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## **PERFORMANCE IMPROVEMENTS IN BOF AT ARCELOR MITTAL JOAO MONLEVADÉ BY TECHNOLOGY SLAGLESS® LANCE**

### **Abstract**

In these hard days for Brazil steel market, all steel shops want to achieve the same goal, work with: productivity, low costs and high performance. In this scenario the Slagless® technology (which is applied into BOF converter) was important to reach these targets. After use has been reduced the number of times of tip exchange in more than 04 times. Was reduced too, the time to remove lance skulls. Lance keeps clean during all his life with record number of the life 1255 .Blow keep stable due strong measure control at the nozzles and more improvements are planning.

### **Keywords**

BOF, cartridge, process control, post combustion tip life, lance skull, safety.

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## 1. Introduction

Brazil in special, suffering the effects of huge amounts of steel in this beginning of century XXI has specific reasons for focusing attention in low cost units and on maximizing volumes instead of the closure of high cost units, generally been associate to low scale of production and its impact on fixed cost and final product.

Each day has been common to increase the demands for productivity with an increase of production mix, making it necessary have an optimized process to survive in the market. So, it is fundamental to improve the practices and concepts to get the productive excellence.

The Arcelor Mittal João Monlevade plant is an integrated steel plant producing long steel wires with high quality requirements, mainly those ones destined to the production of Wire Cord. Figure 1 presents an aero photo of ArcelorMittal Monlevade.

The steel plant Arcelor Mittal João Monlevade began his operation in 1957, being one of the pioneers in Brazil using the recent development LD (Linz Donawitz) converters, nowadays known as BOF (Basic Oxygen Furnace). Since the beginning operating with two converters on cycles “hot stand by”. Passed some years, increased the heat capacity, starting on 100 tons passing to 130 tons of liquid steel. Increasing the capacity from converters as well as production rhythm, bringing in practical terms as number of heats per day, demands the availability of the equipment as the blowing lance that has other effects, one of those are the formation of scrap on the spear. This study aims to present recent developments increasing performance of the oxygen lance equipment at the Arcelor Mittal João Monlevade plant.



Figure 1 – Photo view for Arcelor Mittal João Monlevade <sup>[1]</sup>.

## 2. Methods and Materials

The methodology used was based on successive cycles of PDCA <sup>[3]</sup> according to the scheme presented in Figure 2 followed by a commercial model based on the cost reduction according to the performance increment of the nozzle and nozzle joint components.

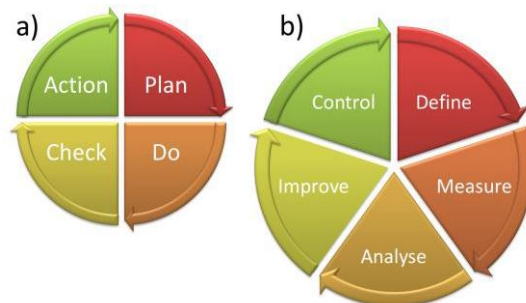


Figure 2 - PDCA cycle.

Traditional PDCA cycle doesn't approach clearly all phases, for example what is the best way to obtain the data in the phase data collect and what do with these data. Due to this, others studies improved the PDCA cycle generating a positive spiral of knowledge about productive process. In this case the improvement of blow stage and the parameters influence on the cartridge life and formation of undesirable skull lance is the main goal of this job. The skull lance is the solidification of the emulsified material on the lance surface. The skull may be metallic, formed only by slag or mixed composed of metallic parts, slag and additions of flux and unmelted refrigerators.

The lance skull is a solidification of emulsified material on surface of the lance during blowing. The skull may be metallic, formed only by slag or mixed composed of metallic parts, slag and additions of slags and unmelted cooling materials. Figure 3 illustrates the lance scrap forming process and undesirable consequence.

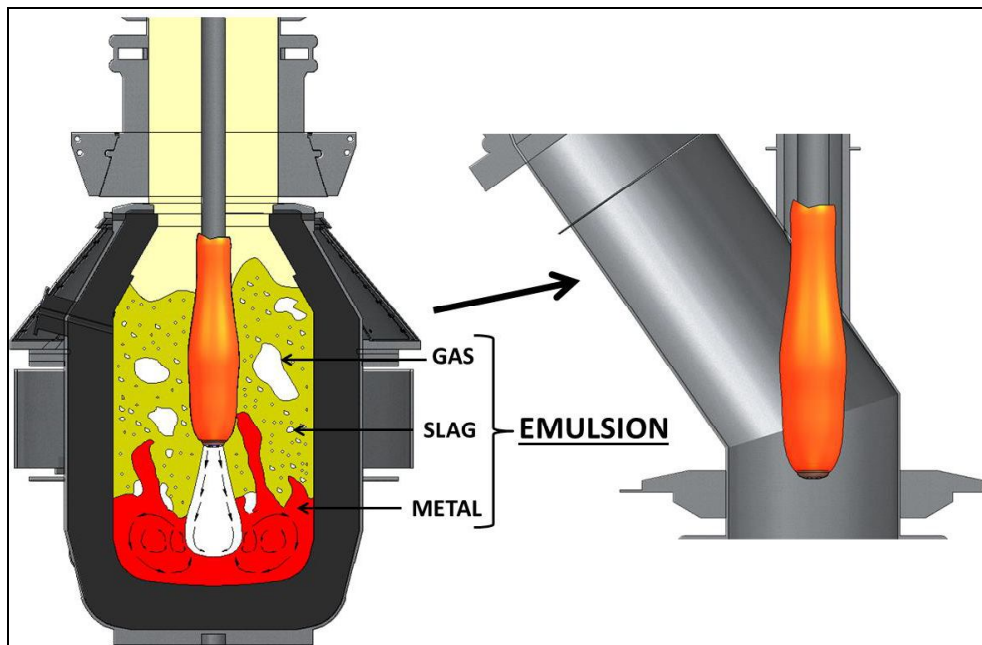


Figure 3 - Illustration of formation emulsion and skull at the lance. (Adapted from <sup>[2]</sup>)

During consecutive blows, gradually emulsified materials are solidified in the lance body and conventional tip lance, increasing the lance diameter. Extreme cases, the diameter increases so much that the lance passage through the dome in the gas collection system can be compromised or causing damage to the refrigerated pipes of the system. Setting, potentially high risk situation for water leakage into the converter. Figure 4a and 4b shows scrap forming on the conventional lance and lance tip.

The undesirable event presented in Figure 4c implies the necessity to withdraw the operational lance to remove the scrap generated. This activity implies in the displacement of teams of their preventive activities besides the risk of their execution in itself, with great expense of time. Concomitantly, subsequent blows can lead to the formation of new lance scrap, potentially threatening the blowing process continuity due to the lance unavailability.



Figure 4 – Scrap formation at conventional lance and tip face. a) Represent the scrap lance during domo passage and b) Represent the scrap extension along lance length.

Table I shows lance changes by monthly average. Another way to analyze the information is to consider that in the year 2014, at least once a day it was necessary to exchange lance. That's about 1.5 times a day in 2015.



Table I - Monthly average lance changes.

| Year | Monthly average number of lance changes |
|------|---|
| 2014 | 40                                      |
| 2015 | 46                                      |

To improve the productivity and solve this problem in Arcelor Mittal João Monlevade, Lumar Metals proposed to be implemented an innovative concept: the cartridge called as Slagless®, as can be seen in the Figure 5 - an extension of traditional length of the lance tip associated with a new external tapered copper dimension and a high efficient capacity of internal cooling. <sup>[4]</sup>

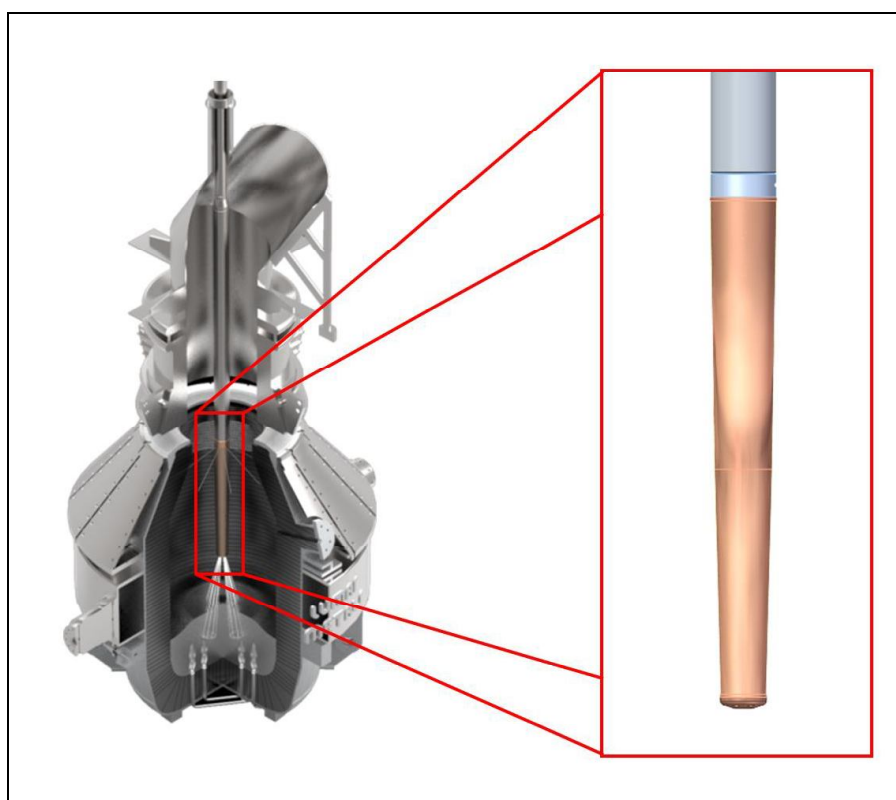


Figure 5 – Slagless® cartridge.

The partnership process with Lumar Metals began in 2013 with the supplying conventional tip lance as a preparatory step to the implementation of Slagless development. In 2015 as a premise to implementation of the Slagless® were established based on the results obtained in other plants <sup>[7-8]</sup>, which:

- Maintain the blow characteristics relative to penetration and lance height, guaranteed through the energy balance <sup>[8-10]</sup>;
- Be competitive considering broad economic aspects: durability, metallurgical results, metallic yield, availability of equipment, etc...
- Reduce the number of lances changed due skulls formations.

Lumar Metals started the preliminary studies, before the first heat blow with Slagless® technology as can be seen in Figure 6. In Figure 6b it is possible to note that Slagless® technology introduces the concept of "cartridge". The cartridge consists of a 3 meter long copper extension with specially shaped. Copper's heat conduction properties associated with geometry and studies of flow and heat exchange from the commercial "Ansys" software give Slagless® technology the ability to rapidly extract heat from the skulls that forms around the lances. The consequence of rapid heat extraction is the rapid solidification of the adhered skulls which cracks by thermal contraction (Figure 6b) and releases from the lance. In cases of steel plants that use additions of metallic oxides through top bins it is common to verify the presence of a thin layer of metal skull that is renewed with each heat as exemplified in the comparative at Figure 6.

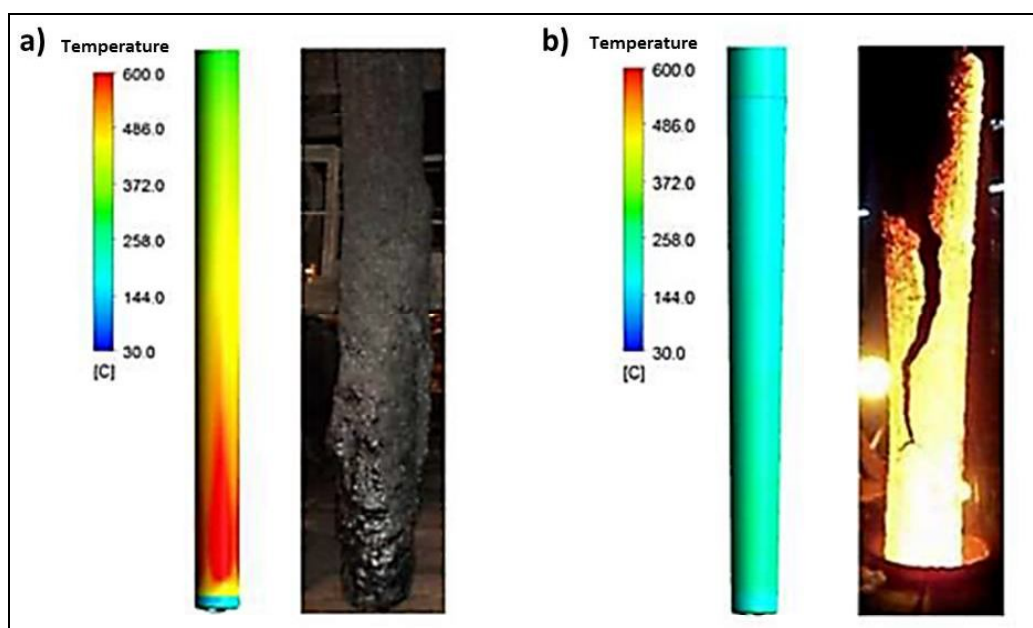


Figure 5 – Heat exchange compare: a) conventional lance and b) Slagless® cartridge

ArcelorMittal João Monlevade has a particularity in project of your TIP, when compared with other industries. Until this moment is the only to perform the post-combustion in the face to tip. Based on this information, Lumar Metals (with respect to existing patents) developed a technological alternative to meet a unique requirement of ArcelorMittal João Monlevade, keep the post-combustion in the face of the nozzle.

### 3. Discussion and Analyses

After realized all project and adaptations, was manufactured the cartridge Slagless® and your assembly was realized in lance 05 represented in Figure 8 bellow.

The cartridge of Figure 7 operated for 607 heats according to the assumptions determined at the beginning of the project, being withdrawn from operation in a preventive way, despite the excellent appearance of the face of the cartridge. Throughout the Slagless® technology campaign presented skulls of different natures but with the standard behavior of thin layer renewal after each run as shown in Figure 8.



Figure 7 - First Slagless® AM JM before first blow and peculiar cartridge face.

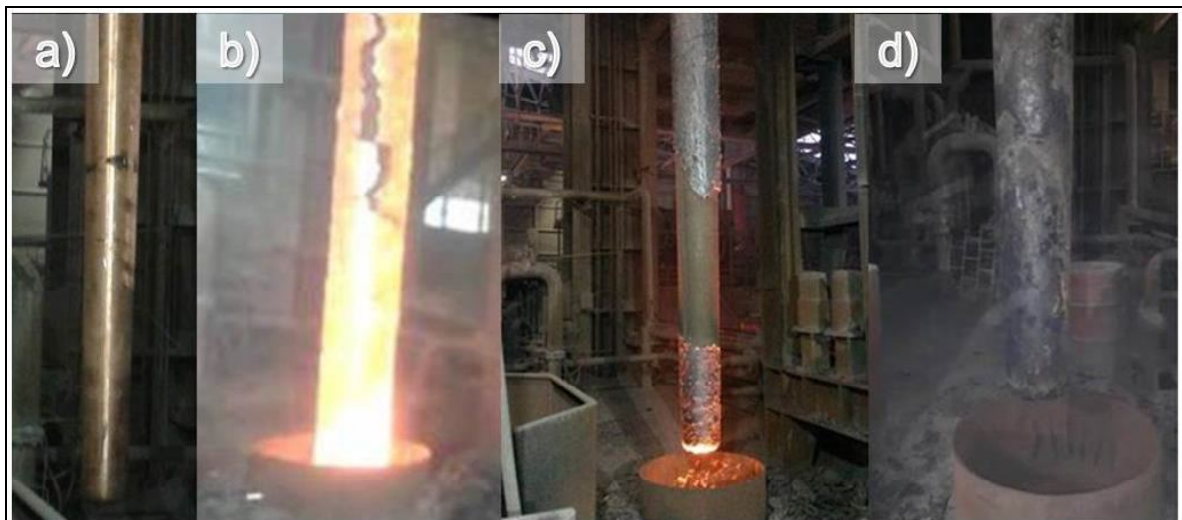


Figure 8 - Typical Slagless® behavior after blow. a) Represent new cartridge, b) Represent cartridge going out operation with slag tricking, c) Represent lance with slag removed partially and d) represent lance without slag.

During subsequent campaigns new challenges appeared compromising some cartridges, but were overcome. Notably after high number of heats, leakage on the cartridge's face.

The analyzes in the cycles of verification, anomaly treatment and control items were the necessary subsidies to determine improvements on the basic Slagless® technology and led to the achievement of the results that will be presented. Figure 9 shows the reduction in the number of lances exchange.

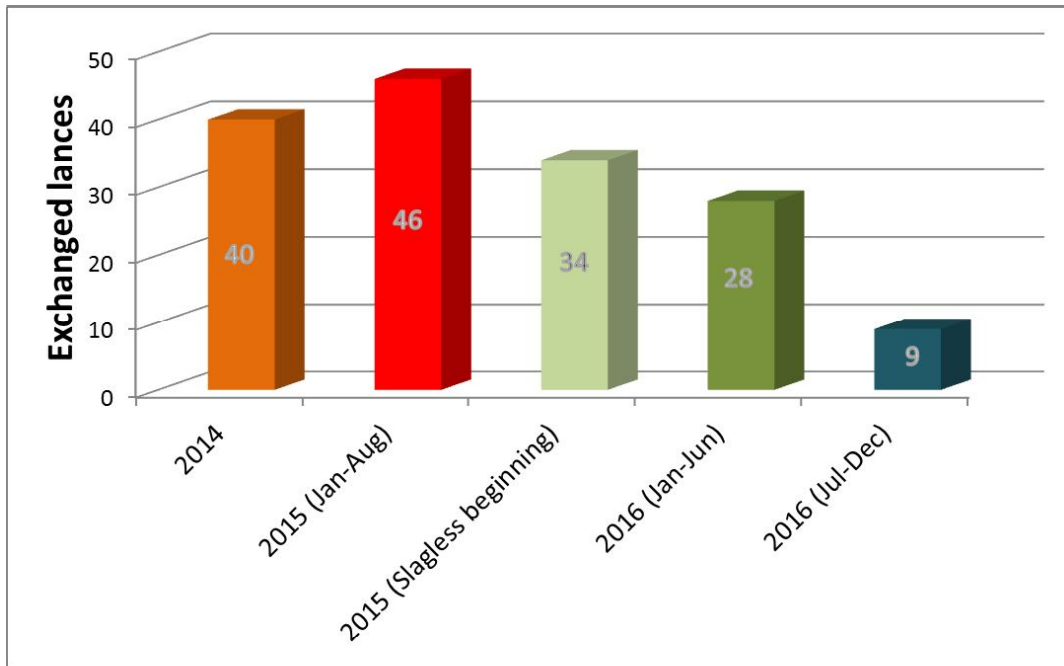


Figure 9 - Monthly average lance changes

The values shown in Figure 9 represent the monthly averages of the periods. It is possible to notice that with the entry of Slagless® technology there was a significant reduction in the need for lance exchange, in order to mean the need to exchange lance once time after three days.

The reduction of the lance exchange is directly linked to the life of the Slagless® cartridge as shown in Figure 10.

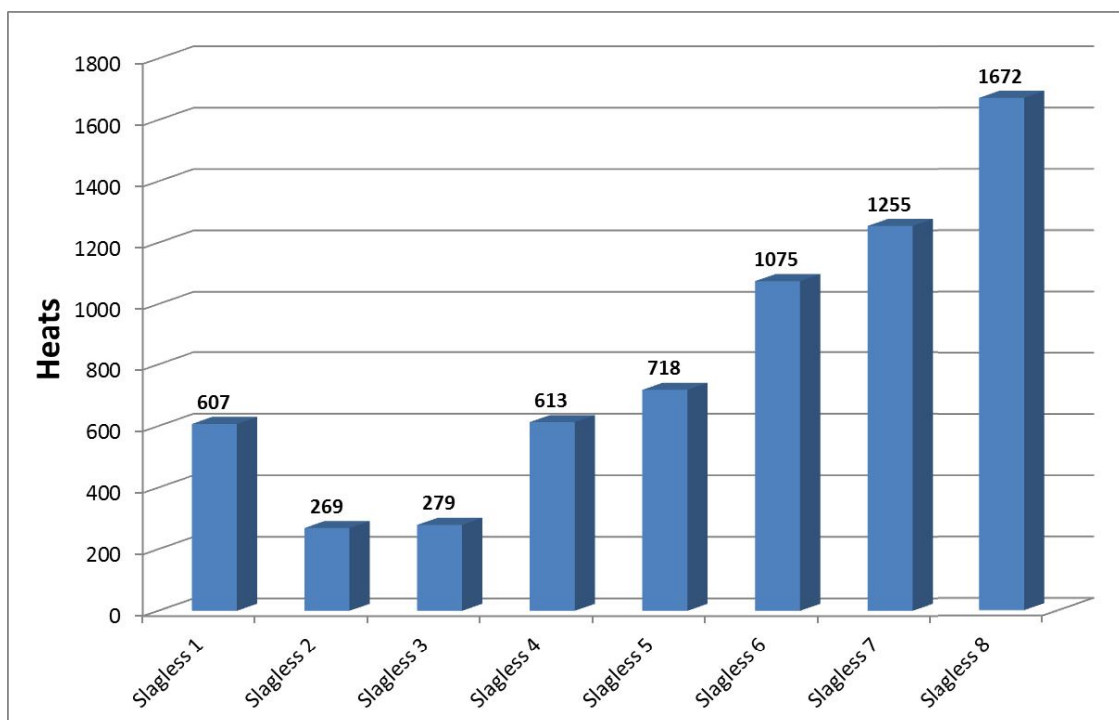


Figure 10 - Slagless cartridge life since start up Sept. 15 until Nov. 16.



In Figure 10 is the life of the Slagless® cartridges considering all the causes that led to the withdrawal of operation, among them there are operational causes, developments and adjustments whose results had bad effects on the metallurgical process as in the case of 2nd and 3rd cartridges. However, the effects are recorded, the causes identified and the implemented adaptations being the response a notable increase in the life of the cartridge concomitantly keeping stable all other metallurgical parameters that imply in the quality of the steel produced. The long life of the cartridge came from the continuous development of the blowing condition which in turn brought positive reflections to blowing stability.

The indirect gain is linked to operational safety. Slagless® technology has made it possible to reduce human intervention in high-risk activity by exposure to high activity in an environment with high levels of carbon monoxide, represented by number of lances changed, show at Figure 11.

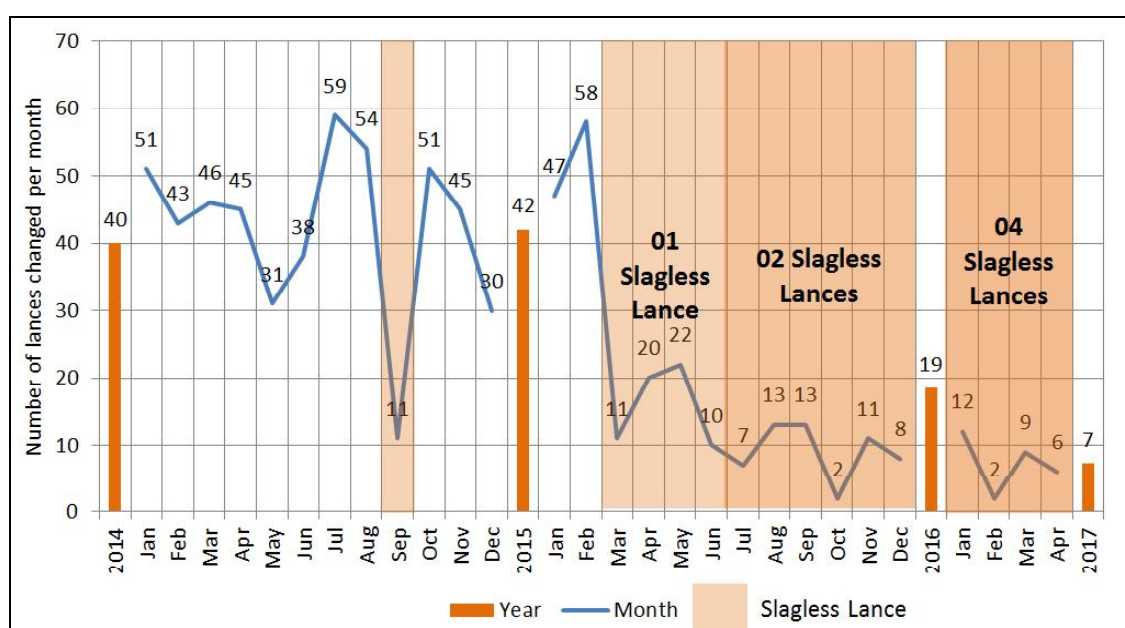


Figure 11 – Number of lances changed.

In Figure 11, since Slagless trial time at September 2015 the number of lance changes reduce strongly and this behavior keeps after continuous use after February 2016. With this behavior it possible to redirect the maintenance team to other priorities, as it also reduced the need for scrap cleaning.

#### 4. Conclusions

By working in partnership and implementing Slagless® technology, it is possible to conclude:

1. There was an approximately 75% reduction in the need for lances exchange;
2. Increase in the average life of cartridges over conventional nozzles more than 100%;
3. Increase in the average life of the cartridges due to the continuous analyzes and improvements of the technology;
4. Reduction of the occurrence of lance exchange to scrap cleaning activities more than 5 times in comparison with conventional lances;

5. Redirection of maintenance teams for activities with more importance value.

## 5. Acknowledgments

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