduce the carbon content while avoiding chromium oxidation. During this stage, called "reduction time", only inert gases, mainly argon, are injected. Heat by heat the mouth of AOD-L becomes more closed due to skull formation. These skulls are very rich in chromium and with very high melting point. It is necessary to stop the production to clean the mouth.

METHODS AND MATERIALS

The target of this work was to reduce skull formation at the AOD-L mouth during the campaign to guarantee good conditions to charge and tap stainless steel, as the AOD-L both charges and taps by the mouth. For this purpose, Lumar Metals developed a new concept called Slagless Clean Up®, as show in **Figure 3**.

The Slagless®(2) cartridge is designed with a high-purity copper special design associated with a particular inner-geometry system for cooling water that promotes extremely effective heat exchange between the pipe and the water. This combination of high-purity copper plus an effective internal cooling-water embodiment avoids skull formation build-up by fostering strong contraction, crack generation and finally falling off of solid skulls. A Slagless Clean Up® cartridge includes a post-combustion module located near the top of the conical copper pipe. The post-combustion module consists of a number of small nozzles designed based on the converter capacity and pointing directly at the converter cone region, as shown in **Figure 4**, where, during slopping, slag and metallic droplets accumulate to form skulls.

Figure 3 - Slagless Clean Up® cartridge and assembly at top oxygen lance.

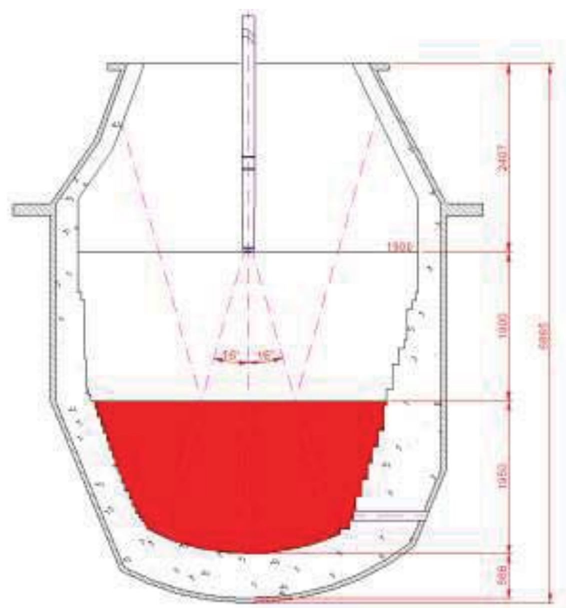


Figure 4 – AOD-L converter and Slagless Clean Up® lance

It was decided during commissioning to install the Slagless Clean Up® lance in the left lance car to keep a good reference between the post-combustion nozzles and skulls formations around cone regions, like ~~a~~ top view shown in **Figure 5**.

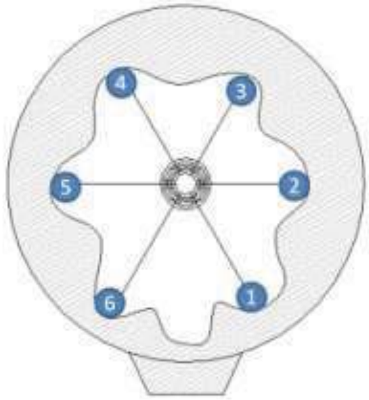


Figure 5 – Six post-combustion nozzle positions around AOD-L mouth.

DISCUSSION AND RESULTS

The Slagless Clean Up® cartridge had good operational performance and was used in combination with conventional lances, taken out of service as a preventive measure due to high life potential, but kept in hot standby position for ready use to control mouth skulls. **Table I** shows the cartridge's life evolution in relation of AOD-L campaign.

Table I - Campaign historical during Slagless Clean Up® performance trial at AOD-L.

Sequence	AOD-L Campaign	Time	Cartridge Use per campaign	Total Cartridge Life
1	436	Nov/13	55	55
2	437	Nov/13	16	71
3	451	Apr/14	76	147
4	455	May/14	92	239
5	456	May/14	94	333
6	457	May/14	59	392
7	458	Jun/14	71	463
8	459	Jun/14	75	538
9	460	Jun/14	74	612
10	462	Jul/14	77	689
11	463	Jul/14	81	770
12	464	Jul/14	64	834
13	465	Aug/14	54	888
14	466	Aug/14	10	898
15	467	Aug-Sept/14	83	981

Skull profile before Slagless Clean Up®

For campaign 461 a conventional lance (lance 5) was used for the entire campaign to permit a base-line register of the skull formation, as shown in Figure 6, without the Slagless Clean Up®.

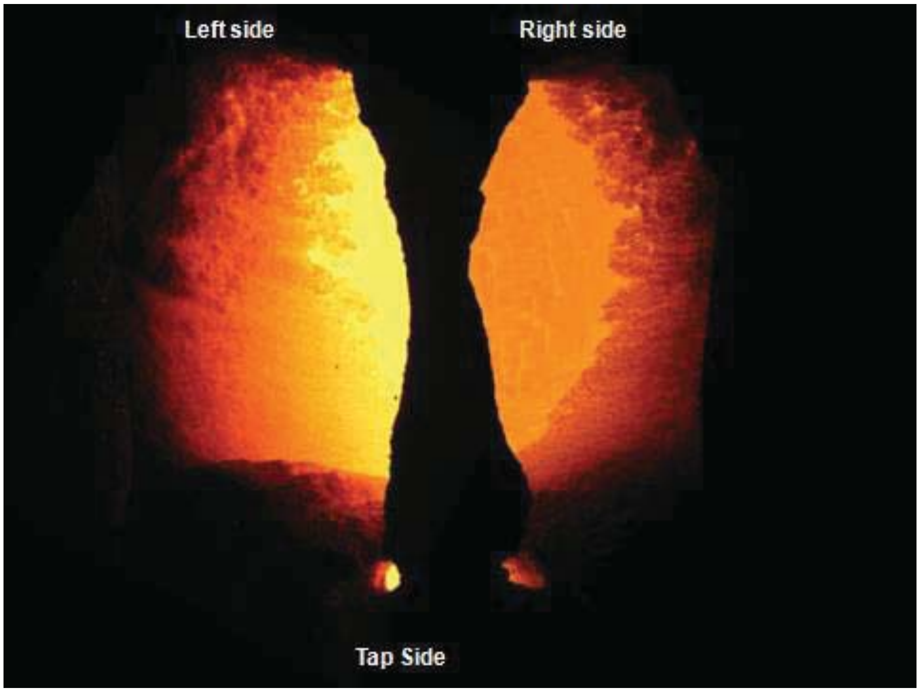


Figure 6 - Skull formation at AOD-L mouth with conventional lance.

Slagless Clean Up® campaigns

Due to the increase in efficiency of heat exchange, an important parameter observed during startup of the Slagless Clean Up® cartridge was the delta temperature profile, as shown at **Figure 7**.

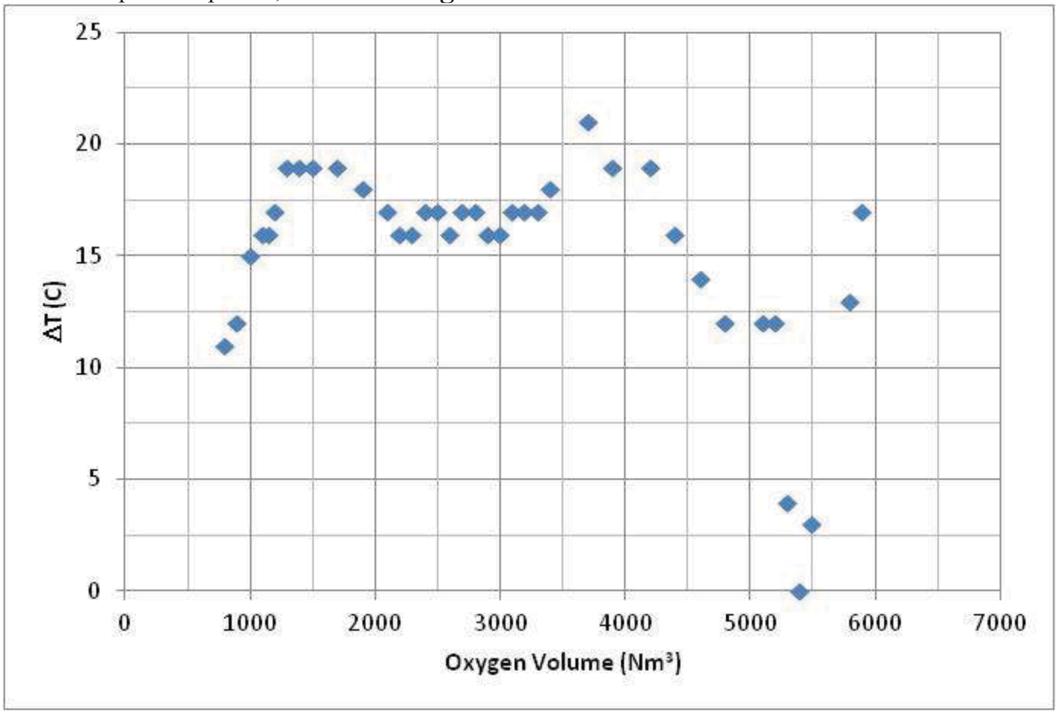


Figure 7 - Delta temperature of outlet water during the first use of the cartridge.

The set point of PLC was corrected and set for a maximum delta temperature of outlet water of 28°C. As shown in **Figure 7**, the instances where the delta temperatures reduced were directly related to the adding of materials from bins just to the right side or MRP-L converter side. The initial water flow was 108 Nm^3/h at 9 bar pressure and after 50 heats fixed around 101 Nm^3/h. The oxygen flow was determined at 120 Nm^3/min due to the grade quality steel 30XX. The maximum oxygen flow was 150 Nm^3/min. The post combustion nozzles start all 6 points with the same flow: 48Nm^3/h. After 55 heats, was possible to check the height that the post combustion was working like shown **Figure 8**.

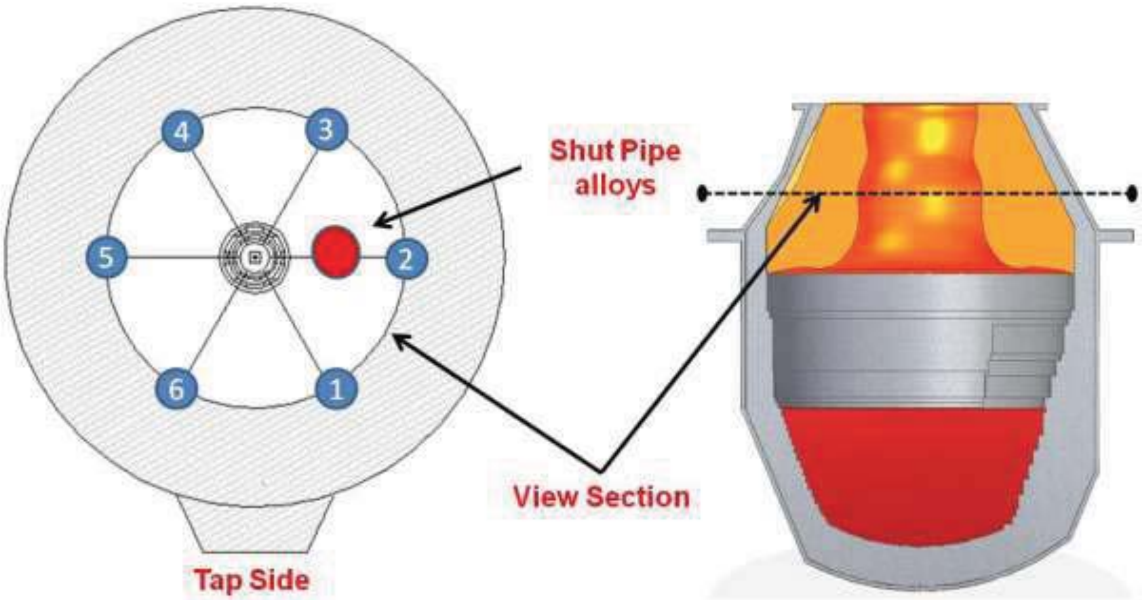


Figure 8 – Representation of Slagless Clean Up® profile mouth cleaning and inner skull aspect.

These shut pipe alloy additions had two influences. Firstly, they contribute to reducing the outlet water temperature as these additions occur near the end of the blow. Additionally, alloys added, mainly chromium alloys are heavy and hard and during the first campaign interfered with post-combustion nozzles 1 and 2, increasing skull formation in right side. During transformation of the conventional lance to Slagless Clean Up® it was possible to see that the wall thickness of removed pipe had been reduced in service. After this observation, we calculated flow rate options for nozzles at positions 1 and 2 as shown in **Table II**.

Table II - Diameters options to increase flow per post-combustion nozzle.

External Diameter (% of exit diameter mainly nozzle)	Flow (% of Total flow)/PC nozzle
14	0.47
16	0.63
18	0.77

The post-combustion nozzle adjustments included the nozzle at position 3 as shown in **Table III**.

Table III - Comparison post-combustion diameter before and after modifications.

	External Diameter (% of exit diameter mainly nozzle)	
Position	**Initial**	**Final**
3	14	16
1	16	18
2	18	18

Skull profile after Slagless Clean Up®

The Slagless Clean Up® worked to achieve the targets of improved mouth cleaning and reduced lance skulls desired by APERAM South America. On some occasions, informal registers were made about skull performance, but formal registers were made infrequently. After 15 heats with a conventional lance on campaign 458, the Slagless Clean Up® cartridge with 499 heats on it at the time was placed in service. After an additional 47 heats on the AOD-L it was possible to observe caves made by the post-combustion nozzles, shown in **Figure 9**.

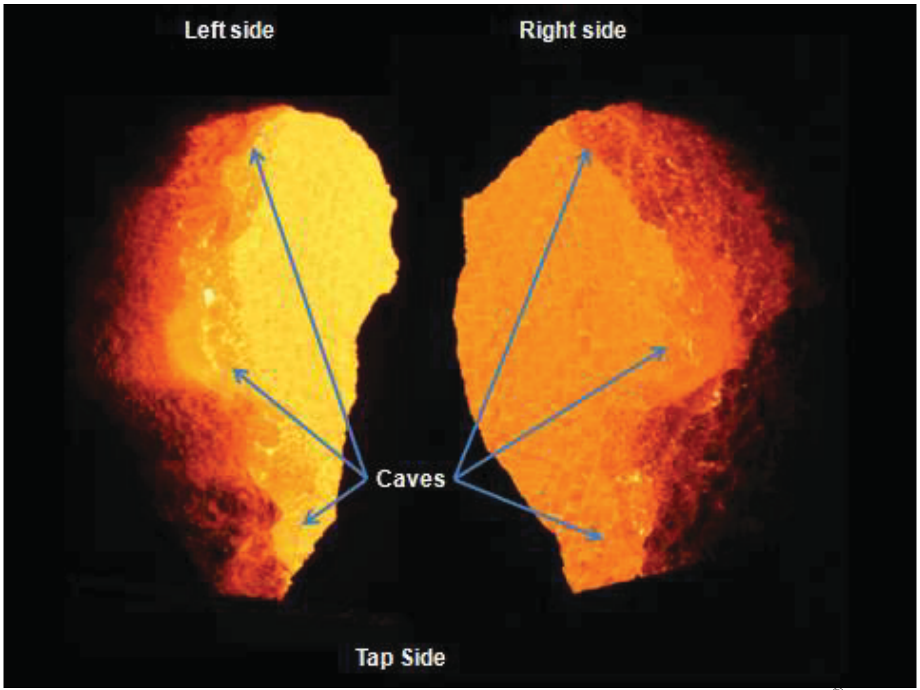


Figure 9 - Post-combustion's caves. AOD with 47 heats, campaign 458. Slagless Clean Up® with 499 heats.

Figure 10 shows AOD-L campaign 460 after 87 heats. A conventional lance was used for the first 15 heats with the target to await skull mouth formation and observe the action of Slagless Clean Up®. Then Slagless Clean Up® with 542 heats already on it was installed. It is possible in the photo to observe the post-combustion's caves after 72 heats using Slagless Clean-Up.

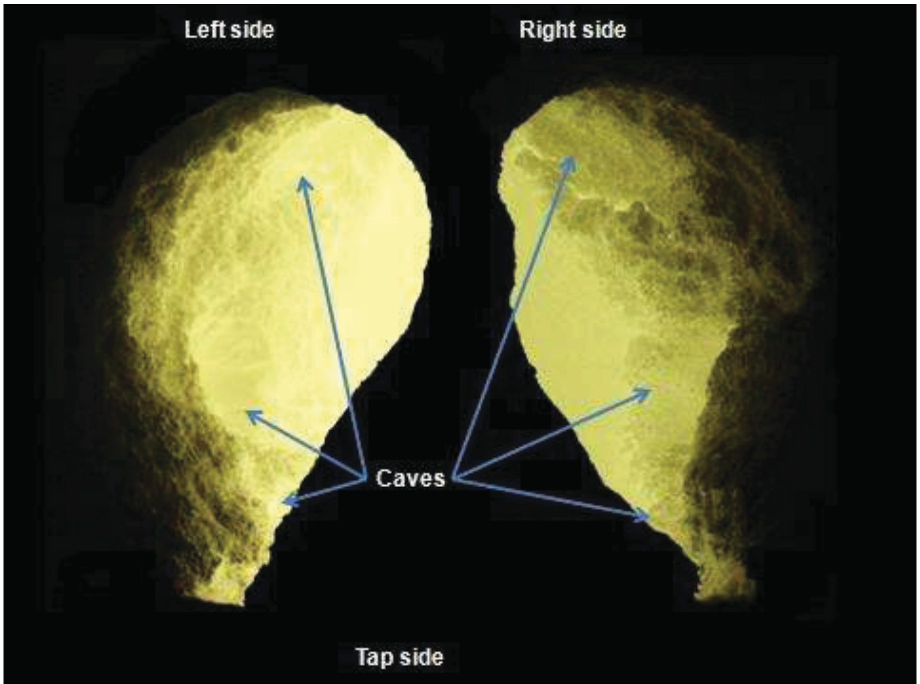
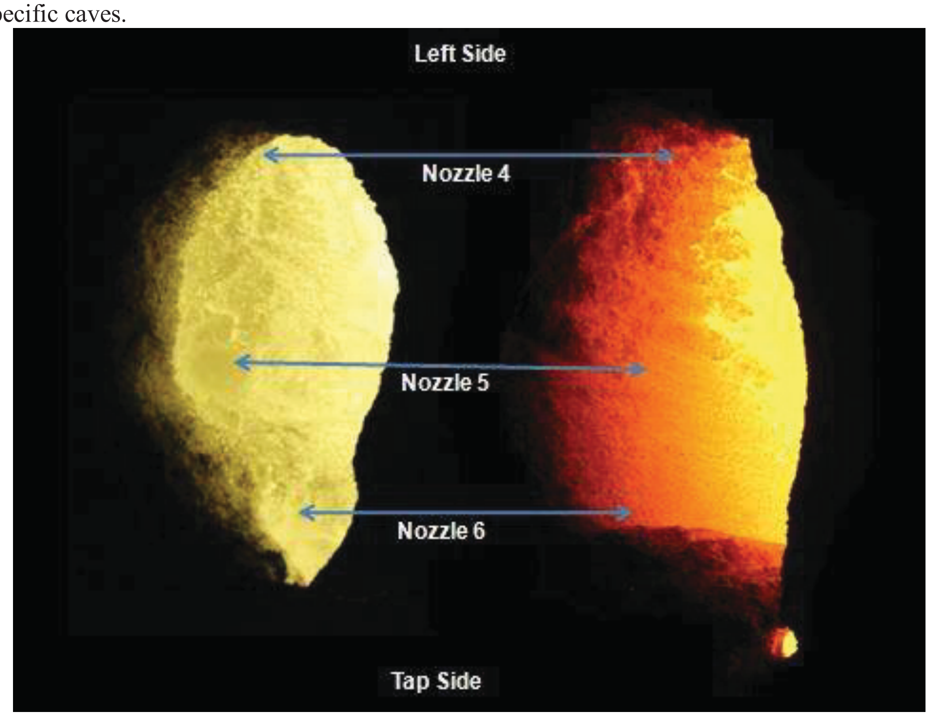


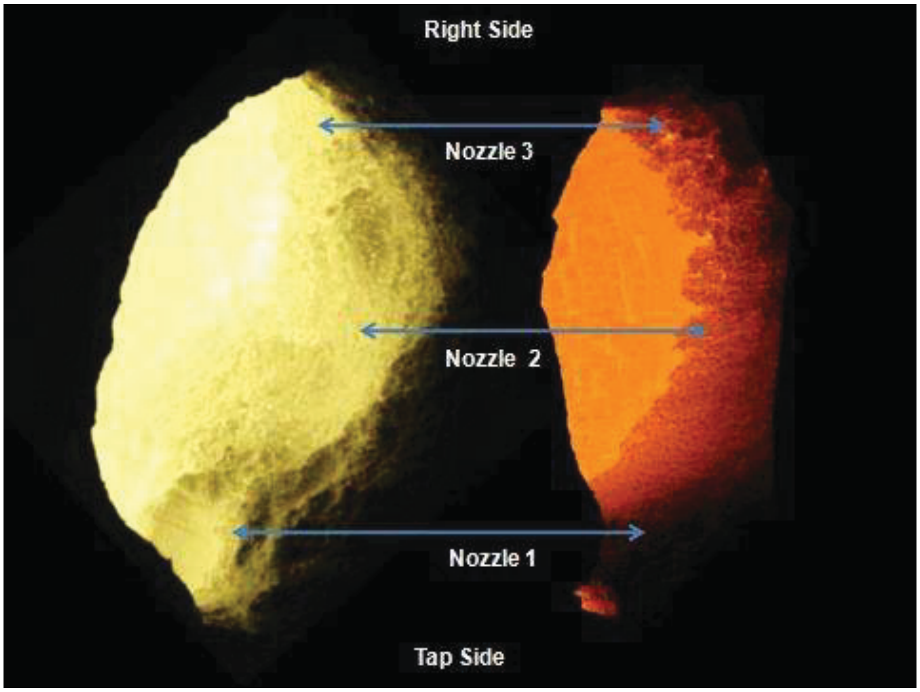
Figure 10 - Post-combustion's caves. AOD with 87 heats, campaign 460. Slagless Clean Up® with 542 heats.

AOD-L mouth clean comparison before and after Slagless Clean Up®

Figure 11 shows the vessel mouth comparing conventional lance (right) and Slagless Clean Up® (left). It is easy to see difference in general mouth and specific caves.



a) Left side for AOD-L or side of Pre Treatment of Hot Metal (PTG)



b) Right side for AOD-L or MRP-L side

Figure 11 - Comparison of mouth cleaning: a) Left side and b) Right side.

It is possible to see the effect of post-combustion nozzles in impacting skull formation around the AOD-L mouth by the caves formed. This behavior means reductions in maintenance time during vessel changes. To fast-change the AOD-L the total weight of the vessel needs to be less 190t. More weight means the necessity to remove mouth skulls by oxycutting, which adds time because skulls formation around AOD mouth is very rich in chromium and with high melting point. During campaigns 464 and 465 it was necessary to change the AOD-L suddenly without any preparations and in both cases the Slagless Clean Up® guaranteed a fast vessel change.

Slagless Clean Up® Performance

After 611 heats, the Slagless Clean Up® post-combustion nozzles were inspected and dimensions were well preserved, as shown in **Figure 12**.

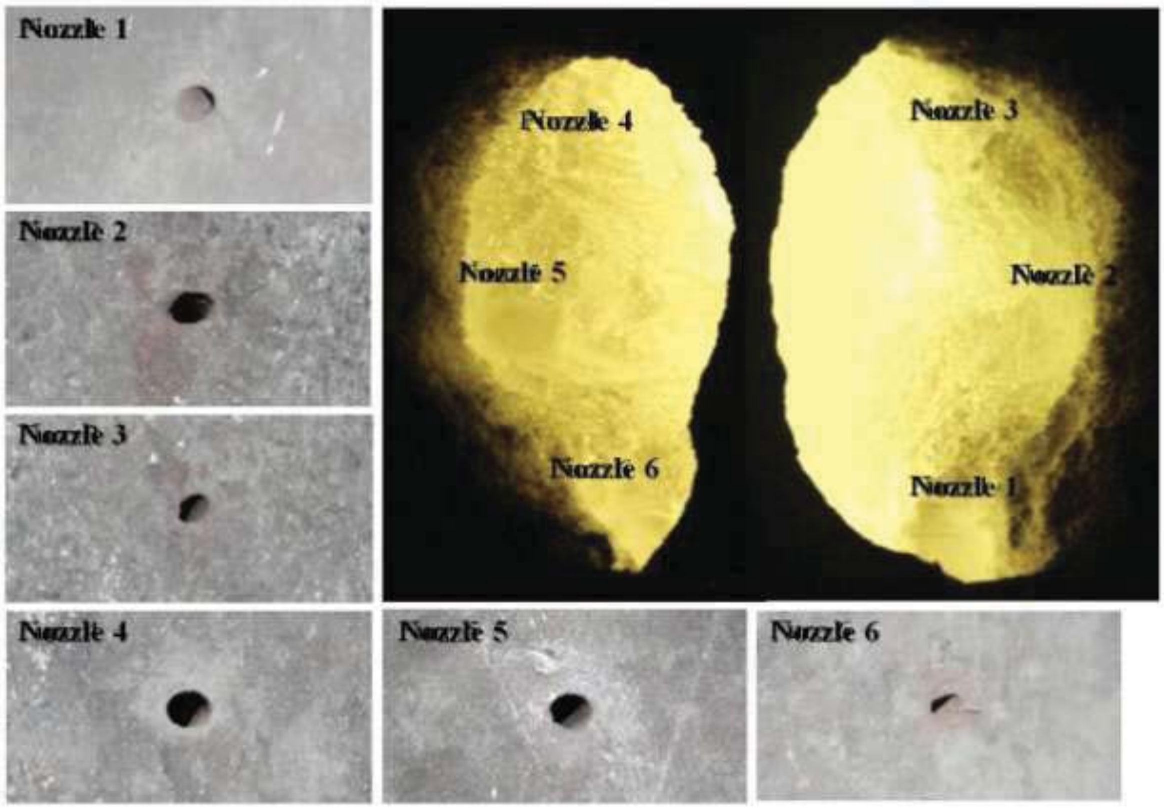


Figure 12 - Slagless Clean Up® after 611 heats. Post-combustion nozzles photos and caves into AOD-L.

Figure 13 - Slagless Clean Up® after 611 heats around tip face.

In **Figure 13** it is possible to see the good conditions around tip face, mainly nozzles after 611 heats. This result is better than conventional tip lances, which obtain an average life of 243 heats, and means that the Slagless Clean Up® cartridge is ready for continuous use. During cartridge use the number of skulls were insignificant.. The **Figure 14** shows a comparison between conventional lance and Slagless Clean Up® Lance.

Figure 14 - Comparison between conventional lance and Slagless Clean Up® after 981 heats. Conventional lance typical skull formation.

CONCLUSIONS

The main conclusions are:

a) Slagless Clean Up® reached target to reduce skulls in mouth of AOD-L converter;
b) Low skull weight in AOD-L mouth has influence to reduce time to change vessel;
c) Post-combustion nozzles of Slagless Clean Up® are adjustable according to typical mouth's skull formation;
d) Lance skulls on Slagless Clean Up® were insignificant;
e) Life of cartridge is nearly 4 times more when compared with conventional lance;
f) Slagless Clean Up® after 981 is in good conditions to use;

FUTURE STEPS

Study the possibility to increase the number of post-combustion nozzles with the target to obtain a more uniform skull cleaning in AOD-L's mouth, as shown at **Figure 15**.

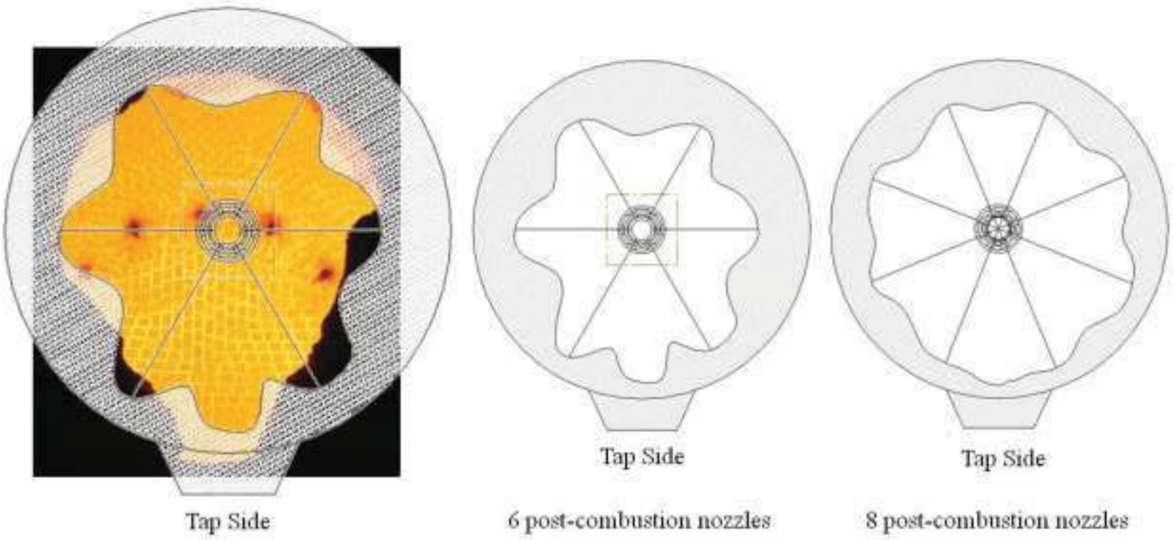


Figure 15 - New proposal to increase the number of post-combustion nozzles.

ACKNOWLEDGMENTS

The speakers of the paper thank Lumar Metals for continuous incentive in research and developments. Thanks to Bruno Alves for quality photos. **Bruno Orlando de Almeida Santos, eternal friend.**

REFERENCES

1 FILHO, D. S. F., MARIN, H., SILVA, J. M. F., PORTO, R., Análise sobre a Redução do Pick-Up de Nitrogênio na Produção de Aços Inoxidáveis. Anais do 42º Seminário de Aciaria Internacional, Salvador, Bahia, Maio 2011.

2 SARDINHA, I. A., Slagless Lance Recent Results at BOF Steel Plants Have Shown a Better Flexibility in Oxygen Blowing. Anais do 6th European Oxygen Steelmaking Conference, Stockholm, Sweden, 2011.