MACROSIM, A TOOL FOR FAST DIAGNOSIS OF THE CONTINUOUS CASTING PROCESS OF SLABS*

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Abstract

The continuous slab casting process needs to comply with potentially incompatible demands: high productivity, lower costs, complex phase transformations during steel solidification and cooling, and semi-products with no defects. It is not always possible to match all these requirements intuitively, as the interactions between the various phenomena that occur during this process can be complicated and, eventually, contradictory. This was the motivation for the development of MacroSim, a digital tool based on Microsoft Excel, that analyzes operational data from the continuous casting machine and performs a process diagnosis from the point of view of slab quality and productivity. Among the analyzed parameters are the chemical composition of the steel, strand dimensions, casting speed, superheat, mold oscillation conditions, mold flux composition, secondary cooling water flow, among others. The variables that must be considered are simple and in a number that will not overburden the operational staff who must provide them. Some examples of MacroSim successful applications are described, where this tool identified the problems of the continuous casting process that were causing quality issues in the slabs.

Keywords: Continuous casting, Slabs, Diagnosis, Quality control.

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1 INTRODUCTION

The continuous casting (CC) of steel has been a major development of the steel industry during the last 50 years. CC has increased steel industry competitiveness due to both higher productivity of this route and lower production costs. Therefore, the ratio of steel produced by the CC route has continuously increased along this period. On the other hand, this process has a complex solidification process, so the development of cracks inside and outside of the CC semis is not rare. It could be thought that, after so many years of research, solidification models, software developments, big data collection and new technologies, the quality problems could be already solved. However, this is not the case nowadays: although quality has improved, problems are still far from being fully solved. There are several reasons for this outcome; some of them are listed below:

- The high number of different steel grades that must be cast at the same equipment: microalloyed, titanium, API sour service grades, AHSS.
- The demands for higher productivity have raised the casting speeds of the CC machines along time. However, in many cases, BOFs and EAFs with small heat tonnage are feeding these new machines, which often lead to frequent variations and reductions in casting speed to keep continuous heat sequencing. This practice leads to low surface temperatures in the slabs which, therefore, induce the formation of transversal cracks due to the low hot ductility of steel in the unbending region.
- The high demand for steels with high Mn, extremely low sulfur and low total oxygen contents requires secondary refining (especially in plants with ladle furnaces), which increase treatment time, creating yet another production bottleneck leading to casting speed reductions which generate the issues mentioned above.
- The castability of high-quality steel depends on avoiding breakouts, cracks and surface quality problems. The surface quality of steel products is mainly determined by the early stages of solidification in the meniscus region of the mold. Steels which undergo the peritectic transition are the most difficult to cast [1].
- Customer requirements for better surface and internal product quality have increased up over the years.

There are many variables that influence the occurrence of these defects and generally many of them act simultaneously. Thus, there is no ready solution to solve these problems. A systematic and detailed statistical analysis of these variables is needed.
Many technical contributions from several authors show the correlation between cause (process variables) and effect (defects in slabs), but they generally are restricted to specific cases of a given defect, not covering the entire range of possible situations. And, sometimes, a proposed change in the process to mitigate a specific defect can potentialize another type of problem.
Considering all these issues, MacroSim, a Microsoft Excel application, was developed to run a model that carries out a global analysis of the continuous casting process.
The model behind MacroSim is based on statistical correlations between the surface/internal quality grade of the slabs and the process variables developed from industrial data got from several continuous casting machines. In addition to the own

authors' data, information from industrial studies developed by several other authors, available in the world literature, was also used [2-16].
Figure 1 schematically presents some of the many correlations between process variables and slab defects available at MacroSim.

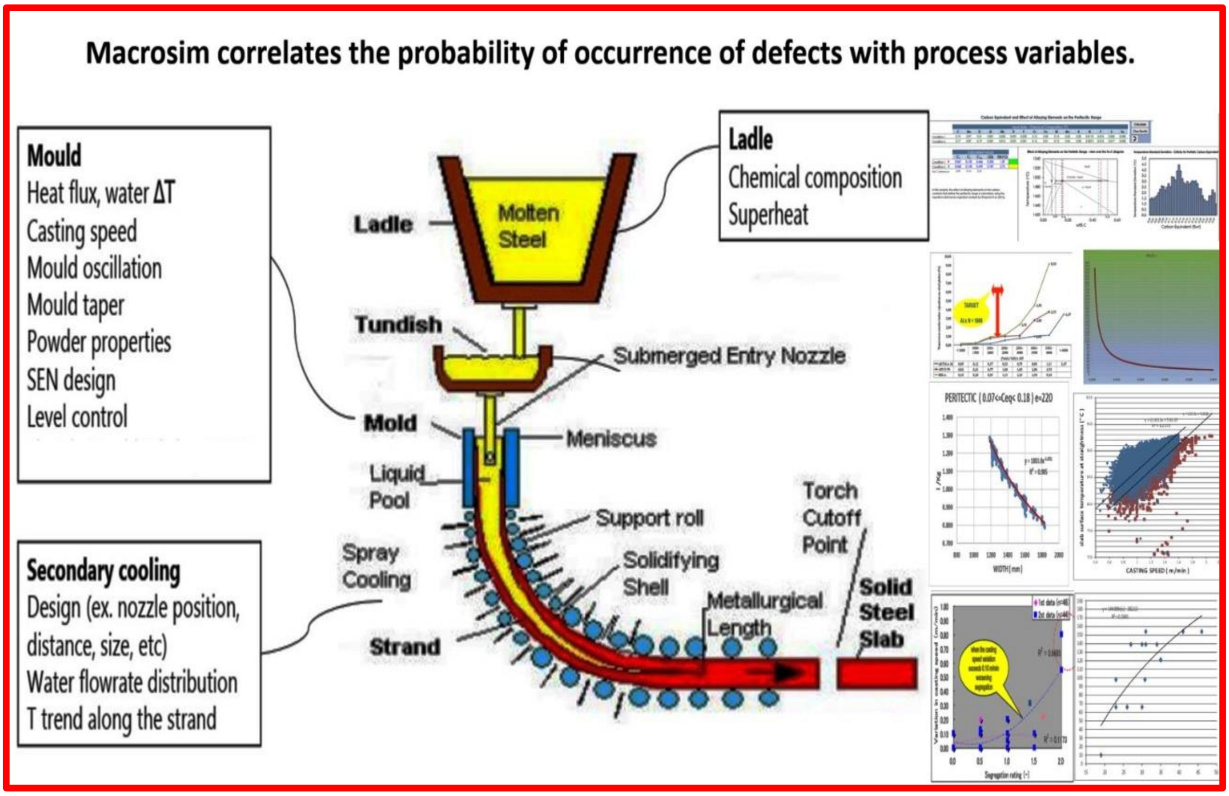

Figure 1. Schematic figure exemplifying the correlations available in MacroSim.

2 DEVELOPMENT

2.1 Description of the MacroSim Model

Unlike the numerous models available on the market, that are excellent, but requires a detailed log of operational and equipment data that are difficult to access and not always known by the operating team, MacroSim, with little input data, easily found in the operational reports of the casting machine, issues a detailed and fast diagnosis of the casting process.
The database used to build the model is valid for steels with carbon content range from 0.06% to 0.19%. The production flow of the data includes LD converter, ladle furnace, RH vacuum degassing and slab continuous casting machine.
The model is divided in four main modules:

I. Data Input
II. Steel Mill Analysis
III. Casting Process Analysis
IV. Summary Report

Each of these stages and its role on the model is described below.

2.1.1. Data Input

Data needed for the MacroSim analysis is input through the Steel Mill and Casting Process Analysis screen (figure 2) or retrieved from cases previously studied. The information required are as follows:

- Chemical analysis at the tundish of the steel grade being studied
- Metallurgical length
- Slab width
- Slab thickness
- Casting speed (minimum, mean, maximum)
- Superheat
- Mold level variation
- Stroke and oscillation frequency (for each casting speed)
- Mold flux composition (%CaO and %SiO_2)
- Water flow rate (secondary cooling)
- SEN angle
- SEN depth

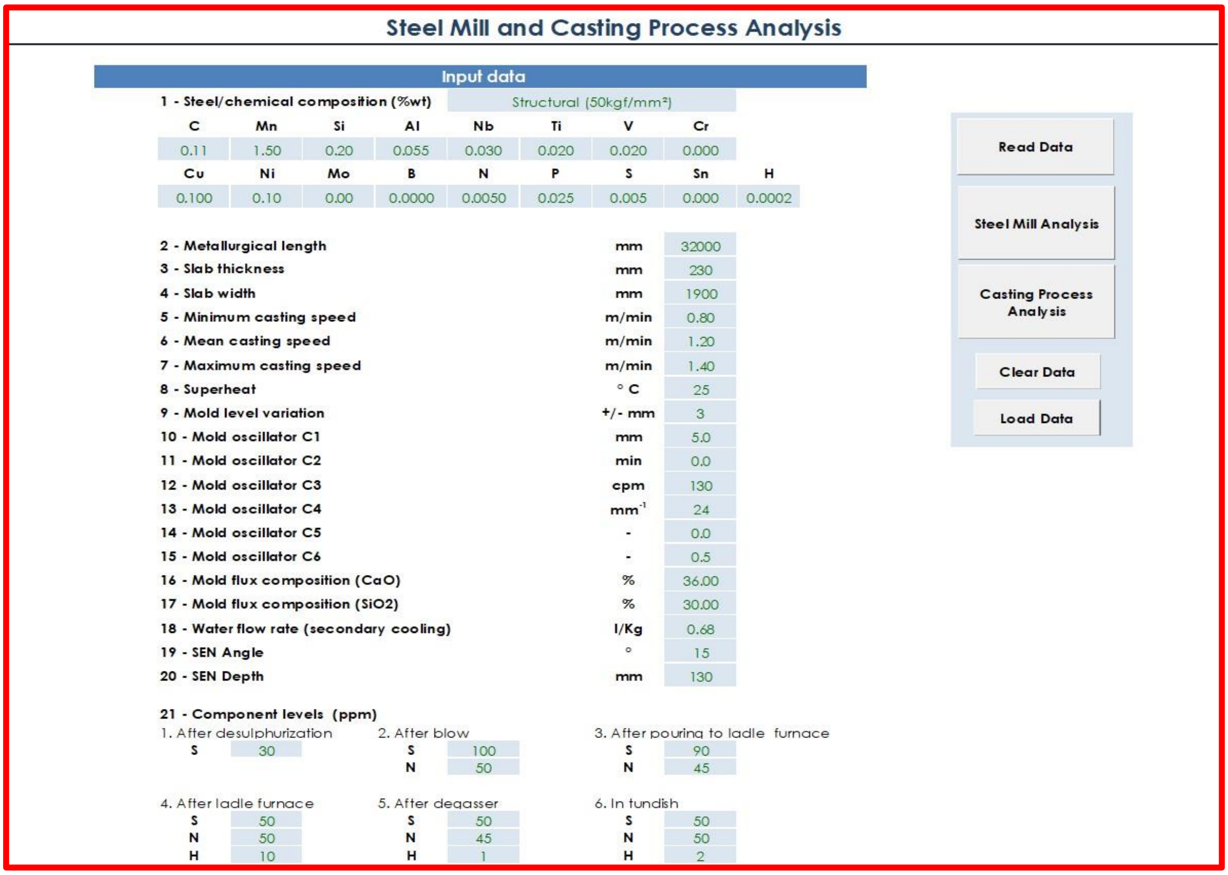

Figure 2. Steel Mill and Casting Process Analysis screen, data input template for the model**.**

This screen comprises five commands, the buttons in the right side of figure 2, as listed below:

- Read Data: load input data of this screen to the application.
- Steel Mill Analysis: directs the user for the Steel Mill Process Analysis screen.
- Casting Process Analysis: directs the user to the Casting Process Analysis screen.
- Clear Data: clear data on the Input Data screen.

- Load Data: retrieves data from a case previously saved in the application.

2.1.2. Steel Mill Process Analysis

Figure 3 shows the Steel Mill Process Analysis screen. The influence of the chemical composition of the steel grade on the occurrence of transversal and longitudinal cracks is evaluated here. This analysis comprises the following response variables:

- Behavior of sulfur content from hot metal desulfurization to the tundish.
- Behavior of nitrogen content from BOF to the tundish.
- Behavior of hydrogen content from ladle furnace to the tundish.
- Mold Temperature Standard Deviation (TSD), Peritectic Index (PI %), Longitudinal Cracks Probability (LCP), Transverse Cracks Probability (TCP), Al x N index, Ni/Cu ratio, Cu equivalent, Mn/S ratio and Ferrite Potential.

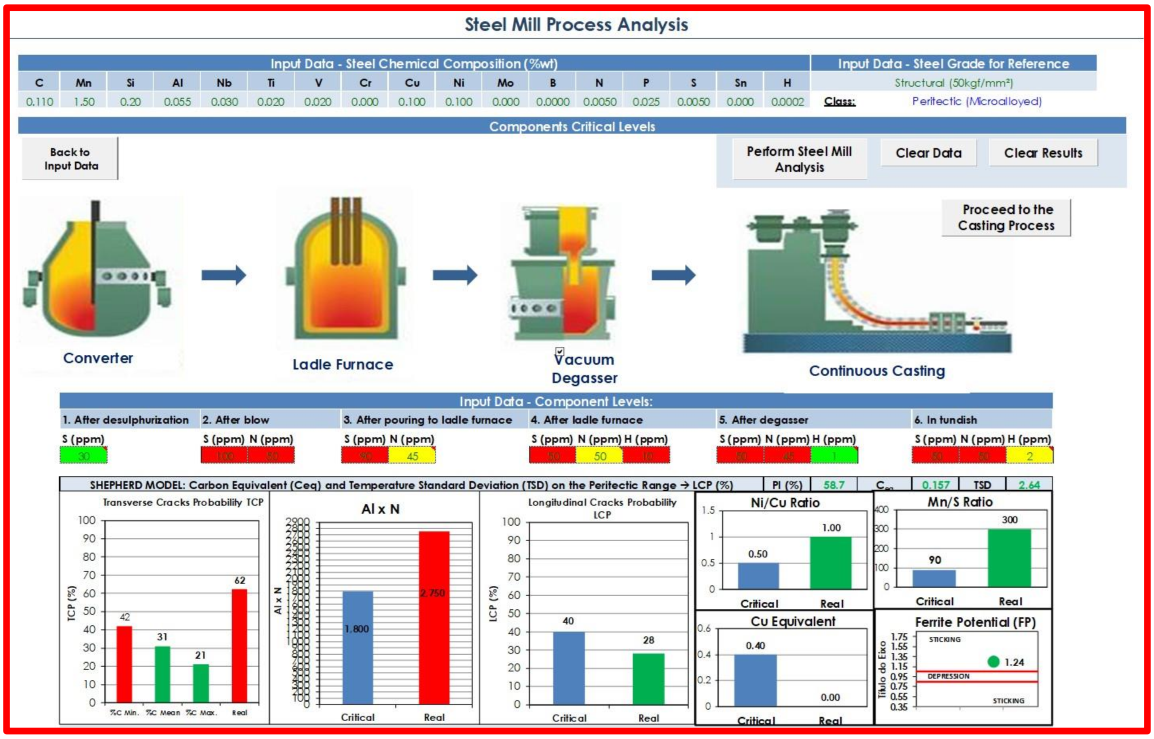

Figure 3. Steel Mill Process Analysis screen**.**

2.1.3. Casting Process Analysis

Figure 4 shows the Casting Process Analysis screen, which shows the influence of continuous casting parameters on the occurrence of transversal and longitudinal cracks, as well on the central segregation levels of the steel. This analysis comprises the following response variables: Mold Level Variation, Mold Level Trend, Factor "F", Mold Power Basicity, Slab Cross Section Trend, Longitudinal Casting Trend, Centerline Segregation Trend, Casting Speed Variation, Mold Oscillation Curve, Water Flow Rate (Secondary Cooling), Unbending Surface Temperature, Strain Energy, Transverse Crack Trend by Casting Speed.
A critical factor is the influence of the mechanical and hydraulic conditions of the casting machines equipment. The same value of a variable can result in different levels of slab quality depending on machine conditions, as shown in the figure 5 [17].

2.1.4. Summary Report

Figure 6 shows the Summary Report screen. The input data, calculated parameters and analysis results are summarized in this report.

Figure 4. Casting Process Analysis screen.

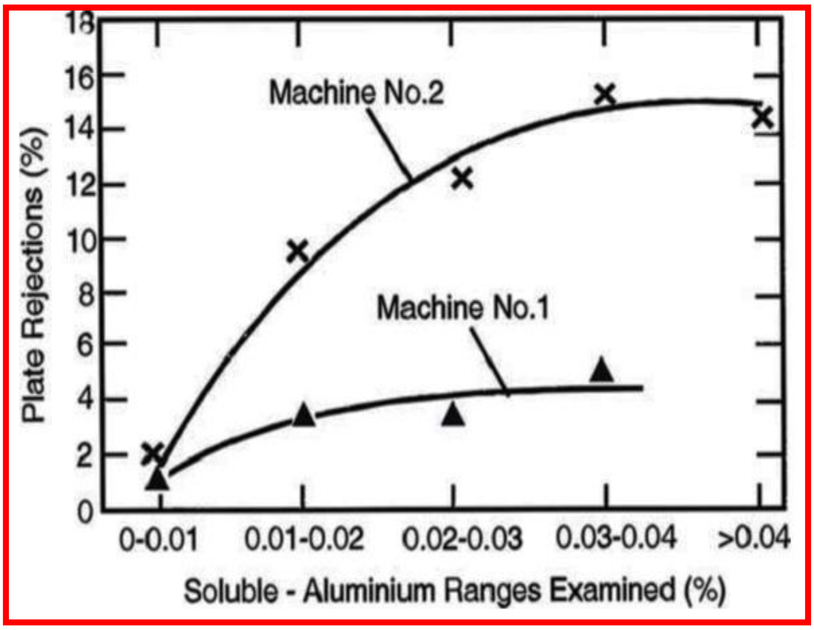

Figure 5. Different quality results depending on the maintenance condition of casters [17].

Steel Mill and Casting Process Analysis - Summary Report

Input Data

1 - Steel/chemical composition				Structural (50kgf/mm²)			
C	Mn	Si	Al	Nb	Ti	V	Cr
0.14	1.35	0.25	0.030	0.012	0.015	0.000	0.000
Cu	Ni	Mo	B	N	P	S	Sn
0.000	0.00	0.00	0.0000	0.0045	0.025	0.005	0.000
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Parameter	Unit	Value
2 - Metallurgical length		32000
3 - Slab thickness	mm	230
4 - Slab width	mm	1900
5 - Minimum casting speed	m/min	0.80
6 - Mean casting speed	m/min	1.20
7 - Maximum casting speed	m/min	1.40
8 - Superheat	°C	25
9 - Mold level variation	+/- mm	3
10 - Mold oscillator C1	mm	5.0
11 - Mold oscillator C2	min	0.0
12 - Mold oscillator C3	cpm	130
13 - Mold oscillator C4	mm⁻¹	24
14 - Mold oscillator C5	-	0.0
15 - Mold oscillator C6	-	0.5
16 - Mold flux composition (CaO)	%	36.00
17 - Mold flux composition (SiO2)	%	30.00
18 - Water flow rate (secondary cooling)	l/Kg	0.68
19 - SEN Angle	°	15
20 - SEN Depth	mm	130

Back to Casting Process | Back to Steel Mill | Back to Input Data | Clear Report

Output Data: Analysis of Results

1-HOT DUCTILITY ISSUES AND TRANSVERSE CRACKS TENDENCY CAUSED BY	CRITICAL VALUE	REAL	RATING
Mn/S	> 90	270	
Ni/Cu	> 0.5	1.00	
CuEquivalent - (f: Cu, Ni, Sn)	< 0.4	0.00	
Chemical Composition (%) - (f: C, Al, N, Ti)	< 40	31	
Al.N Product	< 1800	2750	
Casting Speed Variation (%)	< 25	55	
Minimum Casting Speed (%)	<= 40	80	
Mean Casting Speed (%)		24	
Maximum Casting Speed (%)		0	
Strain Energy at Minimum Casting Speed (MPa.mm / mm)	< 20	9	
Strain Energy at Mean Casting Speed (MPa.mm / mm)	≥20 ≤40	25	
Strain Energy at Maximum Casting Speed (MPa.mm / mm)	> 40	33	
Oscillation Mark Depth (OMD) at Minimum Casting Speed (mm)	< 0.24	0.18	
Oscillation Mark Depth (OMD) at Mean Casting Speed (mm)	< 0.23	0.14	
Oscillation Mark Depth (OMD) at Maximum Casting Speed (mm)	< 0.22	0.13	
Unbending Surface Temperature at Minimum Casting Speed (°C)	≥ 900	856	
Unbending Surface Temperature at Mean Casting Speed (°C)		900	
Unbending Surface Temperature at Maximum Casting Speed (°C)		922	
Maximum Water Flow Rate at Secondary Cooling (l/Kg)	< 0.64	0.68	
2-PERITECTIC TRANSFORMATION ISSUES AND LONGITUDINAL CRACKS TENDENCY CAUSED BY	**CRITICAL VALUE**	**REAL**	**RATING**
SHEPERD MODEL: Longitudinal Cracks Probability - LCP (%)	< 40	28	
Ferrite Potential (0.85 ≤ FP ≤ 1.05 ==> DEPRESSION)	DEPRESSION	1.24	
Mold Level Variation (± mm)	≤ 3.5	3.0	
Mold Level Variation > 3 mm (%)	< 15	0	
PELAK MODEL: Chemical Composition and Casting Variables - LCTPM	< 60	50	
"F" Factor at Minimum Casting Speed	3.00 ≤ "F" ≤ 4.50	3.25	
"F" Factor at Mean Casting Speed		4.85	
"F" Factor at Maximum Casting Speed		5.45	
Slab Cross Section: Longitudinal Cracks Probability (%)	< 40	34	
Mold Flux Basicity (%CaO/%SiO2)	≥ 1.20	1.20	
3-INTERNAL QUALITY ISSUES CAUSED BY	**CRITICAL VALUE**	**REAL**	**RATING**
CENTERLINE SEGREGATION INDEX	HSLA GRADES 51-149	228	

Figure 6. Summary Report screen.

Altogether there are 30 evaluation items for a heat or slab. The real and MacroSim calculated parameters are compared with critical values and classified using green, yellow or red colors. A parameter classified with green color means that it is correctly adjusted and will not cause slab defects; in red color means that it is unfit and have great potential to induce slab defects; finally, in yellow color, the parameter value is in the borderline, so it requires immediate attention.

2.2. Examples of Real Cases Where MacroSim Was Used

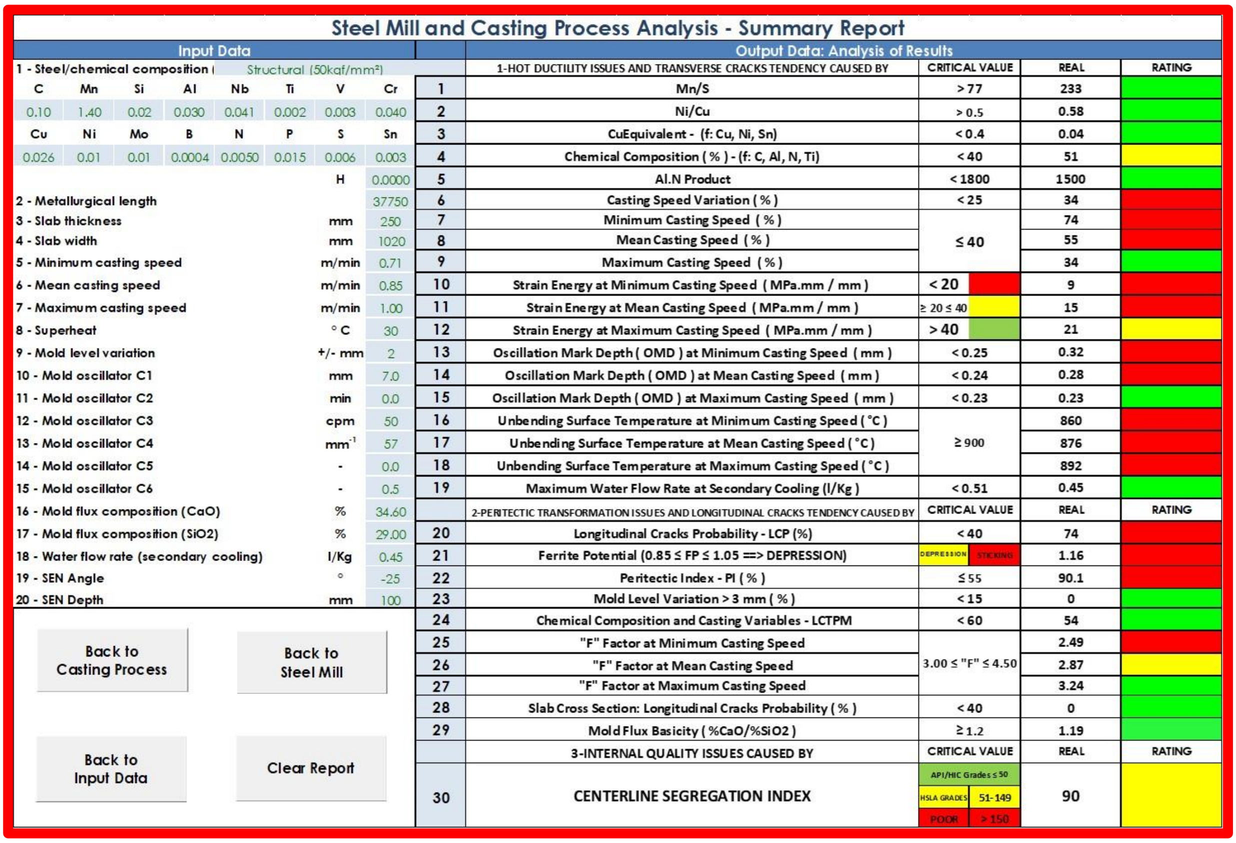
2.2.1. Case #1: Transverse Cracks in HSLA Steel Slabs

A customer asked for help to identify the cause of transversal cracks in the slabs continuously cast in his plant. The diagnosis made by MacroSim showed that steel chemical composition favored the appearance of longitudinal cracks. However, they appear not to be occurring, very likely because the casting parameters were fine-tuned to prevent this defect. On the other hand, casting parameters were unfit to prevent transverse crack (figure 7).
Key issues:

- Low casting speeds
- High casting speed variations
- Low surface temperature at unbending
- Deep oscillation marks

The following improvement actions were implemented:

- Casting speed increase: from 0.71 - 0.85 - 1.00 m/min ➔ to 1.10 - 1.15 - 1.20 m/min, with reduced speed variation range, limited to a 25% maximum.
- Oscillation frequency increase: 20% across in the casting speed range: from 110 cpm ➔ to 130 cpm @ 1,1 m/min.
- Titanium addition observing stoichiometric ratio ➔ Ti (48) / N (14) ➔ 3.4285*0.0050% N = 0.017 %Ti.



Steel Mill and Casting Process Analysis - Summary Report

Input Data

1 - Steel/chemical composition (	Structural (50kgf/mm²)						
C	Mn	Si	Al	Nb	Ti	V	Cr
0.10	1.40	0.02	0.030	0.041	0.002	0.003	0.040
Cu	Ni	Mo	B	N	P	S	Sn
0.026	0.01	0.01	0.0004	0.0050	0.015	0.006	0.003
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Parameter	Unit	Value
2 - Metallurgical length		37750
3 - Slab thickness	mm	250
4 - Slab width	mm	1020
5 - Minimum casting speed	m/min	0.71
6 - Mean casting speed	m/min	0.85
7 - Maximum casting speed	m/min	1.00
8 - Superheat	° C	30
9 - Mold level variation	+/- mm	2
10 - Mold oscillator C1	mm	7.0
11 - Mold oscillator C2	min	0.0
12 - Mold oscillator C3	cpm	50
13 - Mold oscillator C4	mm⁻¹	57
14 - Mold oscillator C5	-	0.0
15 - Mold oscillator C6	-	0.5
16 - Mold flux composition (CaO)	%	34.60
17 - Mold flux composition (SiO2)	%	29.00
18 - Water flow rate (secondary cooling)	l/Kg	0.45
19 - SEN Angle	°	-25
20 - SEN Depth	mm	100

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Output Data: Analysis of Results

#	1-HOT DUCTILITY ISSUES AND TRANSVERSE CRACKS TENDENCY CAUSED BY	CRITICAL VALUE	REAL	RATING
1	Mn/S	> 77	233	
2	Ni/Cu	> 0.5	0.58	
3	CuEquivalent - (f: Cu, Ni, Sn)	< 0.4	0.04	
4	Chemical Composition (%) - (f: C, Al, N, Ti)	< 40	51	
5	Al.N Product	< 1800	1500	
6	Casting Speed Variation (%)	< 25	34	
7	Minimum Casting Speed (%)	≤ 40	74	
8	Mean Casting Speed (%)		55	
9	Maximum Casting Speed (%)		34	
10	Strain Energy at Minimum Casting Speed (MPa.mm / mm)	< 20	9	
11	Strain Energy at Mean Casting Speed (MPa.mm / mm)	≥ 20 ≤ 40	15	
12	Strain Energy at Maximum Casting Speed (MPa.mm / mm)	> 40	21	
13	Oscillation Mark Depth (OMD) at Minimum Casting Speed (mm)	< 0.25	0.32	
14	Oscillation Mark Depth (OMD) at Mean Casting Speed (mm)	< 0.24	0.28	
15	Oscillation Mark Depth (OMD) at Maximum Casting Speed (mm)	< 0.23	0.23	
16	Unbending Surface Temperature at Minimum Casting Speed (°C)	≥ 900	860	
17	Unbending Surface Temperature at Mean Casting Speed (°C)		876	
18	Unbending Surface Temperature at Maximum Casting Speed (°C)		892	
19	Maximum Water Flow Rate at Secondary Cooling (l/Kg)	< 0.51	0.45	
	2-PERITECTIC TRANSFORMATION ISSUES AND LONGITUDINAL CRACKS TENDENCY CAUSED BY	CRITICAL VALUE	REAL	RATING
20	Longitudinal Cracks Probability - LCP (%)	< 40	74	
21	Ferrite Potential (0.85 ≤ FP ≤ 1.05 ==> DEPRESSION)	DEPRESSION / STICKING	1.16	
22	Peritectic Index - PI (%)	≤ 55	90.1	
23	Mold Level Variation > 3 mm (%)	< 15	0	
24	Chemical Composition and Casting Variables - LCTPM	< 60	54	
25	"F" Factor at Minimum Casting Speed	3.00 ≤ "F" ≤ 4.50	2.49	
26	"F" Factor at Mean Casting Speed		2.87	
27	"F" Factor at Maximum Casting Speed		3.24	
28	Slab Cross Section: Longitudinal Cracks Probability (%)	< 40	0	
29	Mold Flux Basicity (%CaO/%SiO2)	≥ 1.2	1.19	
	3-INTERNAL QUALITY ISSUES CAUSED BY	CRITICAL VALUE	REAL	RATING
30	CENTERLINE SEGREGATION INDEX	API/HIC Grades ≤ 50; HSLA GRADES 51-149; POOR > 150	90	

Figure 7. MacroSim diagnosis (Case #1)

With these actions, the diagnosis of the process made by MacroSim improved significantly as shown in the figure 8. The results effectively got in the plant are shown in figure 9.

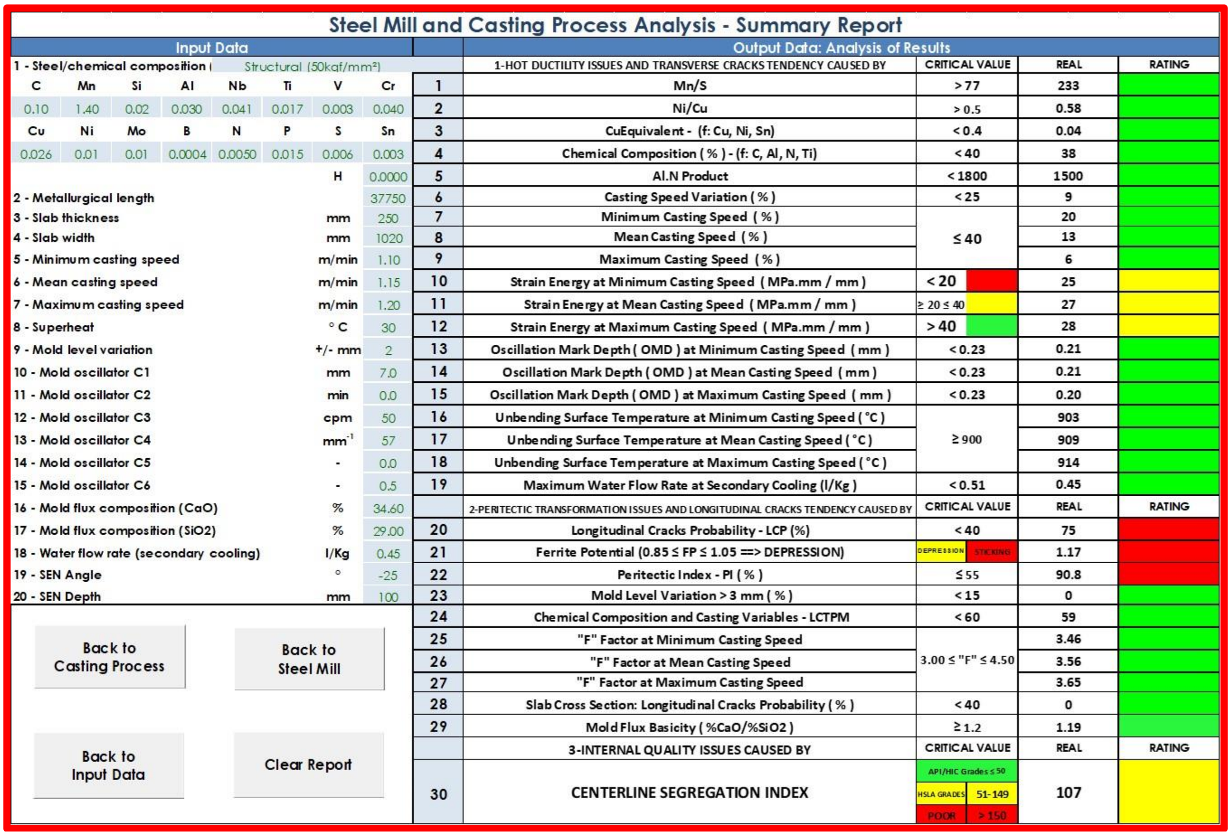
2.2.2. Case #2: Centerline Segregation in Slabs for Shipbuilding Plate

A customer reported that he had been having chronic problems with the internal quality of his continuously cast slabs, which macrographs showed strong centerline segregation and microstructural banding in the hot rolled steel plates, as seen in Figure 10.

A MacroSim diagnosis showed that the process was already optimized (Figure 11). So, why were the defects occurring?

As the process parameters were already optimized, it was necessary to inspect the continuous casting machine on site. It has been observed many spray nozzles clogged into several roll segments (Figure 12). The cause identified for the internal soundness issues was inadequate quality of the water used in the secondary cooling. Its hardness and chlorides levels were too high.

Equipment inspection is always necessary for a complete diagnosis. The analysis carried out by MacroSim does not eliminate the need to follow up continuously the continuous casting conditions of equipment and process.



Steel Mill and Casting Process Analysis - Summary Report

Input Data

1 - Steel/chemical composition (	Structural (50kgf/mm²)						
C	Mn	Si	Al	Nb	Ti	V	Cr
0.10	1.40	0.02	0.030	0.041	0.017	0.003	0.040
Cu	Ni	Mo	B	N	P	S	Sn
0.026	0.01	0.01	0.0004	0.0050	0.015	0.006	0.003
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2 - Metallurgical length		37750
3 - Slab thickness	mm	250
4 - Slab width	mm	1020
5 - Minimum casting speed	m/min	1.10
6 - Mean casting speed	m/min	1.15
7 - Maximum casting speed	m/min	1.20
8 - Superheat	°C	30
9 - Mold level variation	+/- mm	2
10 - Mold oscillator C1	mm	7.0
11 - Mold oscillator C2	min	0.0
12 - Mold oscillator C3	cpm	50
13 - Mold oscillator C4	mm^{-1}	57
14 - Mold oscillator C5	-	0.0
15 - Mold oscillator C6	-	0.5
16 - Mold flux composition (CaO)	%	34.60
17 - Mold flux composition (SiO2)	%	29.00
18 - Water flow rate (secondary cooling)	l/Kg	0.45
19 - SEN Angle	°	-25
20 - SEN Depth	mm	100

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Output Data: Analysis of Results

	1-HOT DUCTILITY ISSUES AND TRANSVERSE CRACKS TENDENCY CAUSED BY	CRITICAL VALUE	REAL	RATING
1	Mn/S	> 77	233	
2	Ni/Cu	> 0.5	0.58	
3	CuEquivalent - (f: Cu, Ni, Sn)	< 0.4	0.04	
4	Chemical Composition (%) - (f: C, Al, N, Ti)	< 40	38	
5	Al.N Product	< 1800	1500	
6	Casting Speed Variation (%)	< 25	9	
7	Minimum Casting Speed (%)	≤ 40	20	
8	Mean Casting Speed (%)		13	
9	Maximum Casting Speed (%)		6	
10	Strain Energy at Minimum Casting Speed (MPa.mm / mm)	< 20	25	
11	Strain Energy at Mean Casting Speed (MPa.mm / mm)	≥ 20 ≤ 40	27	
12	Strain Energy at Maximum Casting Speed (MPa.mm / mm)	> 40	28	
13	Oscillation Mark Depth (OMD) at Minimum Casting Speed (mm)	< 0.23	0.21	
14	Oscillation Mark Depth (OMD) at Mean Casting Speed (mm)	< 0.23	0.21	
15	Oscillation Mark Depth (OMD) at Maximum Casting Speed (mm)	< 0.23	0.20	
16	Unbending Surface Temperature at Minimum Casting Speed (°C)	≥ 900	903	
17	Unbending Surface Temperature at Mean Casting Speed (°C)		909	
18	Unbending Surface Temperature at Maximum Casting Speed (°C)		914	
19	Maximum Water Flow Rate at Secondary Cooling (l/Kg)	< 0.51	0.45	
	2-PERITECTIC TRANSFORMATION ISSUES AND LONGITUDINAL CRACKS TENDENCY CAUSED BY	CRITICAL VALUE	REAL	RATING
20	Longitudinal Cracks Probability - LCP (%)	< 40	75	
21	Ferrite Potential (0.85 ≤ FP ≤ 1.05 ==> DEPRESSION)	DEPRESSION / STICKING	1.17	
22	Peritectic Index - PI (%)	≤ 55	90.8	
23	Mold Level Variation > 3 mm (%)	< 15	0	
24	Chemical Composition and Casting Variables - LCTPM	< 60	59	
25	"F" Factor at Minimum Casting Speed	3.00 ≤ "F" ≤ 4.50	3.46	
26	"F" Factor at Mean Casting Speed		3.56	
27	"F" Factor at Maximum Casting Speed		3.65	
28	Slab Cross Section: Longitudinal Cracks Probability (%)	< 40	0	
29	Mold Flux Basicity (%CaO/%SiO2)	≥ 1.2	1.19	
	3-INTERNAL QUALITY ISSUES CAUSED BY	CRITICAL VALUE	REAL	RATING
30	CENTERLINE SEGREGATION INDEX	API/HIC Grades ≤ 50; HSLA GRADES 51-149; POOR > 150	107	

Figure 8. MacroSim diagnosis after improvements (Case #1)

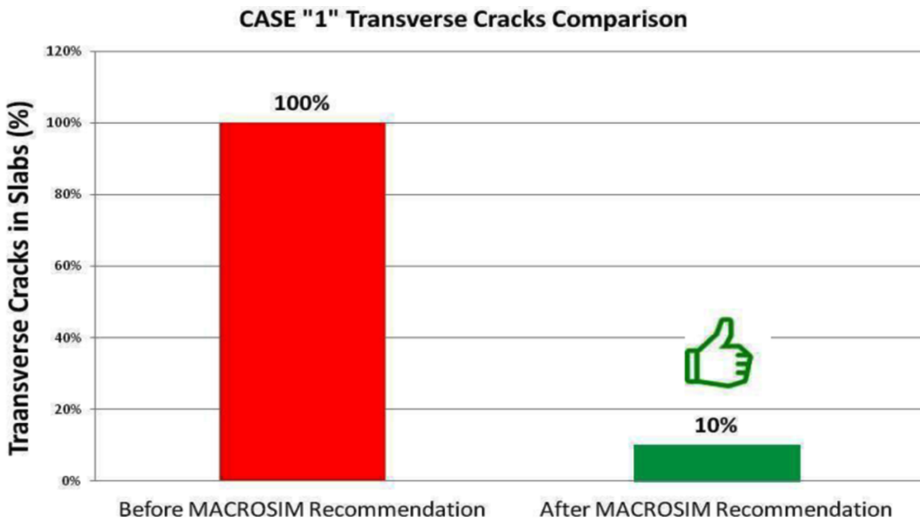

Figure 9. MacroSim diagnosis effectiveness (Case #1).

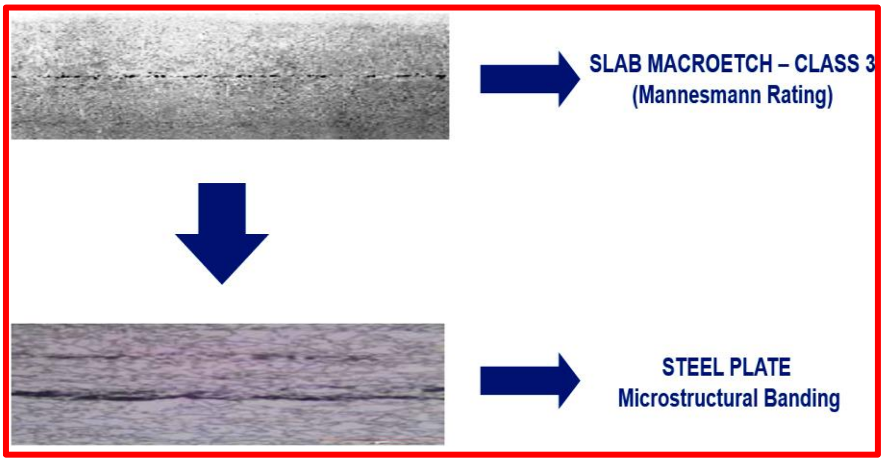

Figure 10. Slab centerline segregation and hot rolled plate banding (Case #2).

Steel Mill and Casting Process Analysis - Summary Report

Input Data

1 - Steel/chemical composition				Ship Building DH-32/36			
C	Mn	Si	Al	Nb	Ti	V	Cr
0.15	1.35	0.35	0.025	0.035	0.016	0.000	0.000
Cu	Ni	Mo	B	N	P	S	Sn
0.000	0.00	0.00	0.0000	0.0050	0.015	0.004	0.000
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Parameter	Unit	Value
2 - Metallurgical length		32000
3 - Slab thickness	mm	300
4 - Slab width	mm	1900
5 - Minimum casting speed	m/min	0.80
6 - Mean casting speed	m/min	0.85
7 - Maximum casting speed	m/min	0.90
8 - Superheat	°C	20
9 - Mold level variation	+/- mm	3
10 - Mold oscillator C1	mm	2.0
11 - Mold oscillator C2	min	4.0
12 - Mold oscillator C3	cpm	160
13 - Mold oscillator C4	mm^{-1}	-10
14 - Mold oscillator C5	-	0.0
15 - Mold oscillator C6	-	0.7
16 - Mold flux composition (CaO)	%	41.64
17 - Mold flux composition (SiO2)	%	29.94
18 - Water flow rate (secondary cooling)	l/Kg	0.47
19 - SEN Angle	°	30
20 - SEN Depth	mm	160

Back to Casting Process | Back to Steel Mill | Back to Input Data | Clear Report

Output Data: Analysis of Results

1-HOT DUCTILITY ISSUES AND TRANSVERSE CRACKS TENDENCY CAUSED BY	CRITICAL VALUE	REAL	RATING
Mn/S	> 107	337	
Ni/Cu	> 0.5	1.00	
CuEquivalent - (f: Cu, Ni, Sn)	< 0.4	0.00	
Chemical Composition (%) - (f: C, Al, N, Ti)	< 40	29	
Al.N Product	< 1800	1250	
Casting Speed Variation (%)	< 25	12	
Minimum Casting Speed (%)	<= 40	16	
Mean Casting Speed (%)		9	
Maximum Casting Speed (%)		2	
Strain Energy at Minimum Casting Speed (MPa.mm / mm)	< 20	2	
Strain Energy at Mean Casting Speed (MPa.mm / mm)	≥20 ≤40	4	
Strain Energy at Maximum Casting Speed (MPa.mm / mm)	> 40	6	
Oscillation Mark Depth (OMD) at Minimum Casting Speed (mm)	< 0.24	0.13	
Oscillation Mark Depth (OMD) at Mean Casting Speed (mm)	< 0.24	0.13	
Oscillation Mark Depth (OMD) at Maximum Casting Speed (mm)	< 0.24	0.13	
Unbending Surface Temperature at Minimum Casting Speed (°C)	≥ 900	906	
Unbending Surface Temperature at Mean Casting Speed (°C)		912	
Unbending Surface Temperature at Maximum Casting Speed (°C)		917	
Maximum Water Flow Rate at Secondary Cooling (l/Kg)	< 0.49	0.47	
2-PERITECTIC TRANSFORMATION ISSUES AND LONGITUDINAL CRACKS TENDENCY CAUSED BY	**CRITICAL VALUE**	**REAL**	**RATING**
Longitudinal Cracks Probability - LCP (%)	< 40	23	
Ferrite Potential (0.85 ≤ FP ≤ 1.05 ==> DEPRESSION)	DEPRESSION / STICKING	1.15	
Mold Level Variation (± mm)	≤ 3.5	3.0	
Mold Level Variation > 3 mm (%)	< 15	0	
Chemical Composition and Casting Variables - LCTPM	< 60	29	
"F" Factor at Minimum Casting Speed	3.00 ≤ "F" ≤ 4.50	3.96	
"F" Factor at Mean Casting Speed		4.24	
"F" Factor at Maximum Casting Speed		4.52	
Slab Cross Section: Longitudinal Cracks Probability (%)	< 40	15	
Mold Flux Basicity (%CaO/%SiO2)	≥ 1.20	1.39	
3-INTERNAL QUALITY ISSUES CAUSED BY	**CRITICAL VALUE**	**REAL**	**RATING**
CENTERLINE SEGREGATION INDEX	HSLA GRADES 51-149	38	

Figure 11. MacroSim diagnosis (Case #2)

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Figure 12. Clogged water spray nozzles in the casting machine.

3 CONCLUSION

MacroSim is an Excel application which provide quick diagnostics about the process of slab continuous casting through the analysis of real operational data, using not only proprietary knowledge, but also information which is available in the specialized literature. Data input has been restricted to the minimum necessary to speed analysis and save work for operational teams, but it is essential that they be truly representative of the actual operation of the continuous casting machine. In such way, MacroSim is an effective tool for preventing defects in continuously cast slabs, like transversal cracks, longitudinal cracks and sub-superficial corner cracks among others, helping to guide industrial operation through the use of the best parameters in continuous casting to get best quality products with high productivity.

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