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# INGOT UPHILL CASTING DEFECT POTENTIAL REASONS AND FORECAST BY DIFFERENT APPROACH AND ANALYSIS.

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*Uphill casting is widely used to cast high quality ingots in order to reduce several defects coming from gas or solid trapped inclusions, inhomogeneity, holes consequent to the direct pour casting etc. Uphill casting reduce turbulence, improve slag removal by floating slag particles on the ingot top. Notwithstanding that, there are several reasons that can generate troubles in the final product with consequent technical and economic damages. Low or incorrect refractory qualities may release polluting parts to the final product, complicated shapes or layouts can reduce the casting speed and efficiency. Experience showed that the quality, shapes and layout of the caster refractories may affect the final products. Other possible analysis consist in:*

*- the use of post-mortem residual bones examinations to identify possible sources of defects*

*- casting simulations by means of Finite Elements Methods (F.E.M.) in order to develop better layouts and shapes to reduce potential defects.*

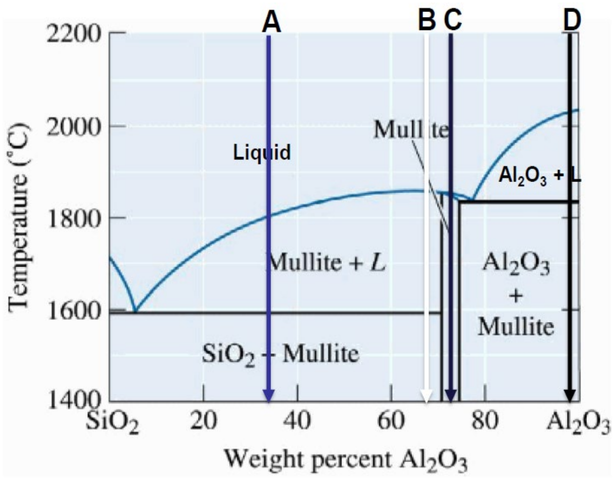
*This paper would like to resume these experimental approaches to promote new and more accurate systems to improve ingot quality with eventual use of AI.*

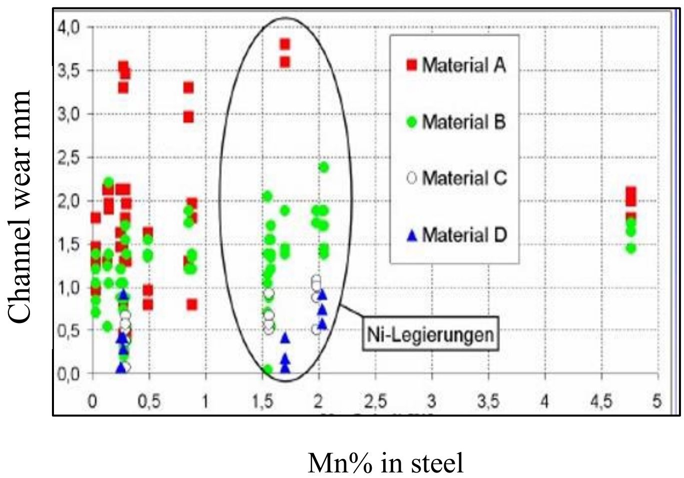
**KEYWORDS:** INGOTS – DEFECTS – STEEL CLEANNESS FORECAST – RESIDUAL ANALYSIS – F.E.M

Uphill ingot casting is a quite old way to cast quality steel ingots in order to reduce polluting inclusions by means of filling ingot moulds from the bottom instead from the top by means of a net of refractory channels surrounding a central feeding funnel. In this way most of the polluting elements – slags, refractory parts, gas inclusions – have the time to concentrate on the very top of the ingots, so giving better chances to be removed after solidification. However, this approach does not grant a complete removal of polluting elements, due mostly to the more complicated way the steel reaches the ingot moulds and the contact with the refractory system required to channel the liquid steel into the moulds.
However this system does not prevent completely the possibility of pollution, either for the casting time cannot be too long – a sure way to grant that all the inclusions find their way to the top of the ingot before its solidification – or the contact with the refractories cannot be avoided. For these reasons a way to predict the possibility of polluting elements trapped in the ingot is quite useful for the future approach of the metallurgist. For example, macro inclusions in ingots bound to produce metallic wire could create breaks in the wire line forcing to stop the process with cost increase due to shorter coils, waste of time, etc.

**Tab. 1** – Main refractory types for uphill casting

| **Main Raw Material** | Chamotte | Bauxite Andalusite | Bauxite |
|---|---|---|---|
| **Chemical Composition** | | | |
| Al2O3 | 50,0 | 69,0 | 79,0 |
| SiO2 | 45,0 | 25,0 | 16,0 |
| Fe2O3 | 1,5 | 1,6 | 1,2 |
| TiO2 | 2,3 | 2,4 | 2,5 |
| K2O | 0,8 | 0,6 | 0,4 |
| **Physical Properties** | | | |
| Bulk density (g/cm3) | 2,20 | 2,49 | 2,60 |
| Open Porosity (%) | 21,0 | 20,5 | 24,0 |
| CCS (Mpa) | 38,0 | 53,0 | 70,0 |
| **Refractoriness Under Load T05** | 1300,0 | 1380 | 1520 |
| **Thermal Expantion (% at 1000oC)** | 0,6 | 0,6 | 0,7 |




**A:** semi-plastic $SiO_2$-$Al_2O_3$ product **B:** semi-plastic mid $Al_2O_3$ product
**C:** semi-plastic mid $Al_2O_3$ bauxite product **D:** dry pressed high alumina product

On the other side the extremely various casting plates for dimensions, distribution, channel diameters, number and size of moulds, casting ladle sizes and so on, force the use of part of refractory shapes based on semi-plastic medium alumina refractories, whose thermal and chemical resistance could be not enough to stand the high temperature and chemical aggressivity of certain steel types. The large variety of shapes of the casting plates forces to use still a large amount of semi-plastic refractory mixes in the brick production, reducing the possibility to increase the alumina content and forcing to use plastic clays that introduce a large amount of water to the system.

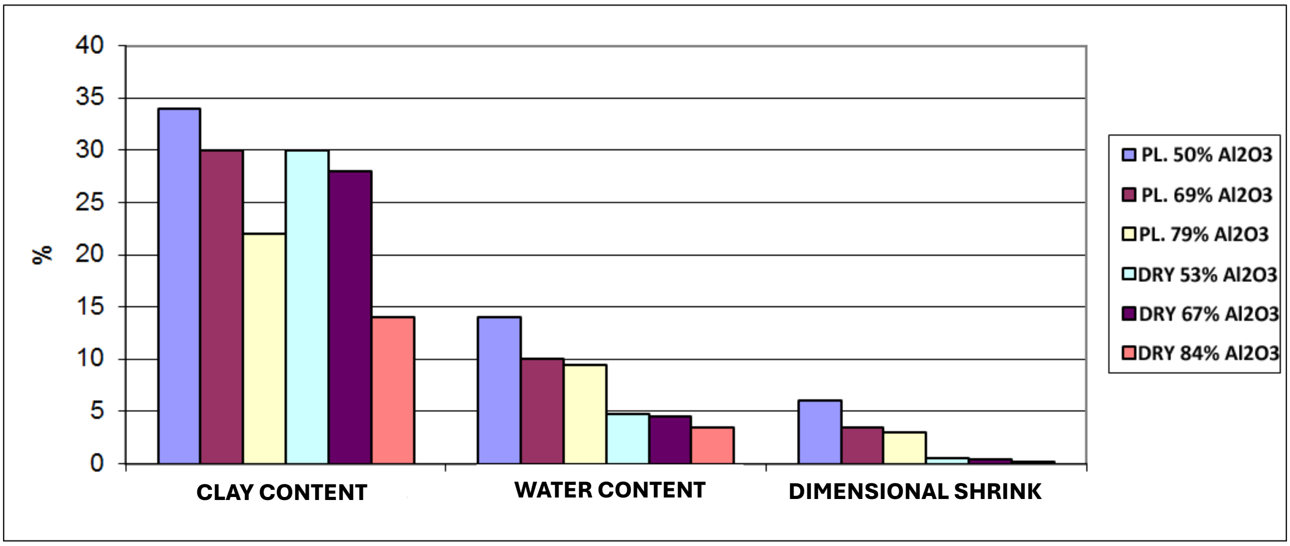



**Fig.1**– Comparison among different refractory bricks

This paper would like to analyse some ways of forecasting possible pollution troubles in the final products mixing the job of archaeologist, due to the old-fashioned casting system, with that one of coroner asked to understand who, in which way and where the damage may have been generated.

## READING THE BONES

The oldest and most traditional way to foresee possible troubles in the final solidified products is to analyse the residual "bones" in the used refractory parts. At the end of the casting the whole refractory net – vertical feeders, distributors, horizontal channels, risers – are left filled of solidifying steel melt, whose appearance could be examined when the caster is dismantled. The way these bones are looking may allow to predict different troubles inside the cast ingots:

1. Low metallic plate parts tightness: accurate installation of the metallic parts, their tightness granted by blocking systems in order to counteract the casting steel pressure, is required to prevent infiltrations in the joints.
2. Poor quality and installation of the filling mix: the role of the filling mix is to stop any eventual infiltration from the channel joints. Low quality or bad installation of the filling mix may enhance the trouble and in the worse cases become a source of ingot pollution.
3. Low joint tightness between the different parts and coupling level: as for the point 1, poor tightness may either create infiltrations and allow air or polluting materials enter the cast
4. Contact reactions with the channel refractories: poor or unfit quality of the channel refractories may bring to macro-inclusions in the ingots or breakthrough of the refractory arrangement during the cast.
5. Water vapour in the channels: refractory parts – bricks, mortars, mixes – not perfectly dried may generate water vapour in the casting line either polluting the ingots even damaging the caster.

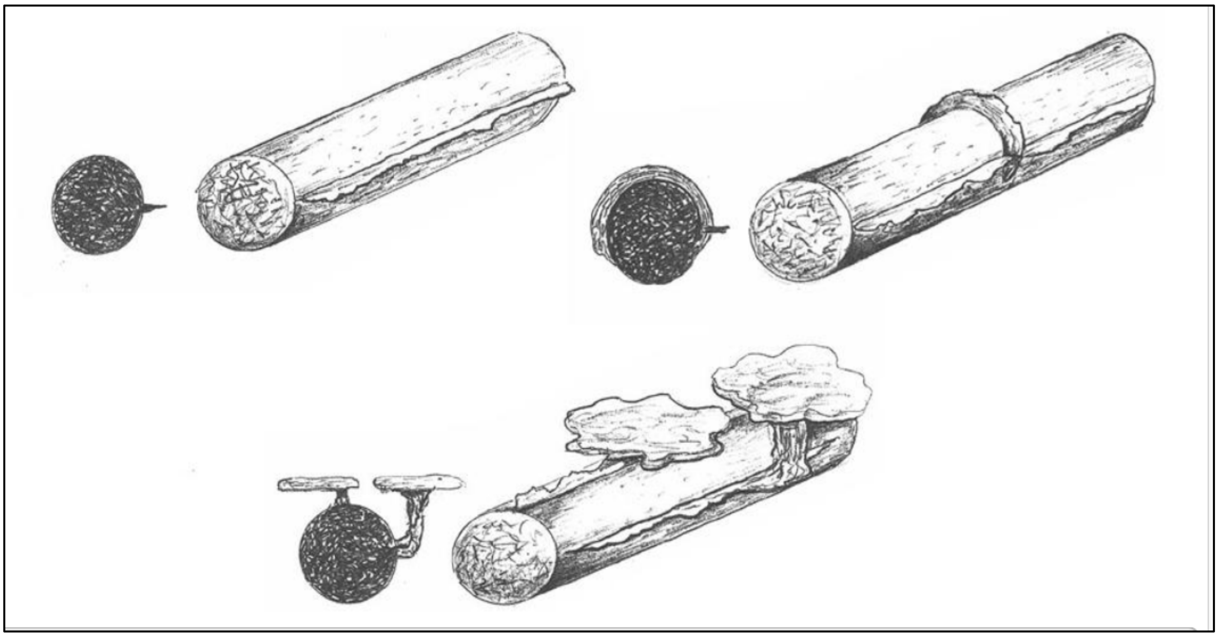


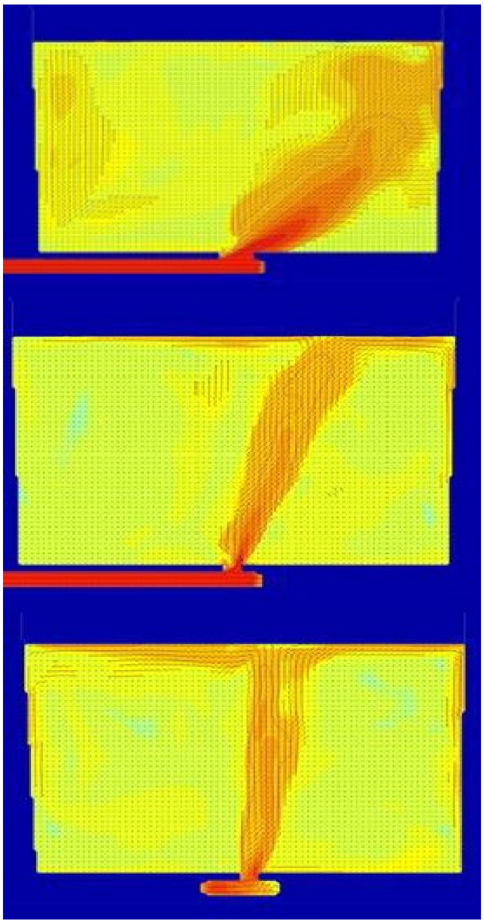
**Fig.2**– Examples of residual channel bones

**CASTING SIMULATION**

In the past shapes, diameters and thickness of the parts composing the casting assembling were chosen by experience and attempts. Nowadays, simulation models, either bi- or tri-dimensional, based on Finite Elements Methods allow to :

- Evaluate flux speed in every point
- Evaluate the ingot thermal profile during the cooling time
- Design the best fit shapes of end-bricks and risers
- Foresee the inclusion formation according to the steel flux characteristics into the ingot mould

**Riser shape simulated effect on the steel flux:**

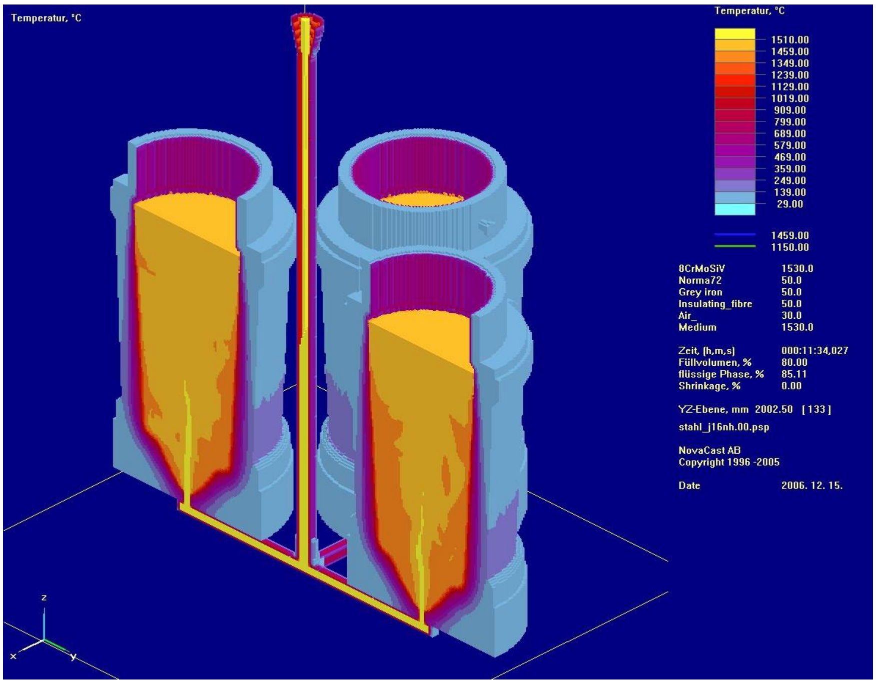


1. **Large diameter short riser:** high turbulence towards the mold wall, high risk of ingot inhomogeneity

2. **Oval riser:** better oriented flux but with, ingot inhomo-geneity still possible

3. **Lower diameter high riser:** nearly vertical and sim-metric flux , very low ingot inhomogeneity

**Simulated temperature distribution during casting and cooling down**




## CONCLUSIONS

To forecast the possible defects and inclusions in the uphill casting ingots is important to grant high quality products, in general requiring this type of process. Provided that the system could offer a slow and smooth casting process, so allowing to reduce the trapped inclusions, most of the troubles could come from the refractories used to line the channels and their peculiar shapes, often required by the incredible variety of metallic plates in use in the different steelworks. To improve refractory quality and consequently reduce the use of semi-plastic products, whose clay content affects either the chemical and physical level of the products, a big effort should be done to minimize the shape number, often coming from the incredible amount of different casting plates in the same steelwork. In this sense AI could become an important support for this improvement. A second possibility could consist in some sort of turn-key solution, where the casting plates are supplied by the refractory company through a full-service agreement. In this way the casting plates could be designed to accomplish the customer’s ingot requirements, allowing to line the channels with dry-pressed parts and reduce the inclusion risks. .

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