TUNDISH SEQUENCE LENGTH INCREASE FOR AL KILLED AND TI-SULC GRADES AT ARCELOR MITTAL FOS SUR MER STEELMAKING PLANT[1]

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Abstract

Arcelor Mittal Fos sur mer steelmaking plant has developed, in the frame of a fruitful and tight cooperation between Arcelor Mittal flat carbon European steel plants and ARCELOR Research, a zero clogging process leading to a significant improvement of the tundish sequence length. Such "zero clogging" process with no CC nozzle change pushes the limits for Al killed steel and IF steel above 1600 t of liquid steel per nozzle and 2680 t of liquid steel per tundish. In this paper the key factors for the zero clogging process are first presented. They are mainly located in the secondary metallurgy area (ladle slag composition, re-oxidation, Ti recovery etc…). The results and the process performance are completely described. With such zero clogging process Arcelor Mittal Fos sur mer steel plant reaches a world class low cost and a high productivity level for Ti-SULC grades and Al killed grades. The way toward 2000t of Ti-SULC grades cast per tundish nozzle is achievable.

Key words : Clogging; Inclusions; Ladle slag; Ti losses.

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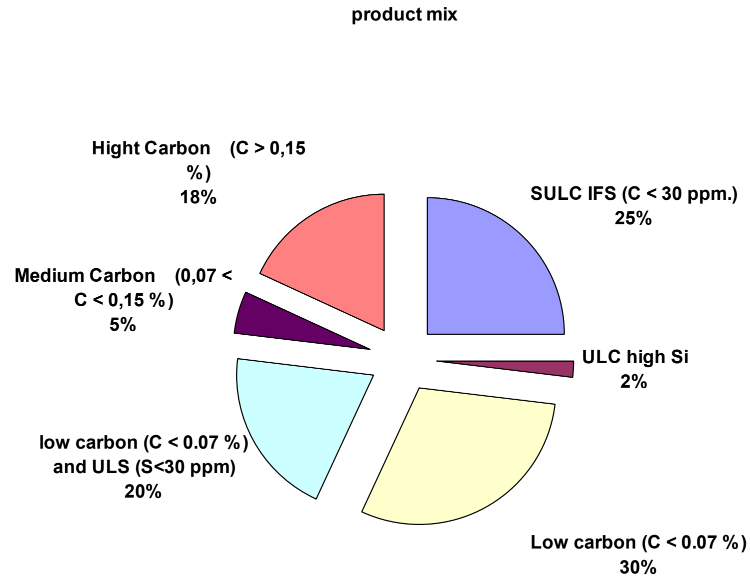
[2] *ARCELOR Mediterranée.*

[3] *ARCELOR MITTAL*

1 INTRODUCTION

Arcelor Mittal Fos sur mer steelmaking plant located in south of France has a yearly slab capacity of 4,5 Mt. A business plan is launched in order to reach a yearly slab capacity of 5,3 Mt in 2010. The Figure 1 presents the product mix and market share of the steel plants. The customers belong mostly to the Mediterranean market (Italy, Spain, Greece, Turkey and Portugal). The Table 1 resumes briefly the main steelmaking tools.



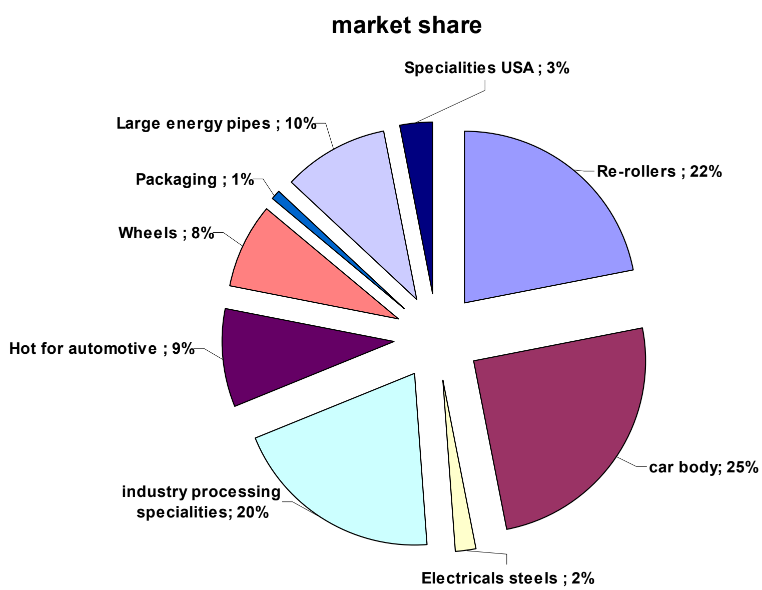


Figure 1: Arcelor Mittal steelmaking product mix and market share

Table 1: Fos steelmaking tool description

	Type	Nb	capacity
Hot metal desulphuration	CaC2 injected in torpedo	2 strands.	Torpedo : 380 t
Ladle	Stirring with porous plug	17	335 t
BOF	LET – sublance Slag retention with dart and Infrared camera	2	335 t
Secondary metallurgy	Steel desulfuration station	1	Ar lance Ca wire injection
	CAS - OB	1	
	RH		8 steam ejectors
Continuous caster	Curve	2 strands : 850-1600 x 223 mm	V max : 1,85 m/min
	Verticale curved	2 strands : 1050-2200x 223 mm	V max 1,65 m/min

In the frame of the business plan, an important process work is done in order to increase the steelmaking tool productivity and reliability. This paper presents the results obtained at Arcelor Mittal Fos sur mer steelmaking plant in the field of the tundish sequence length. A reliable "zero clogging" process with no CC nozzle change is used with castability limits for Al killed steel and IF steel pushed above 1600 t of liquid steel per nozzle and 2680 t of liquid steel per tundish. This industrial result comes from a fruitfull and tight cooperation between Arcelor Mittal flat carbon European steel plants and ARCELOR Research. This paper resumes first the key factors for the zero clogging then describes the results and the process performance leading to a world class low cost, a high productivity and quality production level at Arcelor Mittal Fos sur mer steel plant.

2 ZERO CLOGGING KEY FACTORS

In the following, clogging is related to a rapid increase of the Continuous casting lift stopper position and/or discharge occurrence leading to important mold level fluctuations. The clogging phenomena are studied for years.[1,2,3] The mechanisms are known and already presented[4,5,6] in details. They involve three main key factors: inclusions, Argon and continuous casting refractories.
In this paper the zero clogging process only focuses on the inclusion topic mainly the Ca-aluminates and the Ti-aluminates.

2.1 Ca Aluminates

Concerning the Ca-aluminates, important investigations performed on the nozzle deposit reveal that the nozzle deposit size is related to CaO activity of the ladle slag. Increasing the CaO activity of the ladle slag leads to an increase of the nozzle deposit size and consequently to a raise of the clogging phenomenon occurrence. This result is confirmed by other publication.[3] One key of the zero clogging process is to adjust and control the CaO/Al2O3 ratio of the ladle slag in order to avoid the Ca transfer from the slag to the liquid steel. For many years at Fos sur mer steelmaking plant lime is added during BOF tapping aiming at a CaO/Al2O3 ratio equal to 1.1 for Al killed steel at the secondary metallurgy. This value is the best compromise between the refractory wear and the clogging phenomenon. Nowadays due to the process and uncontrolled parameters, this ratio exhibits a large scattering around the aimed value (Figure 2). The main task of the zero clogging project was first to understand this scattering and then to find the countermeasure to drastically reduce it. Based on a year production with slag analysis measurement at the secondary metallurgy, the CaO/Al2O3 scattering investigations reveals that

- the returned slag quantity and slag analysis coming from the previous ladle heat explains 45% of the scattering
- the slag quantity deviation coming from the BOF during tapping explains 35% of the scattering
- the Al2O3 quantity deviation coming from the steel de-oxidation explains 20% of the scattering

According to this analysis, the main countermeasures to reduce the CaO/Al2O3 scattering are:

- Quantification of the BOF slag amount going into the ladle during tapping. For such aim, the BOF slag amount(7) is determined by an infrared camera response analyzing the steel jet during tapping. Then using this slag carry over quantification and a combination of the results of the last 10 BOF heats and different BOF process parameters such as end blow carbon, end blow temperature), the BOF slag amount is predicted.
- The returned slag mass and analysis evaluation coming from the last ladle heat. For such determination different ladle process parameters are taken into account such as empty ladle weight evolution, ladle refining process of the last heat.
- Better evaluation of the Al203 amount due to steel de-oxidation. Different BOF and tapping process parameters are taken into account: End blow oxygen activity, end blow carbon, steel weight, alloying quantity, tapping time, Al addition.
- Ladle slag composition measurement at the liquid refining stations (CAS-OB, RH or steel desulphurization station). This control allows to follow and even to correct the process model parameters.

Figure 2 compares the CaO/Al2O3 ratio distribution obtained with the old and new process. The new process leads to a strong scattering reduction. The CaO/Al2O3 values lower than 0,6 and higher than 1,4 are no more obtained according to a better prediction and control of the BOF slag carry over (CaO), steel deoxydation (Al203) and the returned slag from the previous heats (slag quantity).

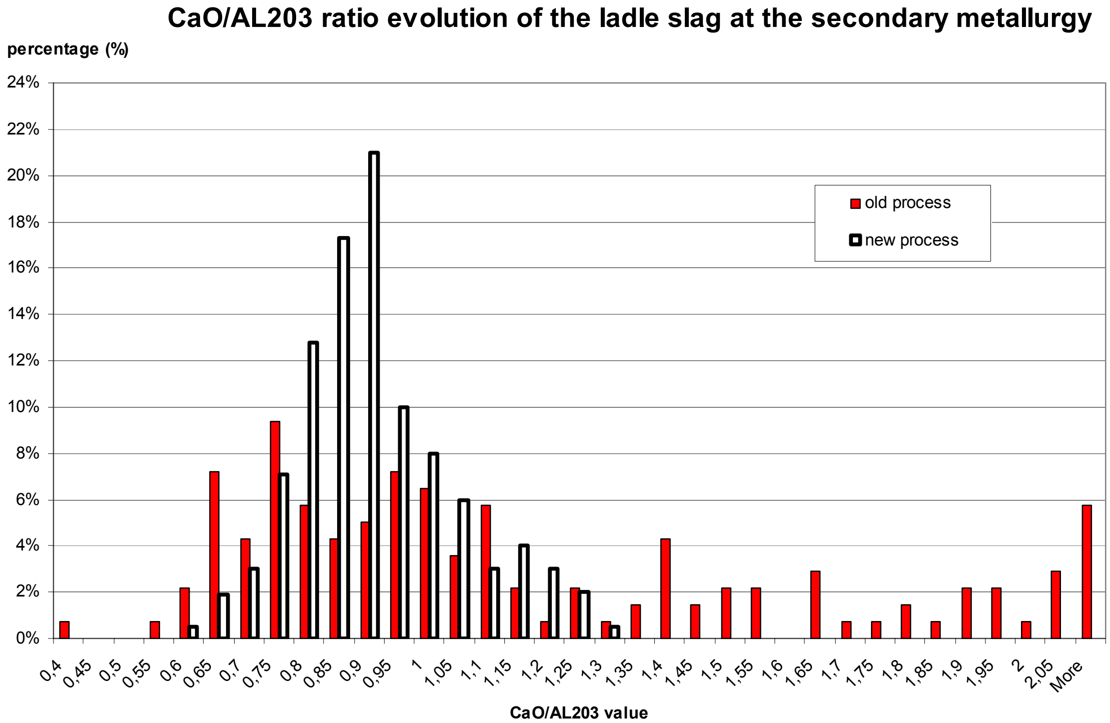


Figure 2: CaO/Al2O3 ratio distribution comparison: old and new process

2.2 Ti-aluminates

Concerning the Ti-aluminates, important investigations and publications(8) conclude that one key factor is the Ti oxidation prevention. Reducing or best avoiding the Ti oxidation leads to a decrease of the clogging phenomena due to Ti-aluminates inclusions deposit in the nozzle during casting. For TiSULC a new process is developed leading to an improvement of the clogging phenomena. The Key points of the new process are

- The time delay between Al killing and Ti alloying (at Fos the threshold is 180 s).
- The limitation of oxygen sources after Ti addition: the steel temperature is not adjusted after Ti addition (cooling nor reheating). There is no inclusions elimination process (Ar bubbling) after alloying.

To emphasize such results, Figure 3 compares the averaged Ti losses for the old process (taken as reference 100%) and the new process.
One can notice that the Ti losses are reduced by 45% with the new process. As an obvious consequence, this new process leads to an effective cost reduction by saving Ti.

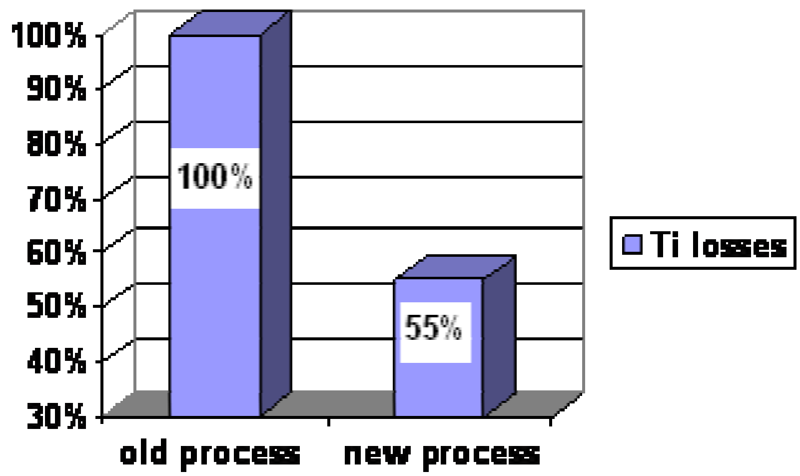


Figure 3: Ti losses comparison for the old (reference) and new process

3 TUNDISH SEQUENCE RESULTS

The zero clogging process leads to a strong increase of the tundish sequence capability. With no nozzle change during casting, the industrial number of heats in a tundish sequence goes from 5 to 8 of 335 metric tons. Trials of 10 heats in a tundish are under progress. For Ti SULC grades an improvement of the castability is obtained. At Fos in order to evaluate the castability, a clogging index is determined for each heat of a sequence. It is a combination of different process parameter behavior during casting. It takes into account the casting time with the mold level in the range of +/- 5 mm, the occurrence and gravity of nozzle clogging and discharging, the argon pressure behavior in the stopper rod, the position of the stopper rod. The index value has no physical meaning. The lower is the value, the better is the castability. It is used for tendency investigations. The Figure 4 compares the averaged clogging index evolution for the old and the new process.

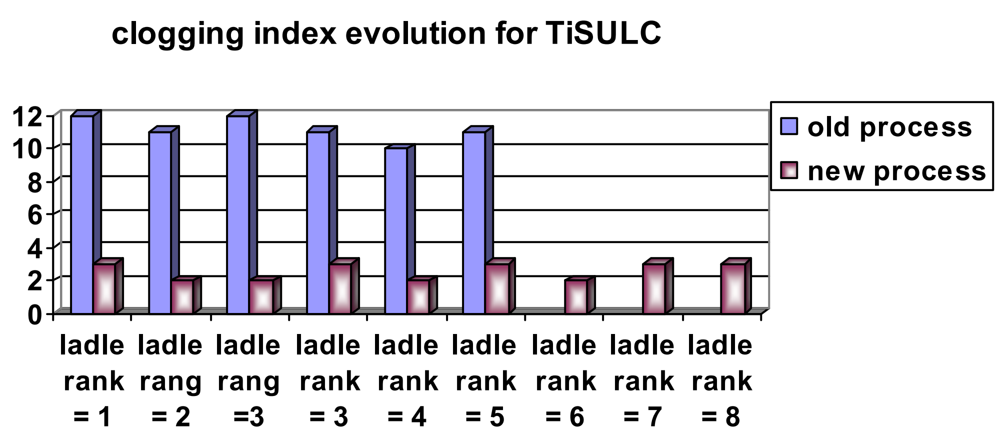


Figure 4: Averaged clogging index evolution for the old and new process.

From Figure 4, one can notice that the clogging index exhibits a real decrease (approximately by a 5 factor) for the new process whatever is the ladle rank in the tundish sequence. The castability is significantly improved. With the old and new process the castability seems to be not related with the ladle rank. The Figure 5 shows a typical time-evolution over a sequence of 8 charges of Ti-SULC grade. No clogging nor unclogging is observed.

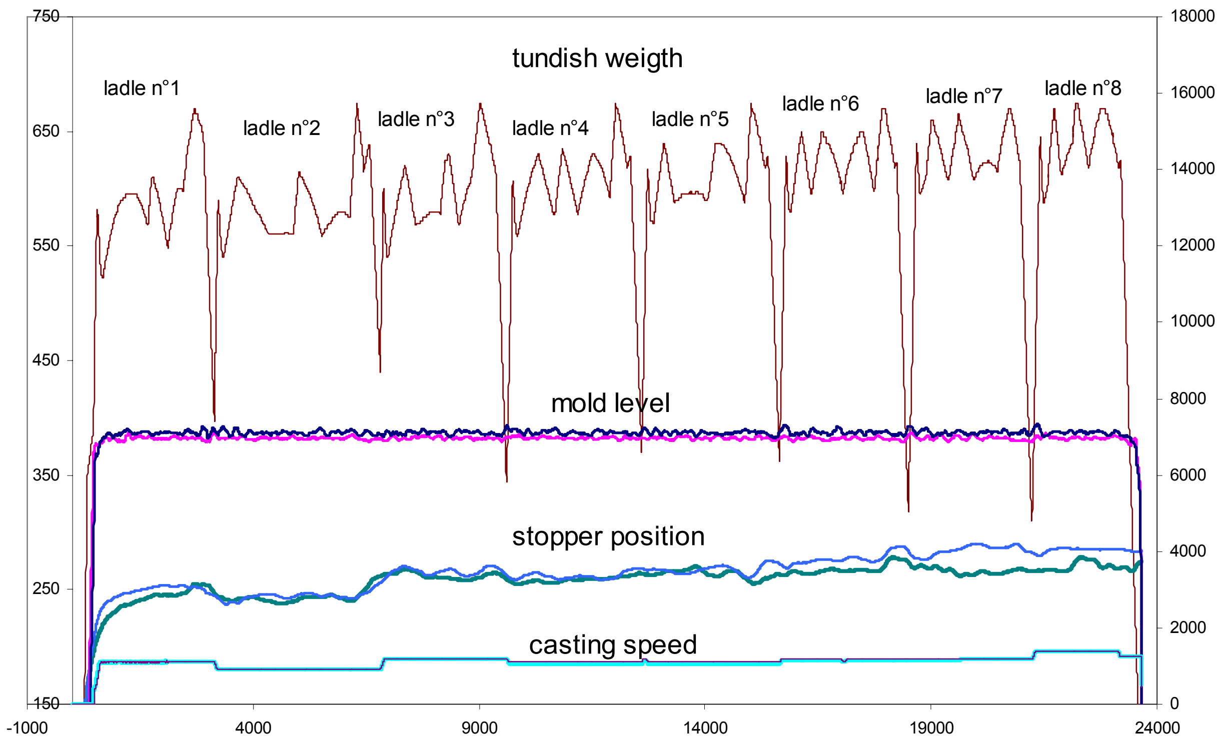


Figure 5: Time evolution over a sequence of 8 charges of Ti-SULC gardes at Fos.

With such tundish sequence (8 ladles of 335 t) the maximum cast ton per submerged entry nozzle can reach now 1630 t (due to the strand asymmetry). Previously it was 900 t. Such tundish sequence increase leads to an important CC yield improvement (+ 60%) and consequently to an effective cost reduction. For comparison, Figure 6 shows the improvement obtained at Fos as well as in the other Arcelor Europe steel plants for Ti-ULC grades since 2003. Results for other competitors are also mentioned. One can notice that the Arcelor steel plant zero clogging process results are at the best world class level. This result is valid for Al killed steel.

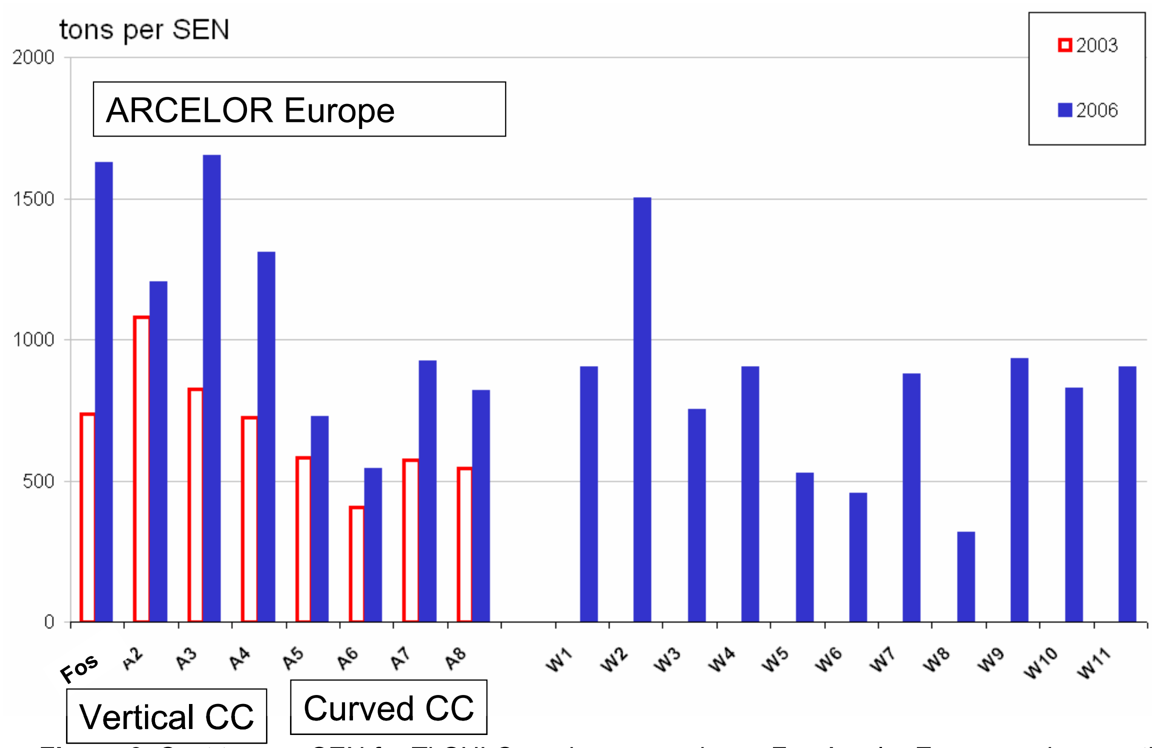


Figure 6: Cast ton per SEN for Ti-SULC grades comparison : Fos Arcelor Europe and competitors(9)

4 QUALITY RESULTS

Due to the improvements of the clogging and castability, the internal product rejection index shows a strong decrease (Figure 7). Taken the old process slab rejection index as a reference for exposed application, the index obtained with the new process decreases by 55%.

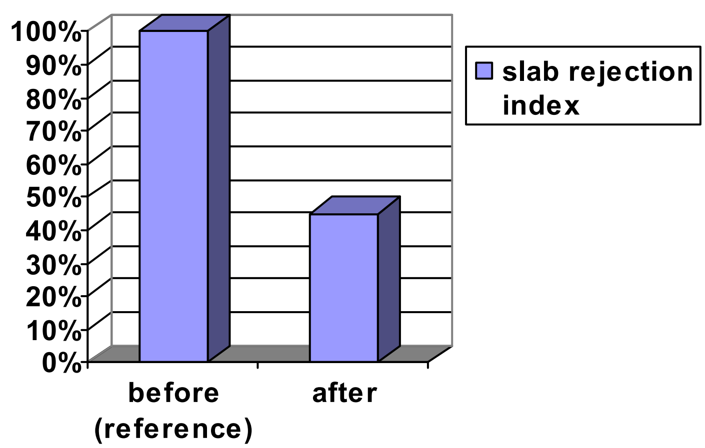


Figure 7: Slab rejection index evolution: new and old process

The zero clogging process leads towards the zero sliver products.

5 CONCLUSIONS

The zero clogging process results from a control of the steel elaboration and of the continuous casting processes. The cast ton per SEN is now around 1600 t with no real limitation due to clogging. This process may pave the way toward 2000t of Ti-SULC grades cast per tundish nozzle. With this process Fos sur mer steelmaking plant has reached a world class low cost and high quality production level.

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