BREAKOUT DETECTION/PREVENTION FOR SLAB AND BLOOM CASTER: A NEW STEP FORWARD WITH « MARTINE »[1]

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Abstract
The EBDS Engineering company has put on the market in the year 2007 a new breakout detection system, which is quite different than what can be found on the market. The system, called "Martine" has been developed and improved during the last 10 years and has been installed in several continuous caster in Europe. Today, EBDS Engineering is now promoting this system worldwide. The "Martine" breakout detection system is based on 2 axis: a thermographical image of the mould, and a quite advanced calculation system. The image represents the four copper faces of the mould. It displays in real-time all thermal events of the « in the mould » newly formed slab, so that every abnormal event is revealed efficiently to the operator. For example, in the case of a sticker breakout, the well known « V »shape will appear. The calculations are based on the possible metallurgical behaviors of the curves. This allows to detects stickers, but also other phenomenas. The system is « auto-adapting » itself to the casting conditions, so that no steelgrade have to be preselected. Depending of the customer's caster behavior, new algorithms can be implemented to fit perfectly the global behavior of the thermal exchanges. Results on European casters are showing significant superiority versus classical well-known system.
Key words: Continuous casting; Breakout.

DETECÇÃO/PREVENÇÃO DE PERFURAÇÕES NO LINGOTAMENTO CONTÍNUO DE PLACAS E BLOCOS: UM PASSO ADIANTE COM « MARTINE »

Resumo
A Empresa EBDS Engineering colocou no mercado no ano de 2007 um novo sistema de detecção de perfurações (breakout), totalmente diferente do que pode ser encontrado hoje no mercado. O sistema chamado "Martine" tem sido desenvolvido e aperfeiçoado nos últimos 10 anos e vem sendo instalado em vários lingotamentos contínuos na Europa. Atualmente, a EBDS Engineering está promovendo este sistema mundialmente. O sistema de detecção de perfurações "Martine" é baseado em dois eixos: uma imagem termográfica do molde, e um avançado sistema de cálculo. A imagem representa as quatro faces de cobre do molde. Ela exibe em tempo real todos os eventos térmicos da placa recém formada "no interior do molde", de maneira a revelar eficientemente qualquer evento irregular ao operador. Por exemplo, no caso de perfuração por colamento (sticking), a conhecida forma em "V" irá aparecer. Os cálculos são baseados nos possíveis comportamentos metalúrgicos das curvas. Isto permite detectar não só os colamentos, como também outros fenômenos. O sistema é "auto ajustável" às condições de lingotamento, de maneira que não se faz necessária a pré-seleção do tipo de aço. Dependendo do comportamento da máquina de lingotamento do cliente, novos algoritmos podem ser implementados para que o sistema se ajuste perfeitamente ao comportamento global das trocas térmicas.
Resultados obtidos em máquinas de lingotamento contínuo na Europa apresentaram significativa superioridade em relação aos bem conhecidos sistemas clássicos.
Palavras-chave: Lingotamento continuo; Perfuração.

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1 INTRODUCTION

EBDS Engineering is a Luxembourg company, specialized in techniques related to the mould area of the continuous caster. It has a incorporated a long experience in that field, and is now able to propose probably the most advanced breakout prevention/detection system available on the market. This system, called “Martine” has been developed and improved during the last 10 years and has been installed in several continuous caster in Europe. Today, EBDS Engineering is now promoting this system worldwide.

The Martine system is based on two axis: the thermographical image, and the calculations.

2 THE THERMOGRAPHICAL IMAGE

The display of Martine is representing the four copper faces of the mould, opened and placed side by side. Actually, we only represent the part of the broadface width in use. So the width of the image will vary in accordance with the casting format. This part of the display is representing the major part of the screen, because it is the heart of the image.

These four rectangles are created upon the values of the thermocouples, in a way that the screen stays globally white when nothing happens, as shown on Figure 1, here after:

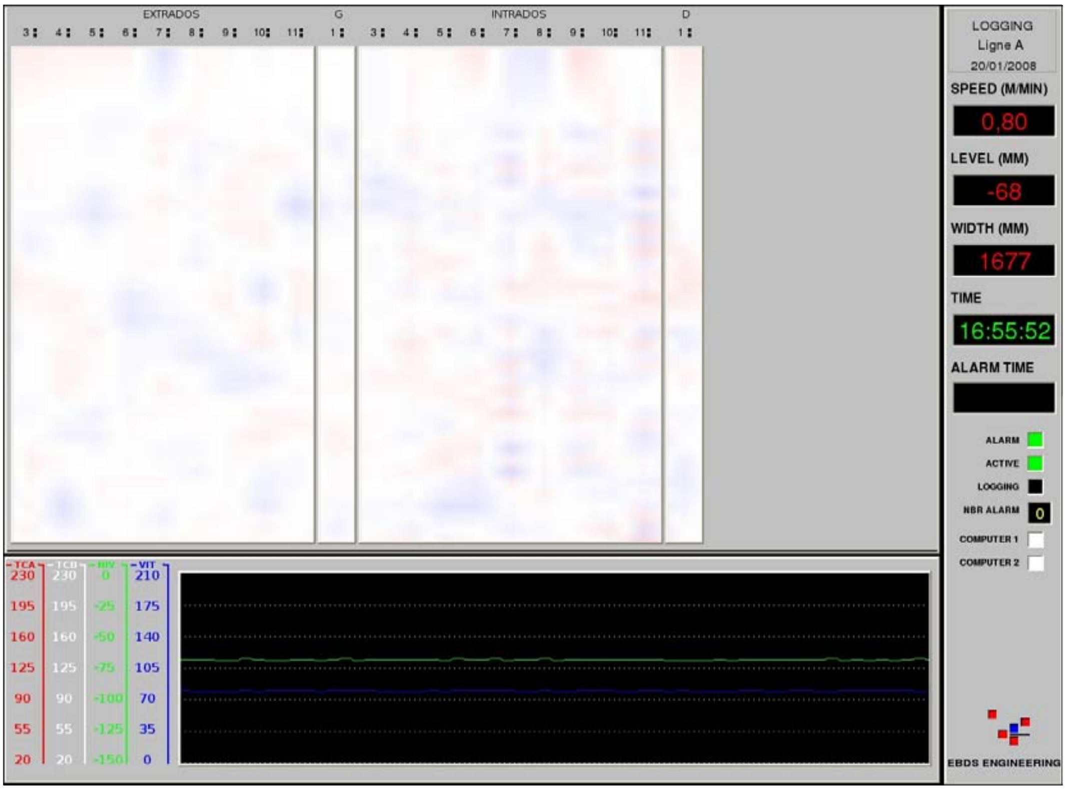

Figure 1 – Martine's display in normal condition

On the right side of this image, some casting information, as well as the different states of the system are displayed.

On the lower part of the screen, a window with trends is proposed. Under normal

conditions, only the casting speed and the mould level trends are displayed.
The thermographical image moves down in accordance with the casting speed, and the length of the displayed faces are similar to the length of the mold. So this way of doing shows the full mould just like if we would have temperature probes everywhere.

2.1 Sticker Breakout

When a sticker breakout starts to form, we all know that it will produce a rise and a fall on one upper thermocouple

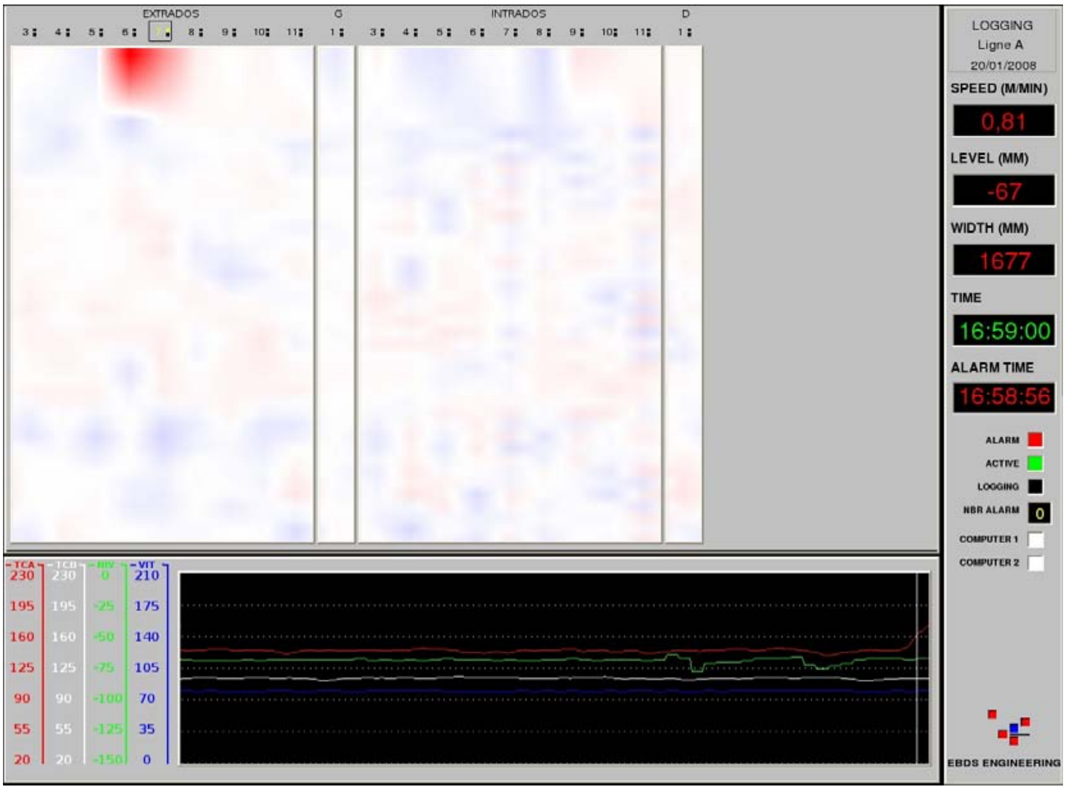

Figure 2 – Martine's display when rise occurs on one upper TC

On Martine's display, one will see a hot spot (red zone) coming from the top. This will be followed by the same phenomena on the corresponding lower thermocouple (Figure 3).
As the sticker zone expand also horizontally, a similar rise and fall will occur on the neighbor thermocouples, but slightly later.
The sticker will induce a kind of “V” shape cut into the shell. The “V” shape comes on Martine's display as shown on Figure 3. If the sticker breakout is not detected, the tear will reach the end of the mould, resulting in a loss of liquid steel into the caster, and an interruption of casting.
The Figure 4 shows a sticker phenomena fully developed till the breakout.

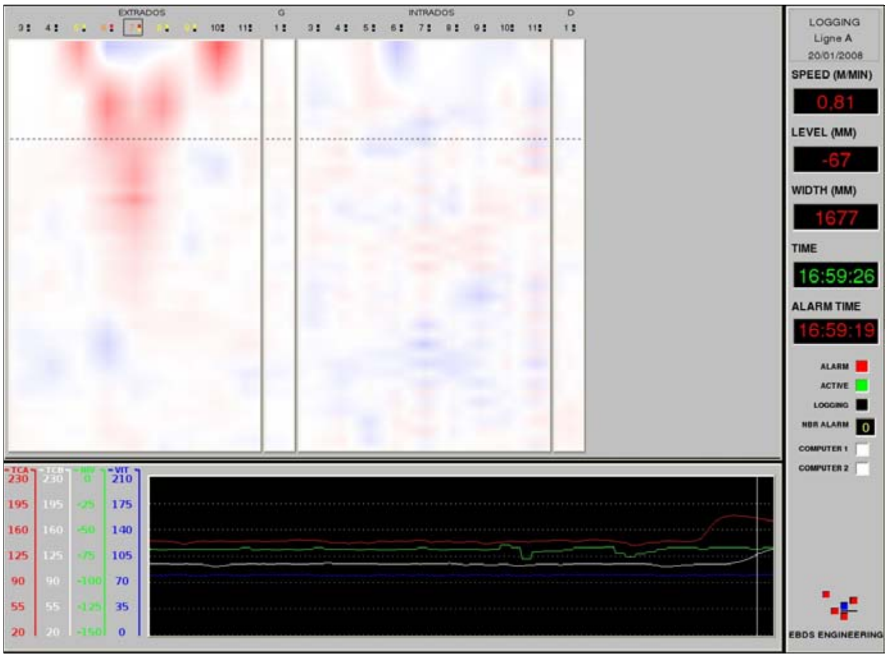

Figure 3 – Martine's display when sticker breakout is developping.

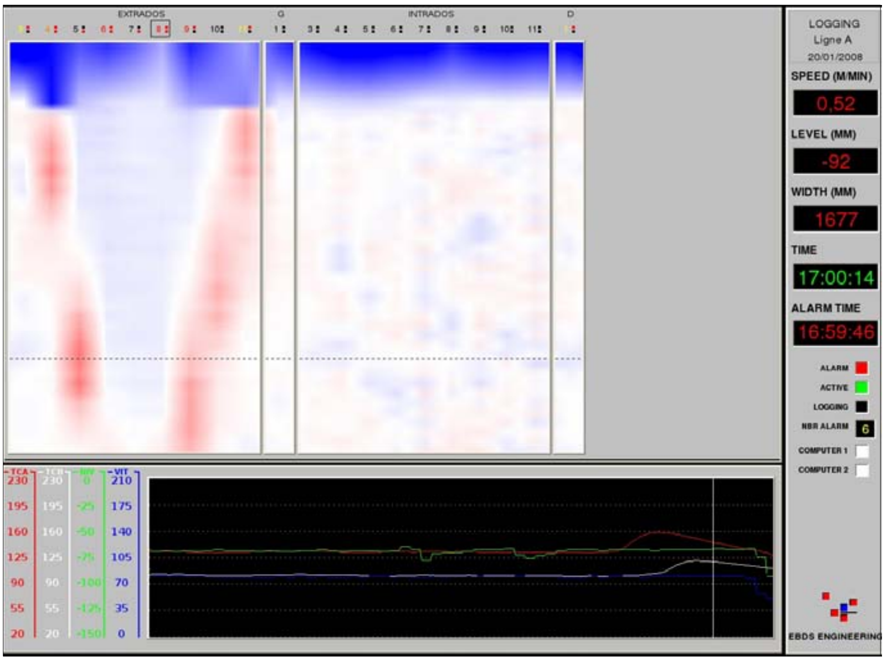

Figure 4 – Martine's display when the breakout has occurred.

One can see that, without any calculation, Martine's display shows in a quite effective manner the propagation of the sticker: a red “V”, symbolizing the tear in the solidified shell, and a blue zone inside the “V”, corresponding to the sticked part of the shell. This representation allows attentive pulpit operators to slow down the caster before the critical conclusion.

2.2 Examples of Other Phenomenas

Other phenomenas can be seen on the screen, as it is a realtime display of the mould thermal exchanges. Here below some examples particular things that can be observed during casting.

2.2.1 Slag film sudden change/rupture

Some steel grades or/and some mould flux are behaving in particular way, and giving rise and fall on vertical pairs of TC (sometimes double pairs if the thermocouples are installed close from on to each other).

These kinds of behavior can be interpreted as a sticker pattern, from the calculation point of view, if the program is not too evolved.

However, from a display point of view, Martine can show that it is not related to sticker problem, because no propagation is coming out:

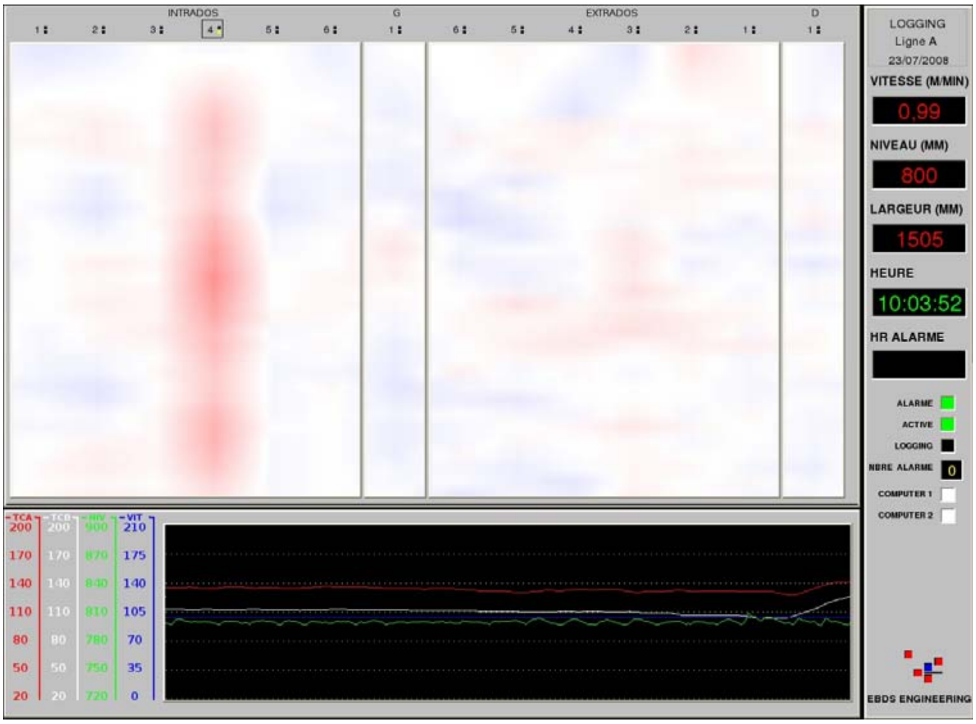

Figure 5 – Martine's display on mould slag film abnormal behavior

One can see that the trace given by the pair of TC involved is long and vertical, not communicating to neighbor thermocouples.

2.2.2 Local lubrification disturbance

From time to time, it is possible to observe local disturbance in thermal exchange. In the figure below, this can be located on the left side of the SEN. One can see that both broadfaces are undertaking the disturbance, in the same area (re-composing the mould from the image would put the two distrubed area in front from another, on the same side of the SEN).

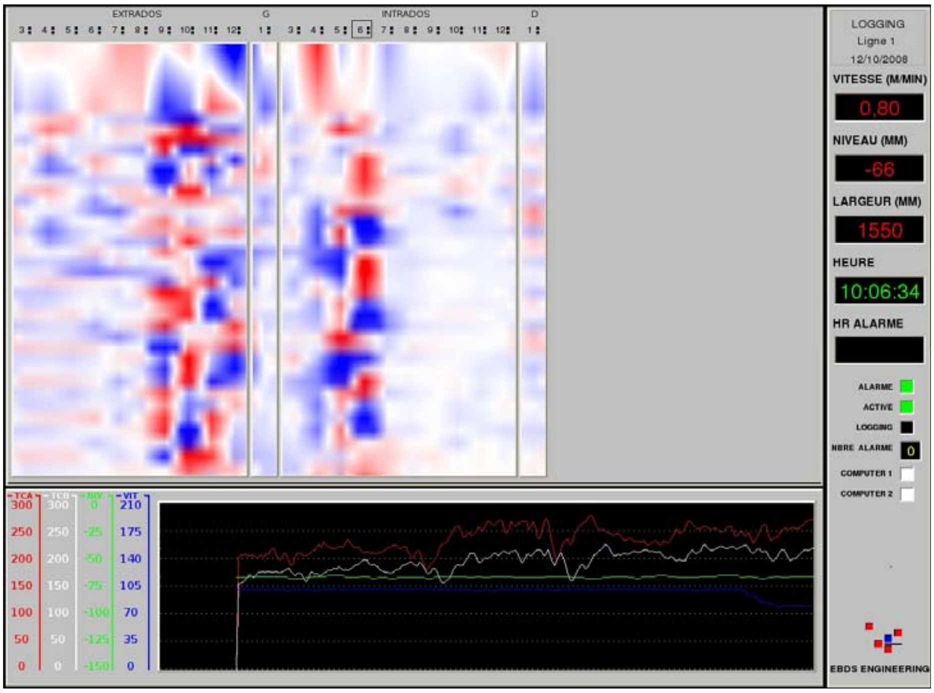

Figure 6 – Abnormal thermal behavior on left side of the mould

It is more commonly observed on a narrow face, as can be seen on the Figure 7.

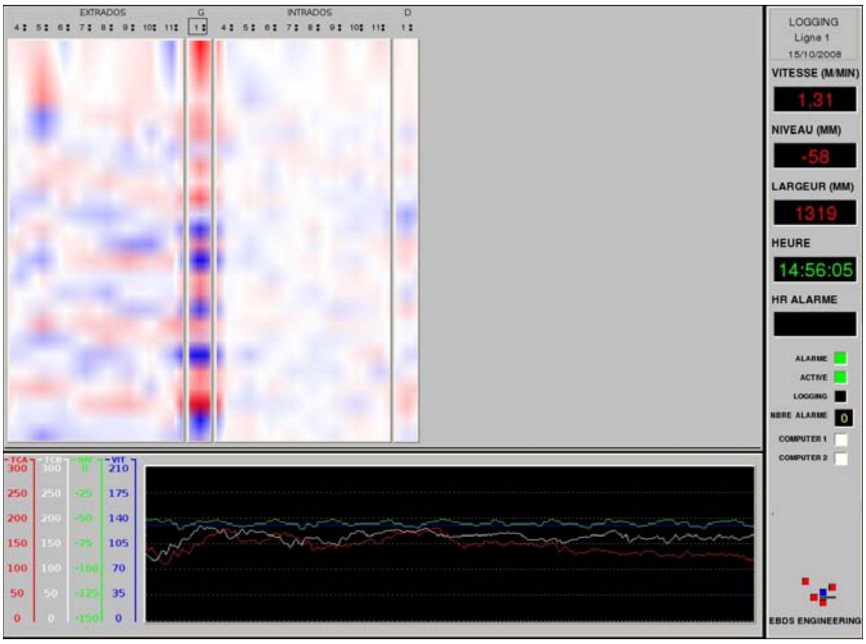

Figure 7 – Abnormal thermal behavior on left side of the mould

When observing these disturbances, the pulpit operator can ask the line operator to check if anything abnormal is occurring in the area of concern.

- *Steelgrade behaviour*

Some steelgrade have particularly disturbed mould exchanges. This is the case of peritectic steelgrades, which, due to the phase transformation in the mold, will show very chaotic exchanges.

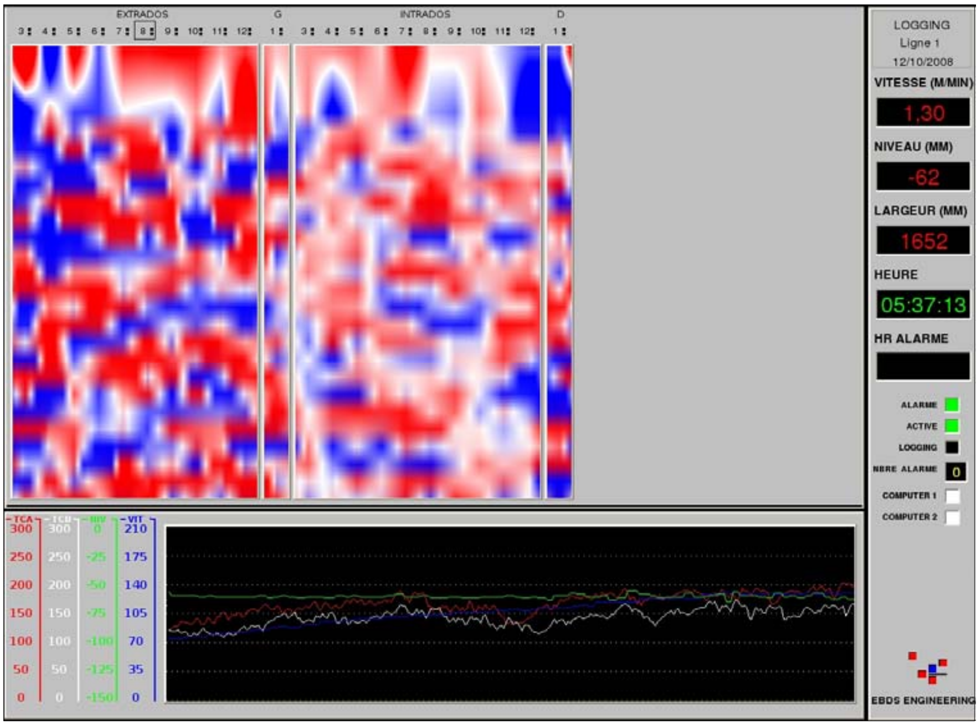

Figure 8 – Peritectic behaviour.

2.2.3 Electrical problems

If the thermocouple signal is not has it should, due to data acquisition problem, or electrical perturbation, the screen will show them out quite obviously. It is easy to diagnose electrical disturbance, because all Tcs will have the same perturbation at the same time. In the figure #9, there is a data acquisition problem on the extrados broadface.

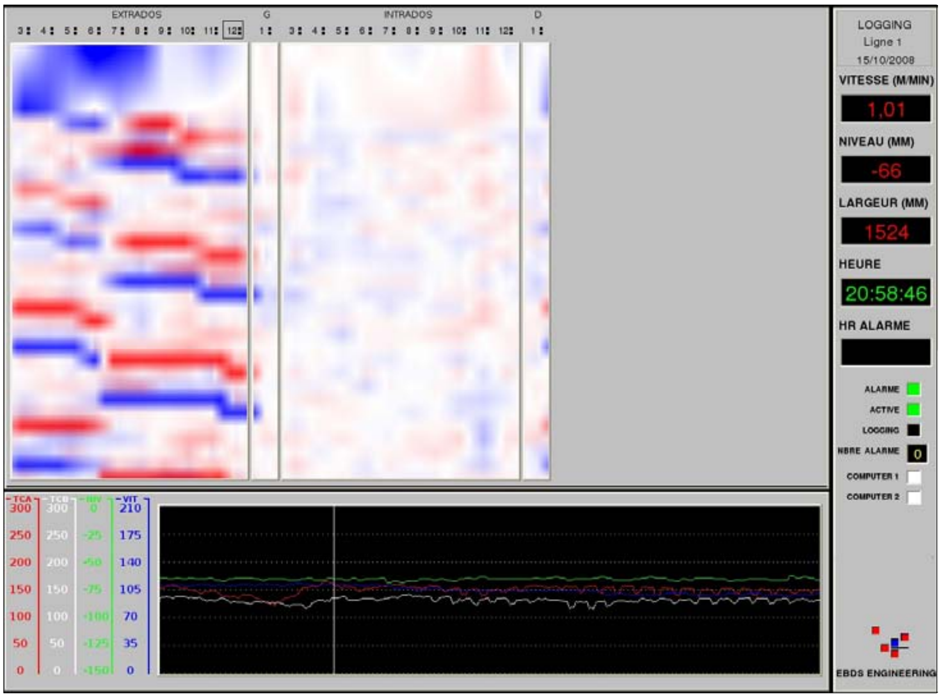

Figure 9 – Data acquisition problem.

In this particular case, the display shows quite obviously a problem that cannot be easily seen on the thermocouple signal.

3 CALCULATIONS

It is generally well admitted that the pattern of temperature that is to be recognize is the theoretically the following:

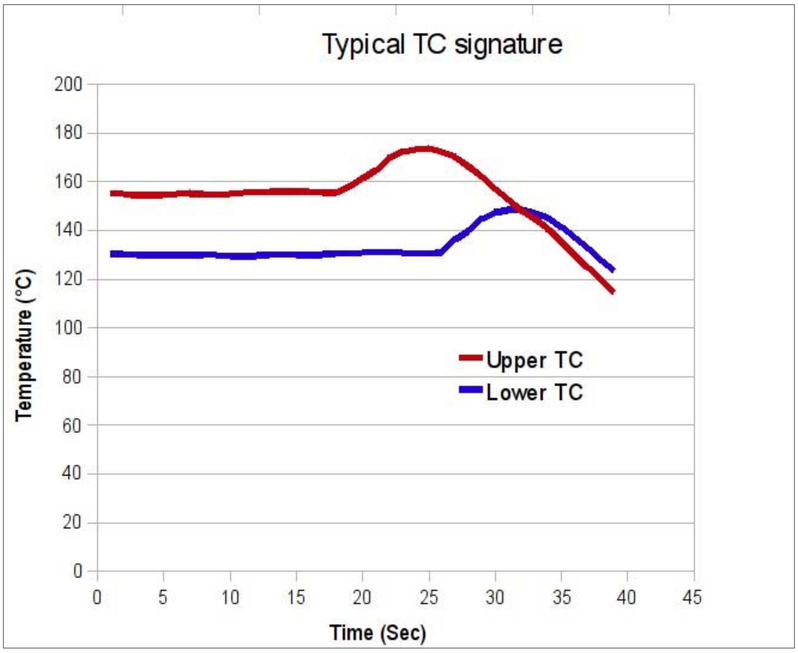

Figure 10 – Typical theoretical admitted curves for sticker BO.

The maximum of the upper TC corresponds to the moment when the tear is passing in front of it. When the tear will be in front of the lower TC, there should be a crossing of the curves.
So most of the breakout detection system are based on the following strategy:
"chase for an "enough" important rise on the upper TC, followed by a fall, and a crossing with the lower corresponding TC."
This kind of strategy is based on a simple mathematical approach of the search phenomena:
"if the curve raise more than x °C in y seconds, than I consider that I have a "significant rise", than I can chase for the fall, and if I have a "significant fall", I can chase for the crossing with the lower TC"
There can be some differences from one to another strategy, like confirmation by a third row, or a side TC, but generally speaking, we observed similar kind of strategy on the majority of the systems.
This kind of strategy presents some weaknesses:

1) <u>The steel grades behavior.</u>
   The different steelgrades cast can have different behavior: we have seen that a peritectic steel generates (figure #8) a lot of disturbance on the thermal exchange. However, LCAK, ULC grades, austenitic stainless grades, for example, are very calm and steady from that point of view.
   So, the definition of a 'significant rise" must be variable according to the

steelgrade cast. Some have then decided to classify their steelgrades so that the parameters of the breakout detection system can be selected accordingly.

The local disturbances.

On a regular basis, we can observe disturbances on TC, not related to steelgrade behavior, but related to the momentary working point of the mould (Argon, mould powder, clogging, bias flow,..).

If the program has determined parameters for selected types of steelgrades, then it will happen that sometimes, false alarms will be released due to local disturbances on a few thermocouples. The only way to go round, in such situation, is to increase the level of the parameters, to avoid un-desired false alarms. But doing so, all “calm” thermocouples will be “de-sensibilized”.

In order to go round these 2 issues, the breakout detection system must have individual self-adaptive parameters, so that each thermocouple works with its own parameters that are being adjusted permanently.

2) The intersection.

As it is generally admitted, and theoretically correct, that there should be a crossing between the upper TC and the lower TC during a sticker breakout development, this criteria is massively used.

However, we can observed, that this crossing does not happen systematically.

The figure #4 is illustrating this case of behavior: even though the breakout has had the time to fully develop, the crossing didn't appear on any of the pairs of TC that were involved. This behavior is not an isolated case, but can often be seen. Sometimes they do cross, but rather late in comparison to the usual expected crossing time.

Another issue with the crossing is related to the general disturbances of the curves. When real phenomenas are occurring in the mould, they passes in front of the upper TC, and then can been seen some seconds later on the lower corresponding TC. The best example is the peritectic steel: all curves are going up and down, and it is easy to see that the lower Tc's are always presenting an analogical curve of their own upper TC. The crossing might become then, in such case, the only trigger for the breakout alarm to be released, with consequences a lot of false alarms.

3) The strategy

In such strategy, where you try to set “several critical angles” which are going to trigger the alarms, the “importance” of the signal is not taken into consideration. Let's imagine the case where two upper thermocouples have the same “significant rise” criteria; we could be in a situation like this one:

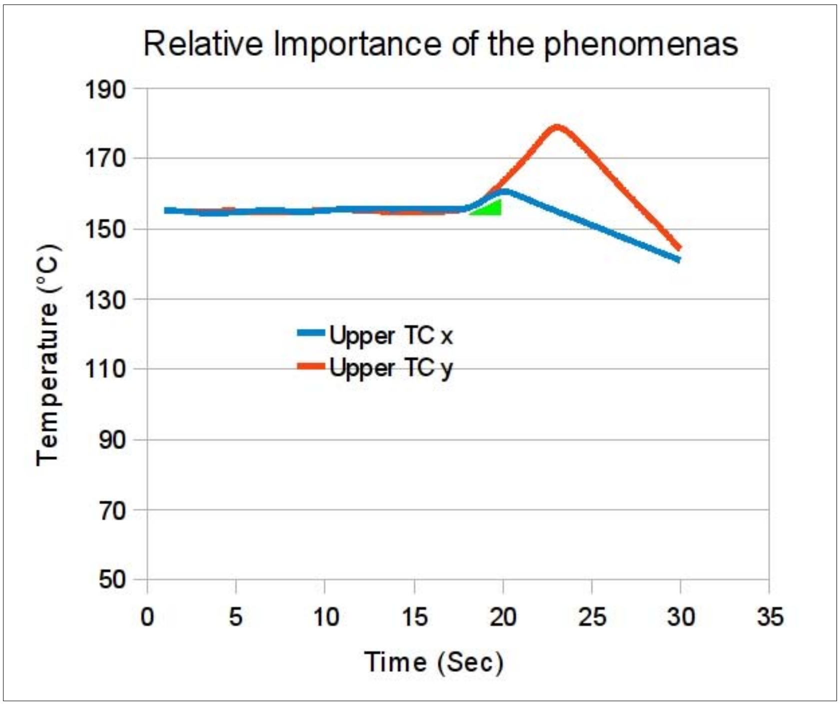

Figure 11 – Relative importance of phenomenas.

The 2 curves are being characterized with the same criteria (passing over the green triangle), but the graph shows us that one phenomena is important (on TCy), and the other one much less (TCx) and they should be considered as such into the system. This is not possible with simple threshold criteria.
A pure mathematical approach is limiting the strategy to a “Yes/No” kind of strategy, which will always be detrimental to the real detection/false alarm ratio.
Martine breakout detection system is integrating into its calculation the full recognition/quantification of patterns for the temperature curves during casting. When a phenomena, which seams to be abnormal regarding the history of the curve is appearing, the system is quantifying the whole evolution, so that we can take the best decision accordingly.
Doing so, we can decide to wait confirmation on other thermocouples (up to 3) or to decide to release the breakout alarm without any further delay. In the case of the figure #11, Martine would have act in a complete different manners, whether the TCx or TCy was involve.
This way of doing authorizes us to detect other TC pattern. For example, we have a recognition of the phenomena mentioned in figure #5 (the slag film sudden change). This pattern, in classical BO detection, is a source of quite a lot of false alarms, because it sometimes appears to be very similar to a BO pattern.

4 GLOBAL PHILOSOPHY OF MARTINE SYSTEM

As said above, the system is based on 2 axis: the image and the calculations. We believe that these two are complementary. The system can release 3 levels of alarms: the first level, which is only one small “beep” sound, is to draw the attention of the operator to watch the screen, because the calculations have found something abnormal. At the same moment, a little green alarm indicator will move to red on the side of the screen. If the phenomena does not evolve in a sticker pattern, no further

alarms will be released. The alarm red square will pass back to green.
If the detected phenomena evolve into what could lead to a sticker pattern, a second level of alarm will be reached, and the beep will become a “beep -beep” sound for some seconds. At this stage, the operator should already have an opinion about what's coming up. Finally, a third level of alarm can be reached (it will be a voice message), if the calculations found the problem to be a sticker breakout. Then, either we give the order to the PLC to slowdown the caster automatically, or we let the decision to the operator.

5 CONCLUSIONS

Martine system from EBDS engineering is setting a new standard in breakout detection system, through the use of an advance thermographical image representation, that will allow to visualize, in an effective manner, all abnormal thermal exchanges, including the well known “V”shape sticker pattern. On the other hand, the classical calculation approach has been completely abandoned, preferring to integrate curve recognition, coupled with possible metallurgical behaviors.
The combination of these two techniques into one system is giving outstanding results. Martine system has been recently qualified to be the best breakout detection system in use, among all ArcelorMittal Western Europe Steel plants.