TECHNOLOGICAL EXPERIMENTS REGARDING THE IMPROVEMENT OF THE TOOL STEELS CLEANLINNES USING THE SLAG PROPERTIES AND THE CHEMICAL HEATING

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ABSTRACT

The paper presents the technological solution tested and applied at the No 1 steel-shop in Târgoviste aiming to improve the cleanlinnes indicators of some tool alloyed steels.

This steelshop was specialised from the ‘70s for that kind of manufacturing but it was not updated during the last 15 years. As a result, the performances, especially in those concerning the cleanlinnes indicators, were modest, being impossible to satisfy the customer’s requests.

The main objectives to be attended were:

- decrease of S content below 100 ppm;
- lowering the inclusions content in accordance with more severe ASTM limits.

Using the existent equipments (a classical electric furnace and a VOD installation) we intended to obtain a particular slag composition (in the system $CaO-Al_2O_3-SiO_2$) and to use it in an efficient manner (for desulphurization and inclusions control), having in mind the simultaneity with the processes like aluminothermic heating or vaccumation.

The obtained qualitative results were good but was registered an increasing of the ingot production cost by 1,25 USD/t.

1. INTRODUCTION

In the ‘70s it was commissioned a production flow for tool steels in the Târgoviste plant, which became the main producer for these grades in Romania.

In the first step of the technological flow, the liquid steel is completely processed in electric arc furnace (12 t capacity), followed by inert gas bubbling through porous plug in the ladle and ingot casting (1-5t).

In addition to the usual quality requirements for these steels, the plant was faced in the last years with some special demands of the customers concerning the control and restrictions upon the non-metallic inclusions level in steel.

In relation with these quality steel demands, we have been identified the extant quality level (reference level), for 2 grades: a ledeburitic cold tool steel (marked X_1) and a Cr-Mo-V hot tool steel (marked X_2). It is presented in table I. This quality level is sure a consequence of the technological practice in the steelshop.

Starting from the demands of the our customers we also have been identified the inclusions targets and also the complementary technological targets, which are presented in table II.

As concerns the experimental program, we have to mention the followings:

1. The two considered grades have somehow a different reference state, but they must be oriented towards the same targets (according to the customer’s demands).

2. The our targets concerning the inclusions level in steel are much more severe than the customer’s demands, in order to find a reliable technological solution.

3. Even if some targets concerning the cleanlinnes state can be found in the reference level, they were realised occasionally or in near-to-limit ranging conditions.

4. We considered as influence factors of cleanlinnes state, the 3 residual elements which can be technologically influenced and quickly quantified [S], [O], [Al].

5. The Al content is not considered as a specification for these grades but it is representing an inherent consequence of the applied de deoxidation technology.

2. THE INITIAL CONDITIONS FOR THE TECHNOLOGICAL EXPERIMENTS

1. The deoxidation and especially advanced desulphuration possibilities using the complete steelmaking practice in electric furnace are known as limited or involving high consumptions of time, materials and manpower.

2. The steelshop 1 of Târgoviste has not yet a secondary metallurgy heating equipment (LF, VAD) but has a VOD equipment used for stainless steel production.

3. Under these circumstances we proposed:

- the intensification of the deoxidation - desulphuraion processes by much more exploitation of the kinetic component for which exist ladle technical facilities (porous plug);

- the exceeding of the high thermal losses handicap, characterising our 12 t capacity ladle (usualy 5^o C/min. during bubbling), by help of a liquid-steel heating solution in the ladle.

- the use of the oxygen present as facility at the VOD equipment and the secondary aluminium as combustion agent for to produce heating energy. This process will carry out at normal pressure; Al - solution was chosen because his heating rate at the same specific consumption is higher compared to Si (32^o C instead of 25^oC), and at the same time, Al - oxides have a better flotability than Si - oxides; simultaneously slag basicity and desulphuration capacity remain high.

4. The EAF is not equipped for slag retention at tapping, but its low capacity allows actually, with some effort, the almost complete removal of slag before tapping.

5. The option for two steel grades, different from the point of view of liquidus - temperature and respectively the pouring temperature ($\Delta \cong 100^oC$) was done in order to check the validity of our technology for two different thermal route conditions.

3. TECHNOLOGICAL DESIGN

Directions:

1. Improving the heating efficiency and circulation route of the ladles in the steelshop, so that the lining ladles have min. 1000^oC at the tapping time.

2. The ensurance of desulphuration slag basicity index 3-4 during the ladle treatment of steel and a forecast slag composition at the end point: 50-60% CaO, max. 10% SiO_2, 20-30% Al_2O_3, (FeO + MnO) max. 2%.

In order to reach these targets we have planed:

- the fluxes quantity (lime + fluorspar) for addition in the ladle during the tapping;

- oxygen blowing conditions (amount, flow rate, lance height), in order to oxidize a minimal amount of Si (min. 0,15%) and to avoid the oxidation of C and Fe.

- assurance of the Al_2O_3content in slag from the aluminothermic reaction;

3. The designing of thermal conditions and calculation of combustion agent quantity (secondary Al, 5 kg/piece). Figure 1 emphasises the thermal schedule for the calculation of combustion agent quantities for both grades.

The planing of all technological parameters was determined by calculation and preliminary tests for each technological processing step.

4. RESULTS

Technological processing diagrams for a single heat of each grade are presented in figures 2 and 3.

- On the whole, there is a good concordance with the technological projection of time - temperature relation, predicted in figure 1.

The combustion process of Al was permanently accompanied by the steel bubbling with argon through the porous plug and was followed by a period of "post-bubbling", divided in 2 steps, with distinct objectives:

1) desulphuration and thermal homogenization,

2) the non-metallic inclusions separation.

- Elements for technological characterisation of steel's chemical heating process are presented in Table III.

The Al recovery ratios in the steel after tapping are related to the steel's deoxidation level at he tapping time, and we appreciate they are good.

We are thinking that the relatively low levels of the effectively thermal efficiency, are determined by the complementary steel cooling process caused by convection, during the bubbling.

- The slag quality evaluated by sampling at the finish first step "post-bubbling" time, therefore subsequent to the chemical heating period too, is presented in Table IV. The Si oxidizing limitation, the lower (SiO_2) content and the good lime dissolution in the ladle have contributed to the realisation of a favourable basicity, for the desulphurization process. The control of the Al_2O_3 content in slag was good also.

- In these processing conditions for liquid steel, the investigations of residual elements and non-metallic inclusions contents, made on samples from forged product (billets • 140 mm from ingot • 3,6 t) emphasised significant improvements. Figures 4 and 5 evidence comparatively the typical range of quality parameters, from the old and the new technology.

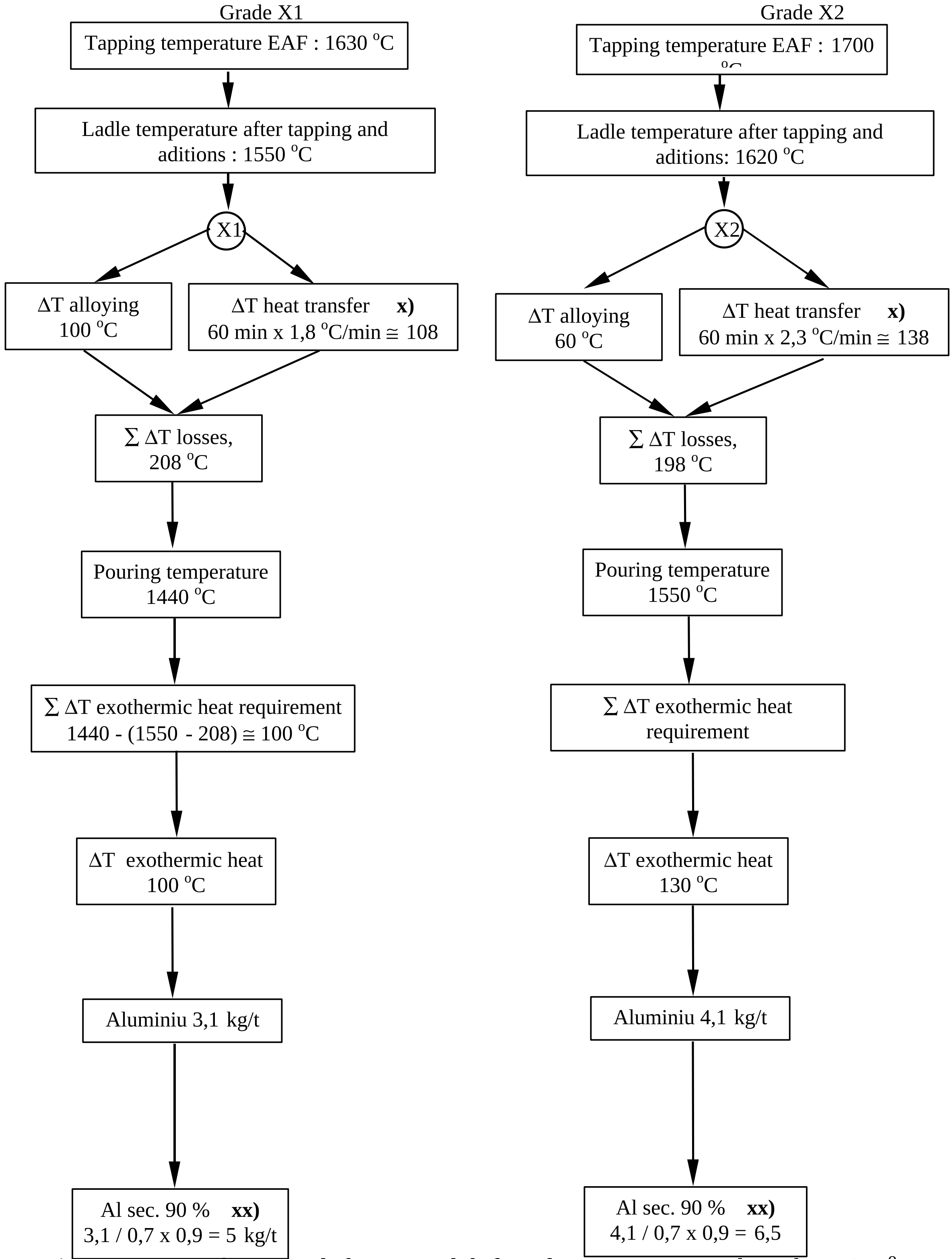
5. CONCLUSIONS

The technological solution experimented in steelshop from Târgoviste showed:

- The main advantage is the new technologicval route, which is a guarantee for producer to obtain better quality parameters, according to the customer's demands, under the circumstances of steelshop endowments.

- Another advantage is that the steelshop has in view to put into operation a ladle-furnace (LF) which will offer a simplified technological solution in order to reach the same aims but, probabily with lower costs; our opinion is that the gained experience will operate as a favourable precedent.

- For the experimental conditions the ingot production cost was higher with about 1,25 USD/t comparatively with the old technology.



x) in the case of X2 grade here are global cooling rates greater than about 0,5 °C/min during entire ladle processing

xx) Al participation efficiency at the combustion process is about 70%

Fig. 1. Heating schedule for the calculation of the combustion agent consumption

Moment	Temperature	Specific flow rate
0	1630	
3		
5	1520	0
5		0,75
13	1470	
23	1455	
28	1540	0,75
28		1,5
38	1520	1,5
38		0,75
53	1490	
55		0,75
55		0
58	1470	

Moment	Temperature	Specific flow rate
0	1715	
3	1605	
5		0
5		0,75
13	1555	
23	1540	
28		0,75
28	1645	1,5
38		1,5
38		0,75
39	1605	
53	1590	
55		0,75
55		0
58	1540	

Elemente	Concentraþie,Otot., Al, ppm	Concentraþie S, ppm
1,5	70	
1,5	85	
3,5	50	
3,5	65	
6,5	20	
6,5	30	
8,5	20	
8,5	30	
11,53		100
11,57		200
13,5		50
13,5		80

Tehnologi veche	Tehnologie noua
1,5	0,5
1,5	2
3,5	0,5
3,5	1,5
6,5	0,5
6,5	2
8,5	0,5
8,5	1
11,5	1,5
11,5	2,5
13,5	0,5
13,5	1
16,5	0,5
16,5	2
18,5	0
18,5	1
21,5	1,5
21,5	3
23,5	1,5
23,5	2
26,5	1,5
26,5	2
28,5	0,5
28,5	1

Cleanlinnes - reference level Table I

Steel Grade	Non-metallic residual elements, ppm		Non-metallic inclusions ratings[x)]							
	O_{tot}	S	A		B		C		D	
			s	g	s	g	s	g	s	g
X 1	70-80	100-150	0.5-1.5	0.5-2.0	1.5-2.5	0.5-1.0	0	0	1.5-3.0	1.5-2.0
X 2	70-85	100-200	1.5-2.0	0.5-1.0	1.5-2.5	1.5-2.0	0	0	2.0-2.5	1.5-2.0

[x)] According to ASTM E 45-95, method A

Cleanlinnes - target levels Table II

Parameters	Target - value for both steel grades
A) Main	
Sulphidic inclusions	max. 1.5 (s); max. 1.0 (g)
Oxidic inclusions B type	max. 1.5 (s); max. 1.0 (g)
Oxidic inclusions C type	max. 1.0 (s); max. 0.5 (g)
Oxidic inclusions D type	max. 2.0 (s); max. 1.0 (g)
B) Complementary	
Oxygen content	$O_{tot} \leq 60$ ppm
Sulphur content	$S \leq 100$ ppm

Technological parameters of the heating Table III

Indicator / Steel Grade	X_1	X_2
Flow rate, Nm^3 O_2/h	600	600
Specific flow rate, Nm^3 O_2/ t, min.	0.84	0.75
Oxygen blowing time, min.	8	11
Combustion agent consumption (Al sec.), kg/t	5	6.5
Aluminium's recovery ratio, %	80.0	77.0
Δ Al oxidized, % Δ Si oxidized, % Δ C oxidized, %	0.36 0.09 0	0.45 0.08 0
Effective thermal efficiency[x)], %	74.0	72.9

[x)] The calculation was made by considering the theoretical temperature increase of 32°C for 1 unit of the aluminium specific consumption

Technological characteristics of the slag Table IV

Slag composition /Steel grade	X_1	X_2
CaO, %	43.5	41.6
SiO_2, %	10.2	9.3
Al_2O_3, %	27.8	32.5
FeO, %	1.07	1.28
MnO, %	0.75	1.05
IB	4.26	4.45

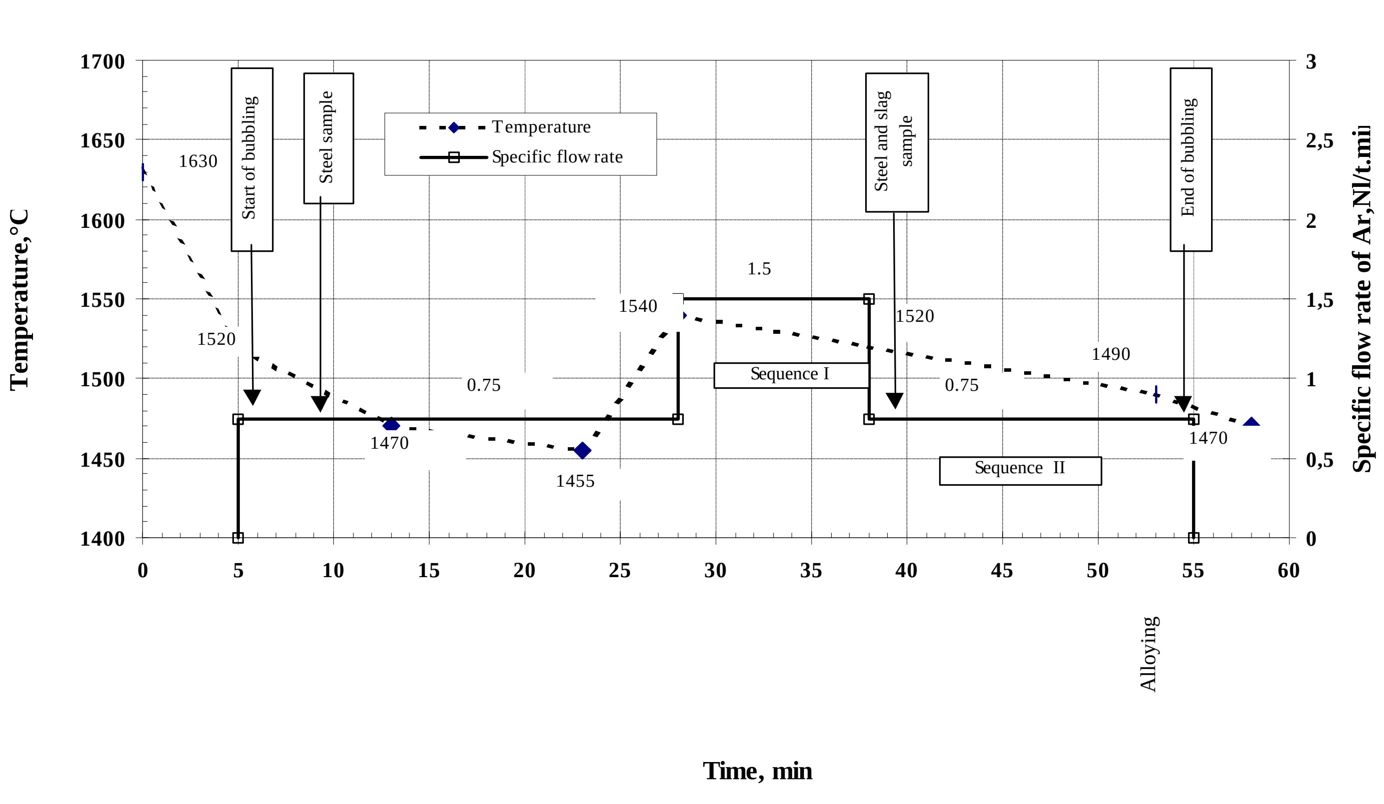


Fig. 2 - Ladle metalurgy diagram for X1 grade

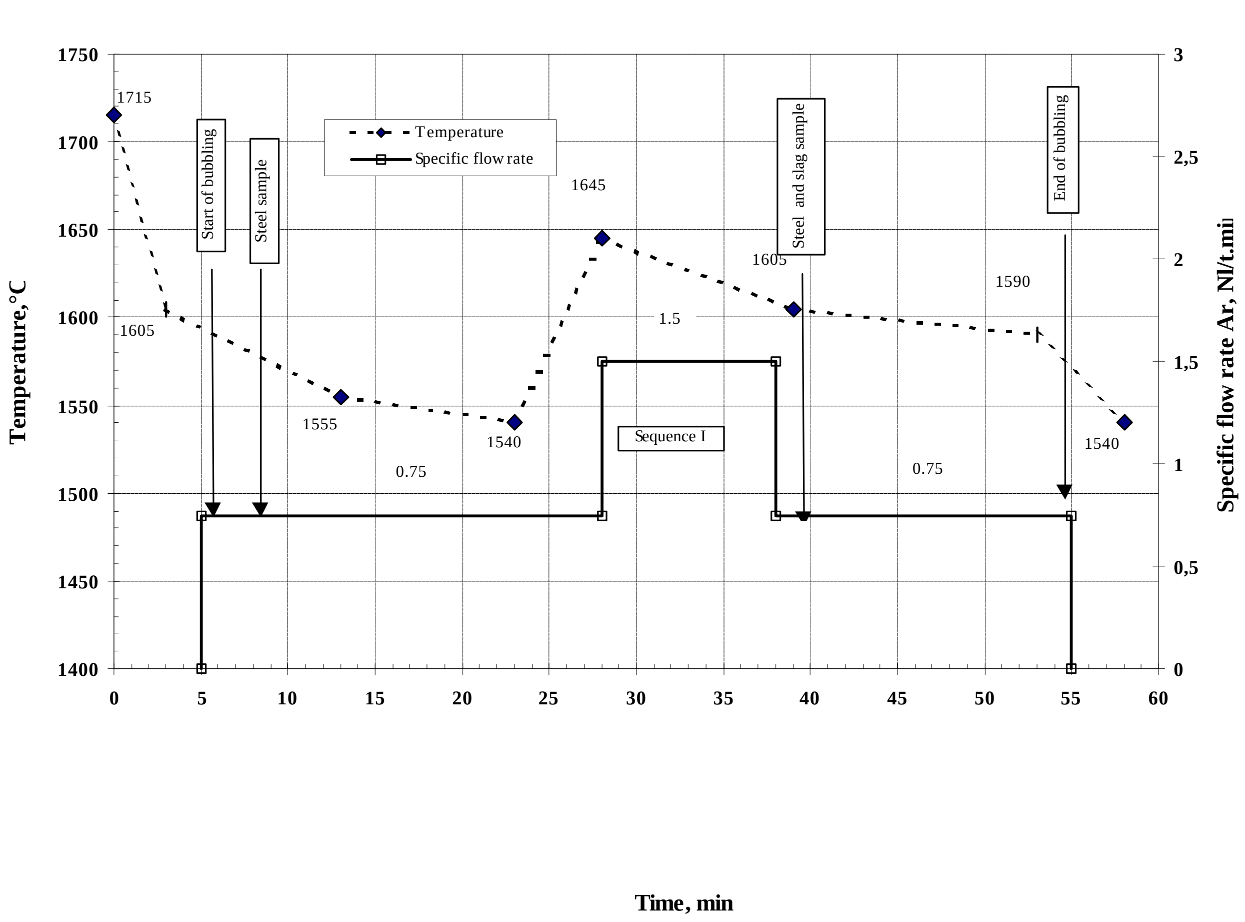


Fig. 3 - Ladle metalurgy diagram for X2 grade

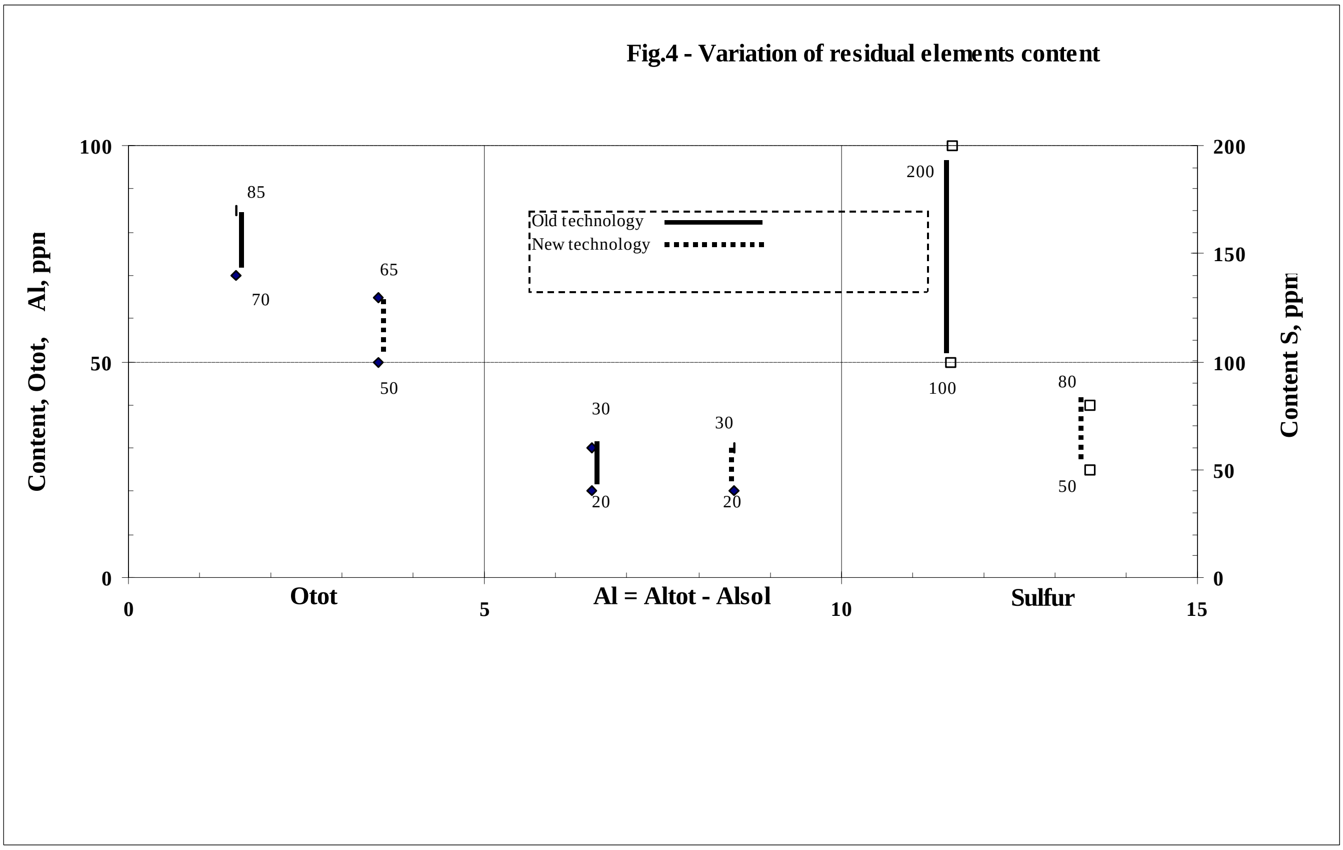


Fig.4 - Variation of residual elements content
Content, Otot, Al, ppm
Content S, ppm
Old technology
New technology
Otot
Al = Altot - Alsol
Sulfur
85
70
65
50
30
20
30
20
200
100
80
50
0
50
100
0
50
100
150
200
0
5
10
15

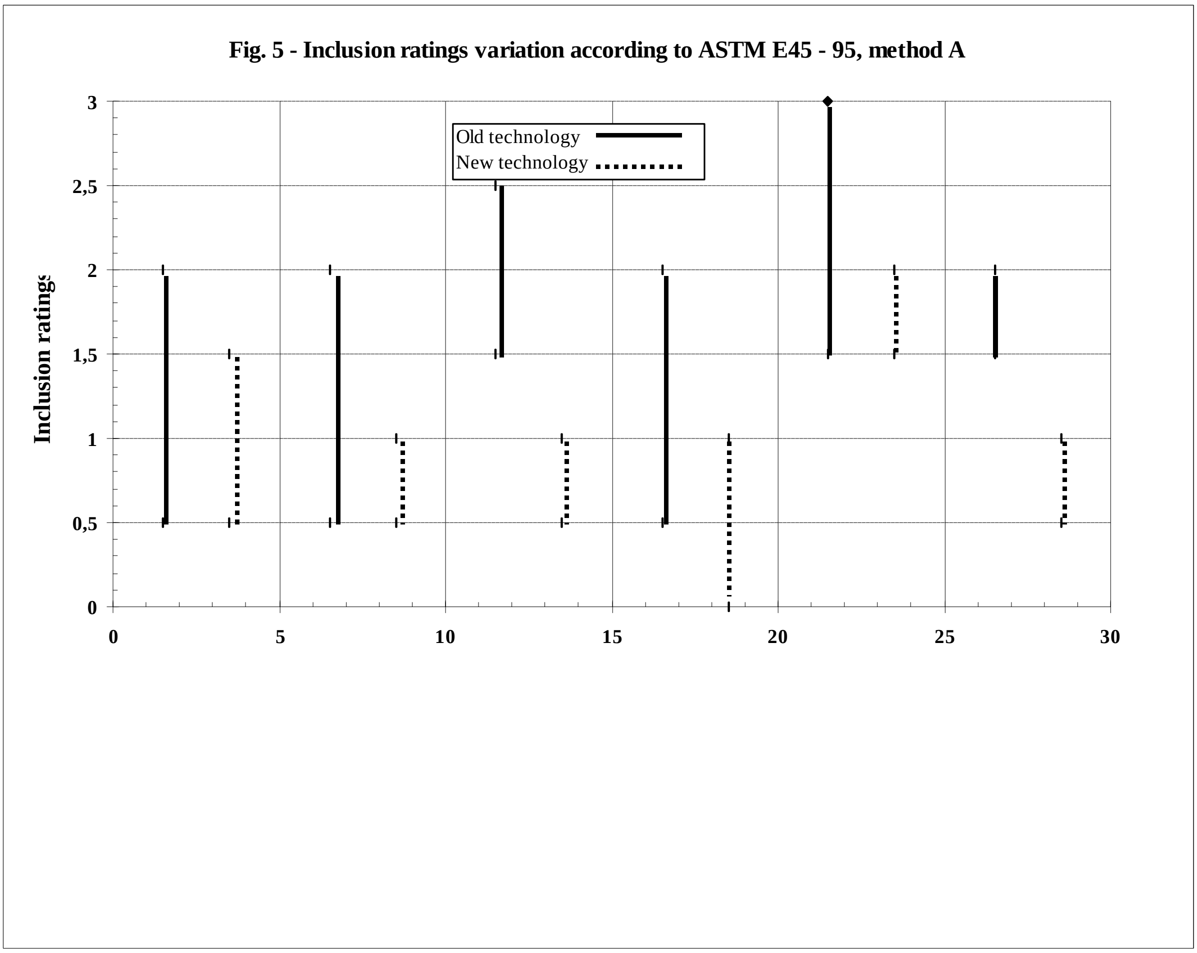


Fig. 5 - Inclusion ratings variation according to ASTM E45 - 95, method A
Inclusion ratings
Old technology
New technology
0
0,5
1
1,5
2
2,5
3
0
5
10
15
20
25
30