



# TECHNOLOGICAL UPGRADE OF SLAB CASTING PLANTS: DANIELI EXPERIENCE FOR PLANT RENOVATION AND PERFORMANCE IMPROVEMENT<sup>1</sup>

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## Abstract

The development of slab casting technology in recent years has introduced several significant improvements both in mechanical design and in the applicable process technology. This development has allowed recently installed casters to operate with performances remarkably better than casters installed in the past. In order to keep pace with Global Players in developing countries that benefit not only from reduced man power costs but now also from the latest technologies installed in their newly commissioned plants, Steel Makers using existing plant have little choice but to initiate comprehensive renovation plans for their casters. Even in times of budget restriction policies, such cost effective action can not only prolong the technical life of their plants but also put them back in line with the latest technological developments, and maintain their competitiveness. Thanks to Danieli's experience, dating back to first slab casting installations in the fifties in UK with the first commercial caster ever installed, Danieli Davy Distinguon largely contributed to the development of the casting technologies and has developed a comprehensive experience in upgrading existing plants with tailor made solutions, that range from limited budget applications of technological packages to major caster revamping. This paper describes the driving force for slab casting renovations, the technological packages developed by Danieli and some significant examples of caster upgrades in recent years.

**Keywords:** Tailor made solutions; Latest technological developments.

## ATUALIZAÇÃO TECNOLÓGICA EM LINGOTAMENTO DE PLACAS: EXPERIÊNCIA DANIELI PARA REFORMAS DE PLANTAS E MELHORIA DE DESEMPENHO

### Resumo

O desenvolvimento da tecnologia do lingotamento de placas nos últimos anos introduziu várias melhorias significativas tanto em desenho mecânico e na tecnologia de processo. Esta evolução permitiu recentemente a instalação de lingotamentos para operar com desempenho notavelmente melhor do que os instalados no passado. A fim de manter o ritmo com os players globais em países em desenvolvimento que beneficiam não só a redução dos custos de mão de obra, mas agora também a partir das mais recentes tecnologias instaladas em suas fábricas em operação, produtores utilizando instalações existentes, têm pouca escolha senão planos de reformas abrangentes para suas máquinas. Mesmo em tempos de políticas de restrição de orçamento, custo, tais medidas eficazes não só pode prolongar a vida útil de suas máquinas, mas também colocá-los atualizados com os mais recentes desenvolvimentos tecnológicos, e manter sua competitividade. Graças à experiência Danieli, desde ao primeiro lingotamento de placas instalado nos anos cinquenta no Reino Unido, com o primeiro lingotamento comercial instalado, Danieli Davy Distinguon, contribuiu largamente para o desenvolvimento das tecnologias de lingotamento e desenvolveu uma ampla experiência na modernização das instalações existentes com soluções sob medida que vão desde pedidos de orçamento de pacotes tecnológicos até reformas completas de máquinas de lingotamento. Este artigo descreve o caminho para as reformas de lingotamentos, os pacotes tecnológicos desenvolvidos pela Danieli e alguns exemplos significativos de reformas de lingotamentos nos últimos anos.

**Palavras-chave:** Com soluções sob medida; Mais recentes desenvolvimentos tecnológicos.

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## INTRODUCTION

Since our first applications in the late fifties, continuous casting technology experience over the years shows a remarkable evolution both in plant design concepts and process features.

Technological evolution has created a progressively increasing significant gap between the mechanical life of the equipment (fixed by the capacity to produce according to the original design specifications) and its technological life (corresponding to its capacity to produce in line with the modern day best available performances).

Considering their expected multi decennial mechanical life, slab casters that have been installed even only 10 years ago and still in conditions to produce, are becoming quite obsolete and very often significantly out of line with the recent developments of technology. In order to meet modern quality requirements such machines often have to significantly reduce production levels to guarantee repeatable quality and this coupled with increased unreliability which naturally occurs over time results in an efficiency level well below the global competition.

It is well known that in the past five years a large number of new 'state of the art' slab casters have been installed in developing countries (most notably in China). As a consequence steel producers with older generation equipment, particularly those in industrially matured plants who were pioneers of the Steel world, are now rapidly finding themselves surviving only due to the great experience developed by their production and maintenance teams. As the new producers grow in experience and master their new technology the pioneers will be unable to overcome the limitations dictated not only by the technical obsolescence of their equipment, but mainly by the restrictions imposed by its original design concept.

Considering the global nature of the steel business, particularly in the flat products sector where the playground is the world market, overall competitiveness on transformation costs and quality is paramount.

In order to keep pace with Global Players in developing countries that can benefit not only from reduced man power costs but now also from the latest technologies, long established Steel Makers using existing plants have little choice but to implement comprehensive renovation plans of their casters that, even in times of budget restriction policies, can not only prolong the mechanical life of their plants but also put them back in line with the latest technological developments, and maintain their competitiveness.

Thanks to Danieli's experience, dating back to first slab casting installations in the fifties in UK with the first commercial caster ever installed, Danieli Davy Distington largely contributed to the development of the casting technologies and has developed a comprehensive experience in upgrading existing plants with tailor made solutions, that range from limited budget applications of technological packages to major caster revamping.

## DRIVING FORCE FOR CASTER REVAMPING

A slab caster can be considered obsolete not only because it is mechanically "old" but also because either it is not possible to respect the increased quality requirements dictated by the Market and/or because the weight of its running cost in the overall plant transformation cost is excessive and not in line with overall competitiveness.



## QUALITY ASPECTS

Today's mills (both HSM and plate mills) have dramatically increased their quality requirements expected from slabs.

New processes such as the mill furnaces hot charge that eliminates the possibility to intermediate inspection of slabs after cast and also the production of new high performance grades such as X100 +, Ultra High Strength micro alloyed steels, multiphase steels ( dual, trip, twip), etc call for slabs of consistently superior quality with improved surface and sub surface characteristics, better internal soundness for consistent mechanical properties, and improved internal cleanliness.

## PODUCTION ASPECTS

In addition to consistent quality production, to be competitive today's casting plants must operate cost effectively by minimising maintenance downtime and caster manning requirements.

In order to reduce transformation costs, it is therefore of paramount importance that caster design provides technical solutions that ensure long production life of the components which are normally subject to wear (such as caster rolls) , quick change of operational equipment (such as mould and segments) and easy equipment maintenance procedures.

Such high levels of reliability are the key to dramatically increasing casting yield with many of Danieli's plants having regular sequence lengths of 1000 ladles and over. Of course levels of production which require casting for 5 weeks and producing 330,000 tonnes without stopping for rethread require not only highly reliable equipment but also the very latest in stable reliable process technology in order to minimise breakout rate, allow flexible in-line slab width adjustment, and provide advanced diagnostic and quality data analysis.

At the same time, an ever increasing degree of plant automation is required , ideally culminating in the "no man casting practice" which not only reduces transformation costs but significantly improves the safety of the plant and, although no one like to admit it, the quality of slab produced.

## DANIELI PACKAGES FOR SLAB CASTER PERFORMANCE IMPROVEMENT

In order to face these challenges the following solutions have been adopted in new casters recently installed by Danieli and can also be implemented in existing plants as technological upgrade packages for key areas of the casting machine.

Issue: Mould & Oscillation

- Moulds require quick change design, integrated advanced breakout prevention systems and in line width adjustment capability, in order to reduce production downtimes due to maintenance, allow flexible on line slab size change, and reduce breakouts.



- Hydraulic oscillating systems should be utilised instead of electromechanical, with advanced guidance system for “zero tolerance” guidance during oscillation, such systems are able to improve slab surface and sub surface quality and reduced the potential for breakout.

The Danieli tool that successfully answers to these requests is the INMO mould (Figure 1) that has been successfully applied in all recent new casters supplied but it can also be applied as stand alone package, as seen in ArcelorMittal Bremen Stahlwerke in Germany) Chengde I&S and Sanming I&S slab casters in China.



**Figure 1** : INMO mould and oscillation system in operation in ArcelorMittal Dunkerque ( france) revamped casters

- Advanced mould level control system, in order to improve meniscus stability. The Danieli tool specifically developed for monitoring and control of mould level, coupled with both radioactive and electromagnetic sensor (according to the specific application) is the Danieli ‘i’ level, intelligent mould level control system It is widely known that unstable level control may contribute to a number of quality issues effecting both surface and internal quality. The Danieli ‘i’ level intelligent level control package combats many of the phenomena which can lead to level disturbances including Dynamic bulging, flush through control, standing wave, in addition to the more usual aspects of speed change control and width control. Correction of poor mould level can have a profound influence on final product quality and can allow casters to return to normal high production levels where they may have been reduced to avoid level disturbance.

Recent applications, based on LQG data processing, show a meniscus level stability with fluctuations below 1,5 mm , even in the most extreme applications in ultra high casting speed for thin slab casters (with casting speeds above 7 meters per minute).



Issue: Mould fluid dynamics control

- Application of innovative multimode electromagnetic in mould technology, that can combine liquid steel flow acceleration, breaking and stirring functions.

Thanks to the close co operation with our sister company, Danieli Rotelec, Danieli Davy Distington has applied on several casters (such as ArcelorMittal Sidmar plant, Belgium) the new MM EMS technology, with the goal to improve slab internal quality. The latest design incorporates the unique capability of changing position (up and down) in the mould according to casting conditions in order to achieve the optimum steel flow in the mould.

Issue: Caster Rolls

- Casting rolls of multiple span design, with improved internal cooling and enhanced cladding, for optimum slab support, long service life and easy maintenance.

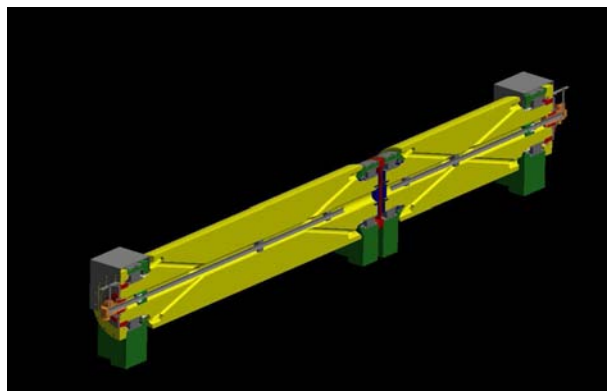
Since 1986 Danieli Davy Distington has adopted multiple split rolls in slab casting, in order to ensure in the meantime small pitch roll diagrams and ensure sufficient slab supporting across the slab width.

The Danieli CoolRoll concept has been developed keeping in mind also maintenance issues , with modular design solutions that allow an easy dismantling for maintenance also after a prolonged permanence in the caster.

Superior multilayer stainless steel cladding has been developed in order to guarantee the correct surface hardening that ensures both to preserve slab surface and ultra long roll life.

Internal roll cooling design is of paramount importance for maintaining roll containment properties and after prolonged strand stoppage which typically can create uneven roll temperature which leads to thermal stress and subsequent roll failure, Danieli developed its original design of Peripherally Drilled Rolls ( PDR) whose reliability provides extra long roll life between dismantling, inspection and in some applications over 10 million tons of cast slabs have been cast between maintenance. Very remarkable considering extra long casting sequences, exceeding 1000 ladles (more than one months of continuous casting operations without restranding).

These concepts are materialized in the last generation of UHP (ultra high performance) Danieli CoolRoll (Figure 2), with either centre bore or PDR configuration, according to roll diameter.



**Figure 2:** Danieli CoolRoll, PDR type.



#### Issue: Secondary cooling

- Dynamic secondary cooling, air mist type, in order to ensure the optimal metallurgical conditions for slab solidification and designed to minimise the mechanical bending/unbending stress on the slab, whilst optimising surface quality and controlling the sump position during the casting process.

The Danieli CoolControl is a Danieli package dedicated to enhancement of secondary cooling performances.

The Dedicated mathematical model, continuously compares the thermal history of each slice of slab according to the real casting conditions and the optimum solidification thermal profile dictated by metallurgy. The Danieli Cool control model then dynamically adjusts the flows of secondary cooling media during both “cruising” casting conditions and any transitory conditions.

The Danieli CoolControl model is applicable to both Air mist and Water only secondary cooling systems, according to process specific applications can be applied. Extended experience has already been matured in developing caster secondary cooling systems that, according to the thermal profile requested, can perform “soft cooling” “hard cooling” and “dry cooling”, thanks to the application of new generation High Efficiency nozzles with extended wet “footprint” area that guarantees a good efficiency in their spray performance over an enlarged regulation range.

Independent control zoning across the slab width allows the Danieli cool control system to adapt the cooling flow profile according to slab width, in order to avoid edge/corner overcooling phenomena.

#### Issue: Segment design and Soft reduction

- Segments of suitable design (Figure 3), low maintenance and proper robustness in order to apply Dynamic soft reduction process to improve internal quality and slab soundness.



**Figure 3:** the Danieli OPTIMUM segment.

Danieli pioneered the application of Soft reduction process since the late eighties both in conventional and thin slab casters: soon the advantages of Dynamic Soft Reduction process emerged.



In close cooperation with the maintenance teams of its customers, Danieli developed the OPTIMUM segment, conceived to properly distribute the roll gap reduction with the necessary position and force accuracy along the casting strand according to the real casting conditions.

Structural robustness of the mechanical equipment is the key to coping with the not insignificant additional stress on segments generated by soft reduction, and at the same time the OPTIMUM segment has been designed to guarantee an easy accessibility to rolls, couplings, nozzles and on board instrumentation for maintenance purposes. Quick coupling design for the majority of utilities and electric connections ensure a short segment change time.

With OPTIMUM segment design, it is possible to control roll gap along the caster for thermal tapering and dynamic soft reduction, but also to adjust final slab thickness according to the needs of the mill, without changing the mould, hence further improving caster flexibility and productivity.

Issue: overall roll diagram concept

Machine type conversion – Curved to Vertical Curved

- A Vertical curved machine design provides significant benefits over the original curved design, where internal cleanliness is paramount (such as IF grades) this is particularly important to achieve high casting speeds.

To remain competitive casting speeds are continual being increased on a curved mould machine this can lead to internal cleanliness difficulties. To overcome this mismatch between the need for high productivity whilst still maintaining cleanliness quality levels the complete roll diagrams are being revamped successfully performed by Danieli, to incorporate a vertical curved mould design whilst still respecting the existing casting floor levels as well as existing foundations.

Of particular significance in this area is the move to the full conversion from curved to vertical curved as in AM Sollac Fos sur Mer slab caster nr.2 (France), where a complete revamping strategy was selected by the Customer.

This full bow revamping was selected following the unsatisfactory quality results experienced in their caster nr 1 which was revamped from curved to vertical by partial “top end only” revamping only just a few years before.

Machine type conversion – Vertical Curved to Curved

On the contrary where low strain is of greater importance than cleanness levels it should be underlined that in some cases, such as in Mechel plant in Russian Federation and in CARSID plant in Belgium, we have also successfully conceived the conversion of a vertical curved caster into curved, allowing the caster to produce a new wider product mix utilising a caster with a larger caster radius.

Issue: man power optimisation

In order to improve efficiency and safety steel plants are continually striving to reduce manpower in the casting area, particularly for potentially dangerous applications, the following stand alone package solutions can be considered to assist in this reduction.

- Remotely controlled oxygen lancing by robot in case of slide gate opening failure
- Automatic powder feeding
- Automatic SEN exchange mechanism
- Remotely controlled sampling ( composition and temperature) in tundish
- Remotely controlled handling of segment during segment exchange
- Remotely controlled of roll gap in segments for automatic thickness change



## **AUTOMATION AND DIAGNOSTIC PACKAGES**

Significant plant performance improvements can be achieved by implementing, as standalone software packages, some dedicated applications specifically developed by Danieli that can help in the collection, interpretation and systematisation of available data from the field, for product quality prediction and tracking.

Among these packages we can mention:

### **ADVANCED MOULD THERMAL MAPPING PACKAGE**

This software together with the proper arrangement of thermocouples in mould, is a powerful tool to monitor “life” what happens inside the mould during the “first skin” process happens.

This tool provides an advance breakout warning function and automatic handling of prevention practices but allows also monitoring of the lubrication powders performances, check of liquid steel flow distribution in the mould and relevant possible anomalies, as well as is helpful in identifying slab surface damages such as longitudinal cracks.

### **DANIELI ‘I’ LEVEL, INTELLIGENT MOULD LEVEL CONTROL**

### **SLAB QUALITY ASSESSMENT IN REAL TIME (QUART) PACKAGE**

This software is able to correlate “live” the information concerning the real casting conditions with the “ideal” casting conditions for each steel grade and product, also considering specific final users specifications, and resent to the plant quality manager a detailed slab quality prediction chart.

With this tool, the slabs can be automatically rated in quality and properly routed for downstream processing ( hot charge, cold charge, visual inspection, grinding/scarfing process) minimizing time and manpower requested by visual inspection of the slabs “by default” after casting. The key to this software is it’s real time analysis which allows the slab cutting schedule to be adjusted to cut out the poor quality material thus maximising yield.

### **MOREINTELLIGENCE PACKAGE**

For overall caster production and maintenance data correlation.

It is a Multi-dimensional Database Analysis system that transforms the huge amount of production and process data gathered by the various automation systems into tangible information for decision-making and improved process knowledge.

Via advanced DWH (Data Warehousing) and OLAP (On-Line Analytical Processing) functionalities, MOREIntelligence rapidly and readily reveals important items of information that are often hidden within the huge amount of data generated by modern automation systems.





## **DANIELI EXPERIENCE IN EXISTING SLAB CASTERS REVAMPING AND PERFORMANCE ENHANCEMENT PROJECTS**

In the last decades Danieli Davy Distington got significant experience both in overall revamping of slab casters and in more limited budget projects, always tailor-made according to customer needs. In the following some examples:

### **Enhancement of the ArcelorMittal slab caster in Acesita plant, Brasil**

Scope of work: revamping of existing caster with upgrade of existing oscillator, new improved roll diagram in unbending area, new secondary cooling system.

Technological packages applied:

Danieli CoolRoll

Danieli CoolControl

Quart, Quality Assessment in Real Time

Danieli 'i' level, intelligent Level Control

### **Enhancement of the CARSID slab caster in Marcinelle plant, Belgium**

Scope of work, installation of hydraulic oscillation in place of electromechanical, new improved roll diagram in unbending area.

Technological packages applied

INMO oscillating control

Danieli CoolRolls

OPTIMUM segment

### **Enhancement of the ArcelorMittal slab caster in Bremen Stahlwerke plant, Germany**

Scope of work: installation of INMO mould and oscillator in place of existing mould with electromechanical drive

Technological packages applied

INMO mould

### **Enhancement of the ArcelorMittal slab caster in Contrecoeur plant ( Canada)**

Scope of work: substitution of all caster rolls, for improved slab support and reduced maintenance.

Technological packages applied

Danieli CoolRoll

Aside these applications Danieli got significant experience also in major revamping projects involving the complete modification of existing slab caster roll diagram concepts such as:

### **Posco 1 4 slab caster in Gwangyang works, Korea converted from curved to vertical curved design**

Technological packages applied

INMO mould

Danieli CoolRolls



Danieli CoolControl  
Danieli 'i' level, intelligent level control

**ThyssenKrupp slab caster in Beekerwerth works, Germany, converted from curved to vertical curved design**

Technological packages applied  
Danieli CoolRolls  
Danieli CoolControl

**ArcelorMittal slab caster CC23 in Dunkerque works, France , converted from curved to vertical curved design**

Technological packages applied  
INMO mould  
Danieli CoolRolls  
Danieli CoolControl  
Optimum segment

**ArcelorMittal slab caster CC22 in Dunkerque works, France , rebuilt keeping curved design, but with enhancemet roll diagram**

Technological packages applied  
Danieli CoolRolls  
Danieli CoolControl  
Optimum segment

**Mechel slab caster, Cheliabynsk works, Russian Federation, converted from vertical curved to curved design, of bigger radius**

Technological packages applied  
Danieli CoolRolls  
Danieli CoolControl  
Optimum segment

**ArcelorMittal slab caster CC21 in Dunkerque works, France , converted from curved to vertical curved design**

Technological packages applied  
INMO mould  
Danieli CoolRolls  
Danieli coolControl  
Optimum segment

**CONCLUSION**

Present marked conditions calls for optimisation of existing facilities instead of supporting the installation of new complete plants:  
In spite of budget restrictions, it is mandatory for existing slab casters to be put in line with the performances given by the new ones installed in recent booming market



years, particularly in developing countries, in order to guarantee plant competitiveness.

Aside overall caster revamping projects, limited investments can be considered to significantly improve existing casting facilities for plants that have not reached the end of their service life but are not equipped yet with the latest state of the art design features as well as , production and maintenance tools.

In order to assist his Customers, Danieli already developed a complete collection of proven solutions and technological mechanical plus automation packages as powerful tools to improve the performances of their casters.