LATEST ADVANCEMENTS AND OPERATIONAL RESULTS IN CONTINUOUS SLAB CASTING

Heinz Hoedl (1)
Karl Mörwald (2)
Franz Humer (3)
Oliver Schulz (4)
Danilo Guzela (5)
Gustavo Morais (6)
Rubens Faco (7)

(1) Vice President Continuous Casting Technology, VAI
(2) Head of Research and Development Continuous Casting Technology, VAI
(3) Project Manager Continuous Casting Technology, VAI
(4) Product Manager Continuous Casting Technology, VAI
(4) Overall Commissioning Manager, Cosipa
(5) Commissioning Manager Caster, Cosipa
(6) Metallurgist, Cosipa

Abstract

Continuous casting of steel has nearly reached its saturation with approximately 80% continuous casting ratio worldwide. In order to cope with the high market requirements regarding

- product quality
- low operation and maintenance costs, and
- high plant availability

steel companies are forced to invest in new equipment and to consider new technologies to match with the changing market situation.

VAI has developed and successfully installed technological packages for the specific requirements of steel producers in order to meet above mentioned market demands. An overview of VAI’s latest status of technological solutions is given:

Advanced technological packages like the DYNAFLEX hydraulically actuated oscillator, the hydraulic width adjustable mold (HYDROWAM), the MoldEXPERT - a tool to ‘look into the mold’ -, and the new on-line thickness adjustable SMART segment with ASTC features (Automatic Strand Taper/Thickness Control) are presented.

On November 30, 2001, exactly 2 years after contract award the turnkey Continuous Casting Plant at Cosipa, Brazil was put into operation. The caster was quickly ramped up to a 3 shift operation within 2 weeks in mid December 2001. First operational results are discussed.
1. Introduction

Continuous casting of steel has nearly reached its saturation with approximately 80% continuous casting ratio worldwide. In order to cope with the high market requirements regarding

- product quality
- low operation and maintenance costs, and
- high plant availability

steel companies are forced to invest in new equipment and to consider new technologies to match with the changing market situation.

VAI has developed and successfully installed technological packages for the specific requirements of steel producers in order to meet above mentioned market demands. An overview of VAI’s latest status of technological solutions is given.

2. Technological Packages

2.1. VAI High Performance Mold

The heart of the continuous casting process is the mold where the new shell is formed and surface quality is generated. The VAI high performance mold (figure 2) not only provides an optimized support for the newly formed shell but also a greater uniformity of cooling for a smooth shell growth.

![VAI High Performance Mold](image)

Each of the copper plates is fixed to a stiff cassette which is mounted to the mold support frame. This rapid exchange cassette reduces the mold turn-around time by more than 50%, thus the size of the mold fleet can be optimized.

The mold is a low mass unit which in turn improves the performance of the mold oscillation.
2.2. HYDROWAM

Within the mold a new package for hydraulic mold width change (2,3)

Hydraulic Width Adjustment Mold – HYDROWAM (figure 3) provides a compact system which has the capability for fast and precise mold width change during casting and also because of its compact nature gives an ideal upgrading package solution for existing molds.

![HYDROWAM mold](image)

HYDROWAM mold hydraulic width adjustment uses compact hydraulic cylinders directly coupled to the mold narrow face assemblies, thus minimizing backlash in the system.

HYDROWAM provides precision accuracy of adjustment that can be combined, if required, with high adjustment speeds and large width changes. The precision is achieved using standard hydraulic components, so maintenance is straightforward. Each mold includes its own individual hydraulic narrow face drives so the molds can be fully set up and tested in the workshop in order to minimise on-line maintenance.

The first HYDROWAM was installed at SSAB Luleå in 2000 and to date 32 HYDROWAM units have been installed or are being supplied.

2.3. DIAFACE

A DIAFACE profile can be incorporated in the mold narrow faces combining the ideal parabolic taper with a unique edge profile thereby reducing shell friction and achieving a homogeneous shell profile.

Uneven shell growth in the corners of the narrow faces of the slab often results in subsurface cracking particularly for plate grades.

The shrinkage of the mold is higher in the upper portion; but if the narrow face taper is strong to compensate the natural shrinkage in the lower part of the mold, pressure peaks occur in the corner areas.

In order to more closely follow the natural shrinkage of the shell VAI have applied the well proven DIAMOLD billet mold technology to slab casting in the form of the DIAFACE design. This provides a high taper in the upper part to compensate for the initial natural shrinkage and a reduced taper in the corner area in the lower part.
Plant trials have demonstrated a reduction in mold friction stress by approximately 12%, reducing excessive friction forces at the lower end of the narrow faces.

2.4. **DYNAFLEX Hydraulic Oscillation**

Mold oscillation greatly influences cast product quality and productivity through effective strand lubrication at high casting speeds. Online stroke and frequency adjustment as well as sinusoidal and non-sinusoidal oscillation can reasonably be achieved only by hydraulic drive systems. A stiff and rigid frame design prevents harmonics and resonances over the entire operating range (figure 3).

The hydraulic oscillator utilizes two hydraulic cylinders directly introducing the oscillating motion into the mold. There are no lever arms, bearings or bushings required, thus avoiding wear or unwanted high frequency resonance. Precision guidance with minimum mold displacement in lateral directions is achieved by wear-free leaf springs. VAI have used leaf spring guidance for lever based mold oscillators since 1986 and for Dynaflex hydraulic oscillators since 1995. Not a single problem has been reported from the large number of reference plants and most plants never ever changed the leaf springs.

Inverse Oscillation
Upon start of casting a short stroke / high frequency practice is used to minimize oscillation mark depth. The oscillation allows control of powder consumption, important for operation reliability and quality. With increasing casting speed the stroke is increased and the frequency reduced according to preset constants. This keeps the negative strip time constantly low for shallow oscillation marks, but increases the positive strip time simultaneously to enhance powder consumption and to reduce sticking tendency.

2.5. **MoldEXPERT**

To achieve the best performance from the various units of the machine head contributing to primary solidification, it is decisive to understand the underlying process, to monitor and
analyse the information pertinent to the process. MoldEXPERT is a tool to provide this important insight into the mold. (6)

The heart of the MoldEXPERT is the acquisition of data, data processing and communication to the environment (figure 4).

The MoldEXPERT comprises key sub packages like the Thermal Package and the Oscillation Package.

2.6. Spray Cooling Control

Dynamic spray cooling is a prerequisite for optimized surface at transient casting conditions. VAI differentiates and offers three levels of dynamic cooling packages – see figure 5.

DYNASPEED and DYNASHELL are more traditional dynamic spray cooling control packages based on casting speed history. DYNACS® is the most sophisticated package continuously calculating the enthalpy of the strand, its temperature profile as well as the shell characteristics. DYNACS® is therefore a suitable platform for dynamic soft reduction. (7)

2.7. SMART (SMART® Segments and ASTC)

In their simplest mode of operation, SMART® segments provide remote, rapid thickness change capability.
The standard VAI segments are easily adaptable to SMART® segments (Single Minute Adjustment during/without Restranding Time). The first full strand implementation of SMART® segments was at Rautaruukki in December 1997 (8).

The latest state of the art SMART® segment design is shown in Fig. 6. The major advantage of the new segment is the maintenance friendly 4 cylinder design for clamping and gap control with only 1 cylinder for the adjustable driven roller.

![Figure 6 SMART® segment](image)

This unique segment type combines:
- Rigid strand support and divided rolls
- Accessible lateral design allowing minor maintenance activities on-line
- All cylinders and sensitive equipment are above the segment and remote from direct heat

In combination with the thermal tracking module of VAI’s DYNACS® dynamic secondary cooling model and ASTC (Automatic Strand Taper/Thickness Control) system, (9) SMART® segments ensure a dynamically optimized adjustment of the roller gap profile. An optimized gap profile is specifically important during transient casting conditions (Figure 7). The thermal tracking module of DYNACS® determines the point of final solidification and the position of the required solid fraction dependent on current casting conditions. The ASTC system and SMART® segments then automatically readjust setpoints for optimum roller gap taper.
3. First Results of the 2-Strand Slab Caster CC 4 at COSIPA

On December 01, 1999, VAI was awarded a contract from COSIPA (Companhia Siderurgica Paulista) / Brazil for the delivery of a 2 – strand slab caster as part of the turnkey expansion of their existing No.2 Steelmaking plant. The 2 strand slab caster comprises the caster bay, a machine- and tundish maintenance and a slab yard with inspection and scarfing area. Main targets of the installation are the
  ➢ Increase of production
  ➢ Improvement of product quality standard by implementing a continuous bending and straightening curve according to the VAI patent, small roller pitches and intermediately supported rollers.
  ➢ Increase of flexibility to serve both the strip mill and plate mill.

On November 30, 2001, exactly 2 years after award of the contract and 2 weeks ahead of the contractual project time schedule the turnkey Continuous Casting Plant was successfully put into operation.

3.1. Design Features and Layout

- Heat size: 160 t
- Productivity: 2.4 Mio tpy
- No. of strands: 2
- Radius: 8 m
- Length of containment: 31.8 m
- Slab thickness: 210 / 260 mm
- Slab width: 750–1900 mm

Figure 7 Overview over the ASTC system

Figure 8 Layout of the COSIPA 2-strand slab caster
3.2. Main Technical Features and Installed Technological Packages

- Type of ladle support: Butterfly turret with independent lift/lowerable C-type arms
- Type of tundish support: 2 gantry type cars
- Tundish content: 50 t nominal
- Steel flow control: Tundish stopper system with automatic mold level control
- Mold: Straight cassette type, 900 mm length, automatic width adjustment with 4 motor drives and future installation of EMBR
- MoldExpert
- Oscillator: DYNAFLEX hydraulic oscillator (on-line stroke, frequency and wave pattern adjustment)
- Containment: 1 bender segment, 5 bow segments, 2 straightener segments and 6 horizontal segments. Segments designed for future “SMART®/ASTC conversion”
- Roller design: Bow segments: 2 divided solid roller. Straightener and horizontal segments: I-STAR Roller (Intermediately Supported Trans-Axle rollers)
- Runout facilities: 2 on-line torch cutting machines, spray marker, deburrer, weighing device, pusher andpiler table.
- Secondary cooling: Dynamic Secondary Cooling System (DYNACS®), 7 zones with air mist cooling
- Dummy bar system: Top feeding

3.3. Start-Up

Figure 9 Start up

- Right from the start of the first heat the plant operated in fully automatic mode including level 2.
- Inverse oscillation mode for DYNAFLEX Oscillator
- DYNACS® secondary cooling system
- Automatic dummy bar disconnection

With the start up the plant was handed over to Cosipa for commencement of commercial production. The caster was quickly ramped up to a 3 shift operation within 2 weeks in mid December. On December 28, 2001, three weeks ahead of the project time schedule the certificate RPT (Readiness for Performance Testing) was handed over by Cosipa due to the excellent performance of the new twin strand caster.
The first weeks of production mainly concentrated on low carbon grades. The corresponding product mix is given Figure 10.

Figure 10 Product Mix

3.4. First Operational Results

The performance guarantees for the low carbon grades have been demonstrated immediately after issuing the RPT certificate in the first week of January.

The tapered casting gap provides excellent centre line segregations: step 0.5 of Nippon Steel Corporation Standard was never exceeded on any sulphur print.

The combination of DYNACS dynamic secondary cooling strategies and inverse oscillation by means of the DYNAFLEX oscillator ensure excellent surface quality over the whole casting speed range up to 1.8m/min.

On line width adjustment with some 30 adjustments over the first 5 weeks of operation provides Cosipa a high flexibility in production planning and logistics.

As a consequence Cosipa has already decided in begin January 2002 to release the production of the new 2-strand caster for hot charging. The VAI-Q quality assurance system of the level 2 automation supports Cosipa’s disposition and hot charging management.
4. **Summary**

Whether a new plant is to be installed or an existing slab caster upgraded the needs are the same – to realise excellent product quality at high rates of productivity, based on the most reliable equipment and systems, built and operated at low costs. VAI’s technology packages are designed and have been proven to meet these needs. A number of the packages are described together with examples of their realisation at operating plants. The full range of packages provide the essential basis for tailor made solutions for new casters or caster revamp projects.

5. **References**


2) T. Haraldson, K. Pirner and H. Eidinger; “SSAB Tunnplåt – DYNAFLEX Oscillator and Hydraulic Width Adjustable Mold”; 8th Int. Cont. Casting Conference 2000; Linz, Austria

3) J. Molnar, H. Fuerhofer and K. Moerwald; “Package Units for Caster Upgrading”; 8th Int. Cont. Casting Conference 2000; Linz, Austria

4) J. Watzinger, etc.; “Applied Process Simulation Techniques in VAI’s Continuous Casting Technology”; AISE 2000 Chicago

5) K. Moerwald; “From Innovative Ideas to the Successful Implementation of New Technologies”; 8th Int. Cont. Casting Conference 2000; Linz, Austria

6) O. Lang, etc.; “The MoldEXPERT of VAI – A Mold Monitoring System for Best Casting Performance”; 8th Int. Cont. Casting Conference; Linz, Austria

7) H Hoedl, A Eichinger and K Moerwald; Advanced Upgrading Concepts for Slab Casters; 3rd European Conference on Continuous Casting 1998; Madrid

8) M. Jauhola, etc.; “Basic Start Up of Rautaruukki’s CC No. 6”; 3rd European Conference on Continuous Casting 1998; Madrid

9) C. Federspiel, etc.; “ASTC – VAI’s Automatic Strand Taper / Thickness Control System”; 8th Int. Cont. Casting Conference 2000; Linz, Austria