DANIELI NEW TECHNOLOGIES IN THICK SLAB CASTING AND REFERENCE PLANTS[1]

ARCELOR MITTAL (DUNKERQUE, FRANCE) AND BAOSTEEL NR. 4 (SHANGHAI, P.R CHINA) NEW CASTERS

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Abstract

In recent years, the production of high quality steel at reduced transformation cost has become an issue of utmost importance for flat products steel producers, considering the booming of the market demand and the emerging of new competitors on the international market. In order to meet with increasing quality demands, world leading producers recently entered into major industrial projects involving either the installation new generation slab casters and the complete rebuilt of existing facilities in order to take advantage of the cutting edge technologies available. The strategies behind these huge investments are: Improvement of slab quality leading to virtually "defect free slabs" in order to allow 100 % hot charge in Hot strip mills, when allowed by metallurgy; Increase caster available time for production, thanks to fully automatic operations, advanced diagnostics, and maintenance free solutions; Improve caster overall yield, reducing off line grinding/scarfing operations and product downgrade. Danieli Davy Distington, the Danieli department in charge of the design and supply of slab casters, developed in close cooperation with his customers innovative equipment such as the patented INMO mould and OPTIMUM segments and perfected the application of advanced casting practices such as dynamic soft reduction, strongly contributing to the enhancement of the casing technology. These cutting edge solutions gave the possibility to Danieli to be selected in recent years as the supplier of some of the most technologically advanced slab casting plants in the world by, among others Posco, ThyssenKruppStahl, Baosteel and Arcelor Mittal. This paper describes these innovative tools and their application in most recent reference plants just simultaneously commissioned by Danieli during the month of December 2006 in Baosteel (P.R China) and Arcelor Mittal Dunkerque (France).

Key words: Slab; Caster; Quality; Productivity

[1] *Tecnhical contribution to XXXVIII Steelmaking Seminar – International, May 20th to 23rd, 2007, Belo Horizonte, MG, Brazil.*

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1 SOLLAC ATLANTIQUE, DUNKERQUE FRANCE, ARCELOR MITTAL GROUP. THE "MELTSHOP OF THE FUTURE" PROJECT

Sollac Atlantique plant, part of ARCELOR MITTAL group and located in Dunkerque, North France, is one of the largest integrated steel plants in Europe with a market leading position, prominent in the in the automotive sector.
The slab casting complex, has originally been conceived with 4 two strands machines, located in two separate melt shops.
Existing slab casters had been originally supplied in the seventies by Demag with the same design, with curved roll diagram and 10,5 meters radius.
In 2005 Arcelor management decided to enter in a comprehensive renovation project of all the casting complex with the following goals:

- Rearrange the production using 3 slab casters only instead of 4
- Increase plant capacity to about 7 Mtpy, by increasing casting speed and availability of the casters.
- Reduce caster production down times, got through a fully segmented design, the application of top feeding dummy bar practice and the use of a fully automatic robot-type segment manipulator for segment replacement.
- Increase the quality of slabs adopting new roll diagram concept, with special emphasis to IF grades for exposed automotive applications.
- Increase casters reliability thanks to advanced low maintenance design.
- Strongly reduce maintenance costs.

These goals, summarized by ARCELOR as the "acierie du future" (meltshop of the future) project, have been materialized by the decision to use for production 3 of the 4 existing slab casters, to be completely rebuilt according to the latest technologies & advanced roll diagram and the shut down of the fourth caster.
The complete revamping of 3 of the existing machines has been scheduled to be realized in following steps, one caster per year, in correspondence to blast furnace scheduled maintenance shut downs.
The overall caster rebuilt order has been awarded to Danieli on March 2006: the first machine to be modified is machine CC23, that just entered in production with the first heat cast on December 19th, 2006, the second (called machine CC 22) is at present under engineering phase (first heat foreseen for autumn 2007, while the third one (Called machine CC21) will be put in production in 2008.

2 GUIDELINES OF THE PROJECT

The overall project involves the complete demolition of the existing machines (only casting platform, supporting structures and discharge areas are conserved practically unchanged) with the installation of 3 new state of the art casting machines with renovated roll diagram and technological equipment.
Considering the extremely diversified product mix of the Dunkerque plant, Arcelor decided to "customize" caster roll diagrams in order to have the possibility to dedicate each of them to a specific product mix. These are the solutions considered:
Machines CC23 and machine CC21 will be mainly focused on IF grades for automotive applications, hence the caster roll diagram is transformed from curved to "vertical curved".
Machine CC22, on which High carbon grades for plate applications will be cast, will remain curved.

Danieli has been contracted as technological responsible for the project, supplier of all new mechanical equipment and automation technological packages, as well as responsible of the execution of the demolition and installation works.

3 CC23 MAIN DATA

The first machine to be completely rebuilt (CC23) has been stopped in August 16, 2006 and put back in operation again on december 19, 2006 with a record breacking shut down time that included demolition of old equipment, modification of civil works and installation of the new machine.
The new equipment include for the two strands: moulds, hydraulic oscillatots, all segments, segment supporting structure, segment manipulator (robot type), top feeding dummy bar equipment.
The start-up of the new caster has been practically flawless, already exceeding the contractual performances for production rump-up (20 heats per day) on Dec 28, having cast 23 heats in 24 hours after 10 days only from first heat: half of the time contractually foreseen for this production milestone.
The old machine was partially segmented, 10,5 mt in radious with mechanical oscillator technology, bottom feeding dummy bar, segment extraction by EOT cranes and guides, no soft reduction applied.
The new machine features a 2,2 meters vertical length, 8,2 meters main radius, 33 meters containment, Air mist/water secondary cooling system, and takes advantage of all Danieli cutting edge casting technologies including INMO mould and integrated hydraulic oscillation , OPTIMUM segments, robot-type segment removal manipulator and PRD (periferically drilled)rolls.
Furthermore it is and already designed for the application of dynamic soft reduction process and in mould electromagnetic flow control systems.
The main data are summarized in the following table.

Table 1. ARCELOR group SOLLAC Atlantique Dunkerque site - CC23 Twin strand slab caster main data after revamping

Type	Vertical curved machine, with top feeding dummy bar and segment manipulator
Main radius	8,2 m
Heat size	270 ton
Tundish capacity	48 ton
Nº of stands	2
Support length	33 m
Length of vertical section	2300 mm
Productivity	2.400.000 tpy
Slab width	890-1980 mm
Slab thickness	247 mm
Mould	INMO MOULD Vertical type Height 900 mm With adjustable width system during casting
Mould level control	Eddy current type level detector
Automatic Break out and sticking prediction system	Complete thermocouple array im mould with Thermal mapping
Oscillation - **Frequency** - **Stroke**	Hydraulicallyactuated 20÷300 cpm 0÷6 mm continuously adjustable
Steel grades	IF (automotive applications|) Low Carbon, Medium Carbon, Peritectic, HSLA
Secondary cooling	Air mist and water
Process	Static sof reduction: provision for future dynamic process with liquid pool prediction mathematical model Multipoint bending/unbending

The new vertical curved design has been designed with the main goal to substantially improve slab quality for IF grades for automotive exposed applications that will represent the main product niche targeted by this caster.
Vertical length and main radius has been selected as the optimum compromise between metallurgical needs of improved internal and surface quality and reduced modifications of existing equipment (casting platform and exist roller ways levels).

4 NEW BAOSTEEL NO. 4 SLAB CCM

On Jannuary 2005, Baosteel group, the leading Chinese steel macker , awarded Danieli the order for a new two strands slab caster for his Baosteel nr.4 plant in Shanghay (P.R.China).
The caster, has been succesfully started up with the first heat at 16:16 on the 16th December 2006.
Originally scheduled for start-up in May 2007, the new No.4 CCM twin-strand slab caster was successfully started 21 weeks ahead of schedule.

The Danieli Automation and Process Control systems enabled the 1st Cast to be carried out in full automatic operation, providing a stable and reliable platform for the caster to reach the 2,800,000-tonnes/year intended productivity coupled with 1st class quality.
Within the first 12 days of operation the caster had already produced 60 (300t size) Ladles, with the yield from each ladle optimised using Danieli's advanced tilting turret design.
A wide range of steel grades will be produced with a maximum casting speed of up to 2.2 m/min.
The two strands thick slab caster has been equipped with the very latest in advanced casting technology, including Danieli's patented INMO Mould with advanced mould width adjustment technology, advanced break out prevention system, Hydraulic Oscillation, Electromagnetic technology in mould, robot-type segment removal manipulator.
Machine roll diagram (vertical curved type with a vertical length exceeding 2,6 meters, continuos bending/unbending design and 9,5 meters main radius) has been specifically conceived for superior slab quality cast at high speed.
The twin strands machine features Danieli's Optimum Segment design, incorporating Dynamic Soft Reduction process with LPC model (Liquid Pool Control) from segment 1 to the end of the machine for maximum internal quality, Danieli's PDR cool roll technology for high production and machine reliability and ELTM Danieli's Element Life Time dynamic air mist spray control model for optimum surface quality.
The main features of the caster are summarized in the following table.

Table 2. Baosteel Iron & Steel group co. Ltd - twin strand slab caster nr.4 P.R. China main data

Type	Vertical curved machine with top feeding dummy bar and segment manipulator
Main radius	9,5 m
Heat size	295 ton
Tundish capacity	70 ton
Nº of stands	2
Support length	41,3 m
Casting speed	Up to 2.2 mt/min
Length of vertical section	2600 mm
Productivity	2.800.000 tpy
Slab width	900 -1750 mm
Slab thickness	230 mm
Mould	INMO MOULD Vertical type Height 900 mm All the moulds are equipped with adjustable width system during casting
Mould level control	Stopper rod, slide gate and Eddy current type level detector
Automatic Break out and sticking prediction system	Complete thermocouple array im mould with Thermal mapping
Oscillation - **Frequency** - **Stroke**	Hydraulicallyactuated 25÷400 cpm 2÷10 mm continuously adjustable
Steel grades	IF, Ultra Low Carbon, Low Carbon, Medium Carbon, Peritectic, Micro alloyed, HSLA, Triop steels
Secondary cooling	Air mist (dynamic control)
Process	Dynamic soft reduction with liquid pool prediction mathematical model Continuous bending/unbendig

5 INNOVATIVE TECHNOLOGIES FOR SUPERIOR SLAB CASTING

Among other features, the new Arcelor and Baosteel machines incorporate two of the most significant innovations developed by Danieli Davy Distington: the INMO mould (INTEGRAL MOTION mould) and the OPTIMUM segment.

5.1 INMO (INtegral MOuld) Design (Danieli Patent)

The INMO mould concept (INtegral MOtion mould) was originally developed by Danieli Davy Distington team together with POSCO Gwangyang technical team, in order to strongly improve the quality of the slabs produced in the existing casters as well as to reduce maintenance issues.

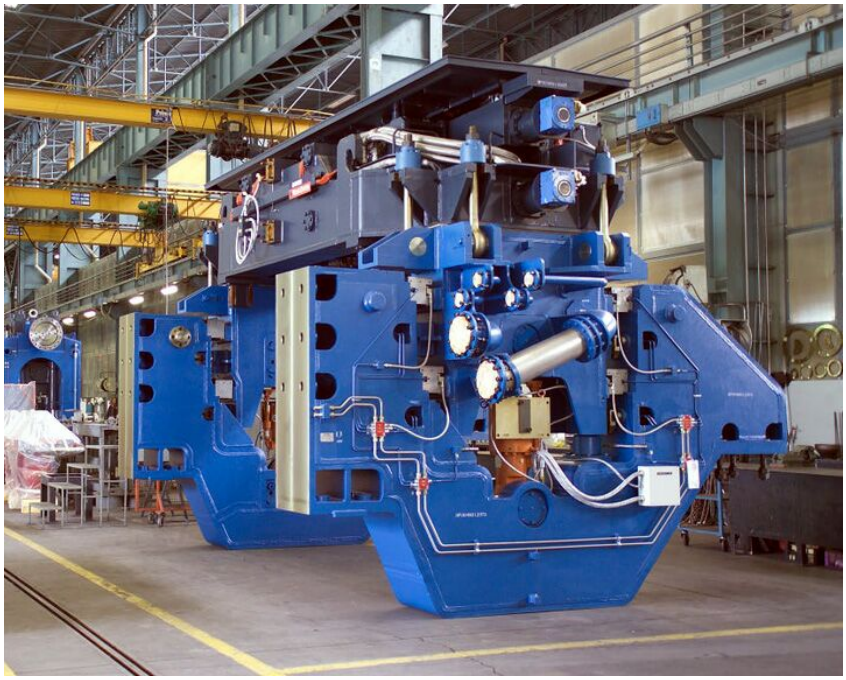

Figure 1: Integral Mould

5.2 INMO Mould Concept

The following features have been incorporated in the INMO concept, in order to get "the perfect mould":

- **5.2.1** Possibility to dynamically change the oscillation parameters according the real casting conditions (casting speed, metallurgical requirements, casting powders properties, etc.)

This is done in the INMO mould by means of HYDRAULIC OSCILLATION drive.

- **5.2.2** Strict control of the geometrical tolerances in the oscillating parameters (limit deviations from theoretical oscillation set in automation system).

This is achieved in INMO mould simplifying the cinematic chain between the oscillation drive (the hydraulic cylinder) and the oscillating mass (the mould movable frame).
No elastic links (es. springs) or parallelogram structure (as in short/long lever oscillators) are considered: the cylinder is directly acting on the oscillating mass of the mould.

- **5.2.3** Reduced maintenance and capability of the mould/oscillating system to keep the accuracy in the oscillating devices over time, without changing " wear parts " in charge of the guidance of the mould during the oscillation in order to recover their "deterioration" (es. uneven wear in bearings or modification of the elastic properties of springs impose to periodically exchange components).

This is achieved in INMO mould adopting a "friction free"(i.e "wear and maintenance free" device: the rolling element" in charge of the strict guidance of the mould.
"The driving device" of the oscillation is made by two hydraulic cylinders (synchronised in motion by means of redundant servo valves) located just below the

mould and directly driving the movable frame of the mould by means of vertically arranged push rods).
This strongly reduces the overall oscillating mass (i.e. reducing overall system inertia).
The motion of the mould (strictly vertical) is guaranteed by means of “rolling elements) acting as “frictionless rolling guides.

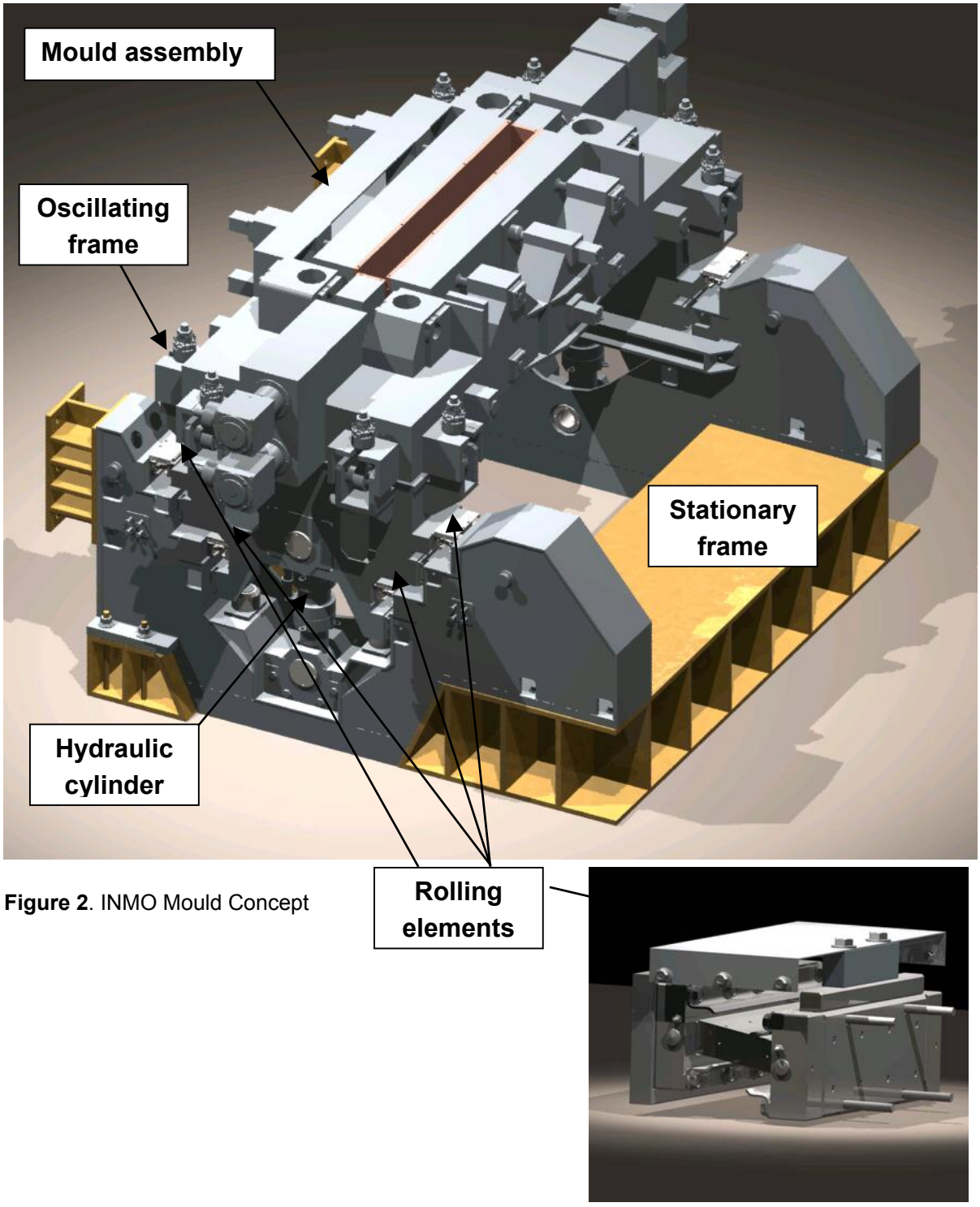

Figure 2. INMO Mould Concept

6 “ROLLING ELEMENT “ GUIDANCE SYSTEM

This peculiar and patented solution allows a precise guidance with the following features:

- Virtually No Friction: it means maintenance free equipment.
- No Inertia given by elastic components (springs): it means precise control of the oscillating parameters.
- Extremely tight guiding tolerances: it means higher slab surface quality.

Because there are no bearings or springs within the “rolling element” design, very accurate mould guidance can be achieved, which can be maintained over time as no wear actually occurs.

7 THE OPTIMUM SEGMENT

Thanks to his experience id supplying advanced slab casting equipment, starting from 1959 with the development of the first slab casters in the world, Danieli Davy Distington team developed a new generation segment, incorporating

- Robust design.
- Easy maintainability concepts.
- And advanced process oriented features specifically conceived for the application of today’s new casting practices, including dynamic soft reduction.

The main features of this new concept of segment are summarised in this name, acronym of:

- Operation Flexibility – Instant thickness changing and Easy segment removal.
- Product dimension control.
- Thickness changing without spacers or shims.
- Increased Production with minimum re-stranding times.
- Maximum Reliability – combined with maximum maintenance access.
- Ultimate Product Quality – With rigid strand support and Dynamic Soft reduction.
- Monitoring and detection of Liquid core End position.

The main features of the Optimum segment design are:

- Robust open ended design.
- Good maintenance access.
- No center guide post.
- No Link bar restricting access.
- Minimal Spherical joints.
- Can be fitted in bow, straightener and withdrawal areas of the caster.
- Hydraulic clamping of rolls.
- Independent Drive Roll Hydraulics.
- Possible to drive in reverse.

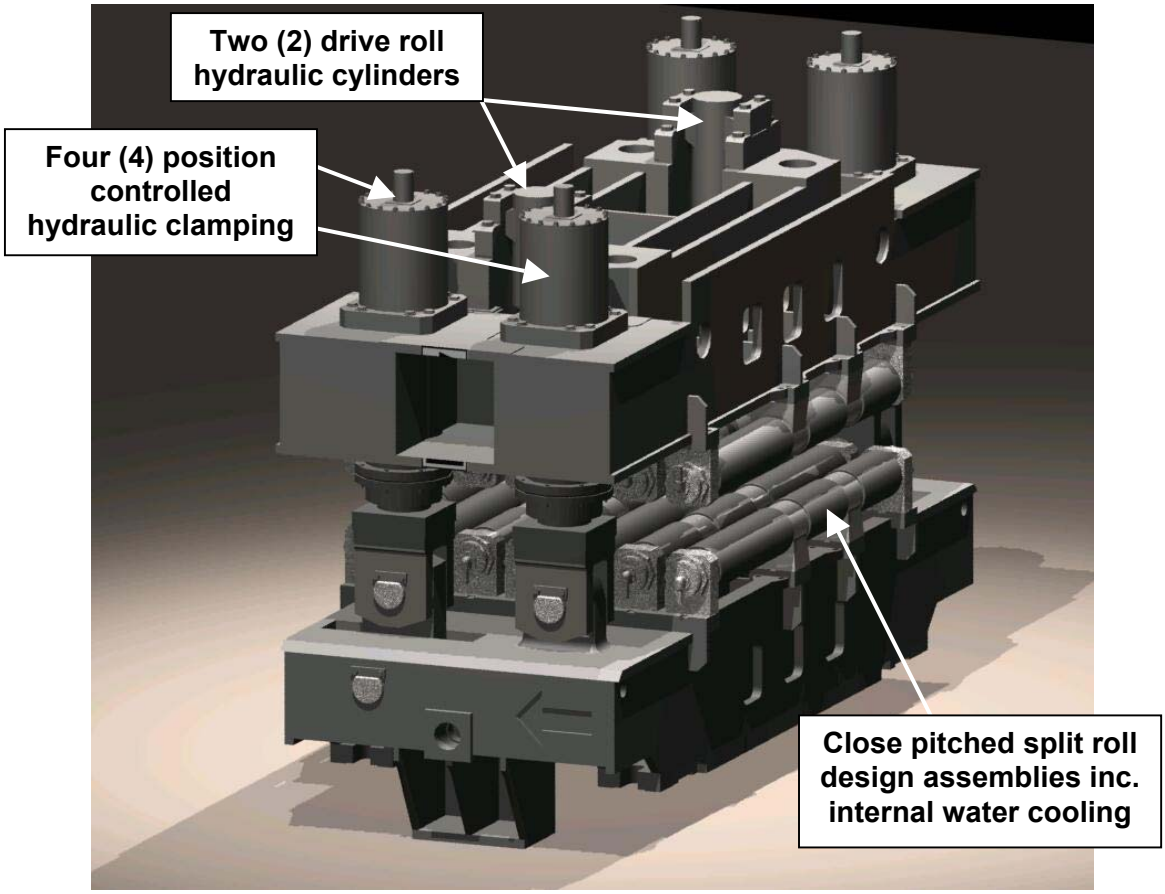

Figure 3. INMO Mould Concept

The segment bottom frame has 4 link rods, one at each corner of the segment. The two link rods at the entry side of the segment can pivot and also take all the shear forces in the casting direction. The two link rods on the outgoing side of the segment have a double-pinned link. The link allows the segment to expand and rotate about the fixed guide while maintaining a ridged-pinned frame.
The segment top frame is constrained by these link rods.
Movement of the top frame relative to the bottom frame is by the use of hydraulic cylinders.
Tilting from inlet side of the segments to the outlet side is necessary for line taper and soft reduction.

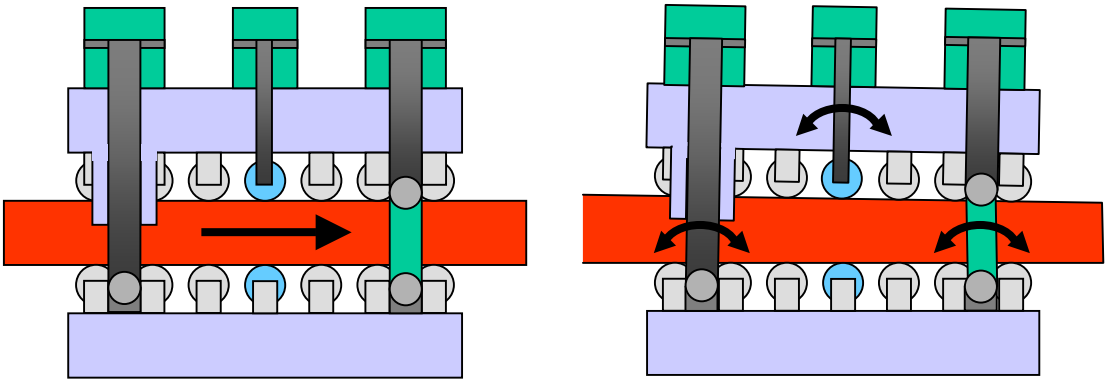

Figure 4. INMO Mould Concept

The top frame is connected to the bottom frame by link rods, which have spherical clevis mounts at the bottom frame.
The entry link rods set the entry gap of the segment and remains rigid and fixed. The exit section link rod has an additional link section and requires no guidance allowing taper and soft reduction gaps to be applied without friction and with total accuracy. The spherical connection also allows tilting in the transverse direction.

8 CONCLUSIONS

Thanks to the continuous development of new equipment , such as INMO mould and OPTIMUM segment Danieli Davy Distington has been selected as partner and supplier from some of the leading steel producers in the world for their new slab casters.
Thanks to his engineering and project management capabilities, Danieli has been able to successfully commission simultaneously in ARCELOR MITTAL Dunkerque, France) and BAOSTEEL (Shanghai, P.R.China) two of the most advanced casters in the world, with full satisfaction of Customers.
The two successful start ups, separated only by 3 days and followed by impressive production ramp-ups, testifies both the success of the joint development of the project in partnership with the Customers and the reliability of the equipment.