Stahl

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METEC Congress 99

International Conference on New Developments in Metallurgical Process Technology

METEC 99

Proceedings

Düsseldorf, June 13–15, 1999

Summary

von Moos Stahl AG, a member of Swiss Steel Group AG, took the bold step to replace its existing four-strand caster with a new three-strand SBQ caster with the aim to improve quality and productivity and, in addition, to venture into new value-added products. The following paper describes the main aspects of the project. Production and quality results, which have met all expectations, are presented for the first months of operation.

1. INTRODUCTION

von Moos Stahl AG has a long history in the development of continuous casting process. In 1956 the von Moos`sche Eisenwerke / Lucerne filed a patent for a curved mould and granted the licence for worldwide marketing of it to Concast AG / Zürich .

With the new in 1998 installed SBQ-billet caster this tradition will be continued with respect to the production of high quality continuous cast products.

Today von Moos Stahl AG is a member of the Swiss Steel Group which has been formed mainly by the von Moos group and the steel division of the von Roll group. Both companies can look back to a long tradition of steelmaking; as a matter of fact it reaches back to the beginning of industrial steel production 150 years ago.
On top of the newly formed Swiss Steel Group firms the stock enrolled company Swiss Steel AG (**Fig. 1**)

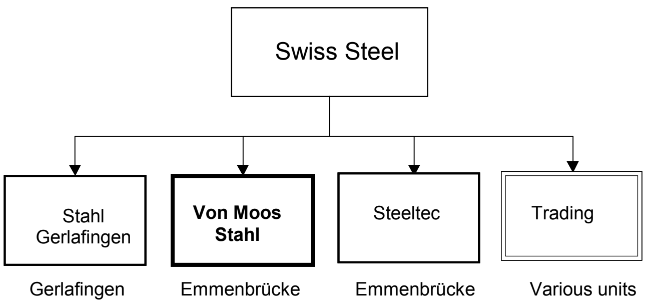

Fig. 1: Organisation of Swiss Steel AG

Its activities in the core business sector of steel are divided into three independent companies. Each of these 'centres of competence' has its own very specific focus, based on an integrated chain of value-added activities. This strategy is reflected in the large variety of finished products produced by Swiss Steel AG:

Stahl Gerlafingen AG
Center of competence for the production and sales of constructional steels, as well as steel-mats, mainly for the Swiss construction industry (buildings and civil works) and for machine construction (600,000 tpy capacity).

Von Moos Stahl AG
Center of competence for the production and sales of quality, special and free-cutting steels, primarily for automotive companies, their sub-suppliers, and the engineering industry in Switzerland and Europe (400,000 tpy capacity).

Steeltec AG
Center of competence for the production and sales of bright-drawn steel-bars, including conditioned bars and special parts for the automotive, machine-building and engineering industries in Switzerland and Europe (80,000 tpy capacity).

Trading
Another division part of the company covers trading activities, e.g., regional trade in steel, ironware and building materials, as well as the national and international trade for fastening elements.

The locations of the various production units in Switzerland are shown in **Fig. 2**: Gerlafingen (steel plant, rolling mill and steel-mat production facility) and Emmenbrücke/Lucerne) (steel plant, rolling mill and bright drawing plant. Both works are based 100% on the use of recycled scrap as the raw material.

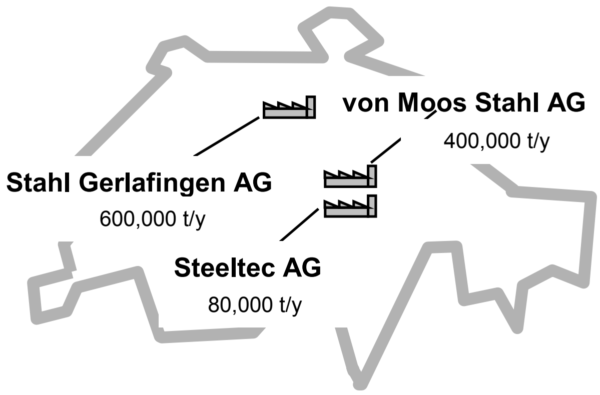

Fig. 2: Production sites of Swiss Steel in Switzerland

2. THE STEEL PLANT AT VON MOOS STAHL

The Emmenbrücke steel plant of von Moos Stahl AG operates a 60 MVA (70 t) AC electric arc furnace and a 15 MVA ladle furnace with a capacity of 350,000 tons/year. Secondary metallurgy is optimized for the product mix and for clean-steel technology that comprises pre-deoxidation and dedicated synthetic slag-fluxing optimized for each steel-grade. Further treatment in the ladle furnace includes inert gas purging, heating, main alloying, slag-conditioning, micro-alloying, calcium treatment and subsequent cleansing (soft bubbling). Purging is performed by an eccentrically mounted bottom purging brick.

Alloys are added by a feeding system from bunkers and by a six-line wire-feeder for fine adjustments. Casting was performed on a four-strand billet caster through September

1998, and was then transferred to a new three-strand Convex® billet caster. The 130-mm-square billets are then fed into a 20-stand wire-rod mill with a d wire block in order to produce straight and coiled bars or wire. A schematic of the production route is shown in **Fig. 3**.

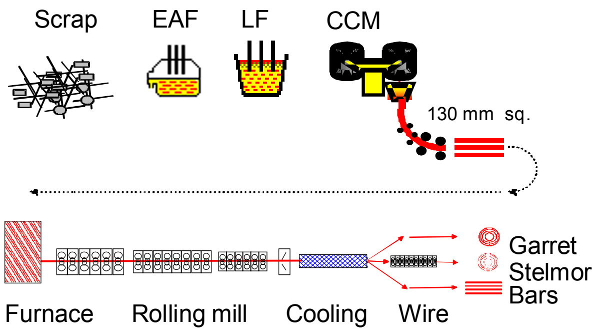

Fig. 3: Schematic of production at von Moos Stahl

3. PRODUCT MIX

The so-called QEA concept of von Moos Stahl AG, as outlined above, is to produce special steels (quality, special and free-cutting steels = QEA in German). The new billet caster is the key process-step to achieve this target, which requires meeting the ever-increasing demands of clients regarding the quality of delivered products. Within one year a dramatic shift took place from commercial to special steels. In 1997, 56.7% of production was commercial steel. This was reduced within a year to 27%, with a corresponding increase in special steels to 73%. An overview of the product mix is outlined in **Fig. 4**.

	1997	1998
Constructional steels	14%	13%
Quality steels	12%	16%
Special steels, unalloyed	9%	14%
Special steels, low alloyed	6%	9%
Free cutting steels	20%	22%
High strength special steels	7%	9%
Reinforcing bars	32%	17%

Fig. 4: Product mix for 1997 and 1998

With lot sizes of 100 to 1000 tons per year, the von Moos QEA concept is aimed at niche products, mainly supplying drawing, peeling and cold-heading facilities. The range of grades is quite broad from constructional to free-cutting steels, also comprising unalloyed and alloyed steels. Basically all the steel grades comply with DIN or EN standards, however there are some micro-alloyed specialities that are customised for the particular requirements of clients. The amount of steels for automotive application is approximately 50%.

4. CONTINUOUS BILLET CASTING AT VON MOOS STAHL AG

The first machine, a one-strand vertical / solid bending caster, was ordered from Concast AG Zurich in 1956 and commissioned in 1959. Heats of 15 tons were cast into billets of 83- and 115-mm-square on this machine, which had a 2.4-m bending radius.

A pilot plant with curved mould, developed by Dr. E. Schneckenburger and Mr. C. Küng, produced its first billets on March 6, 1963. This was the birth of the landmark Model S-type casters that significantly spurred worldwide acceptance of continuous casting technology.
In 1970 a new 70-ton EAF was installed together with a 4-strand 4-meter radius Model S caster having the section range of 80 to 130 mm square. This caster was revamped in 1987, the beginning of the change towards value-added products, implementing submerged pouring technology (tundish slide gates), electromagnetic mould stirring and multi-point unbending.
In September 1997 Concast Standard AG was awarded the order for a turnkey contract to design and install a new high productivity SBQ billet caster. Besides the casting machines, the contract included buildings, cranes, water treatment and media supply and overall project responsibility (**Fig. 5**).

Fig. 5: View of the caster

Main features of the three-strand (8-m radius) caster include:

- Ladle turret with lifting/lowering, weighing, ladle cover manipulator
- Two semi-gantry type tundish cars with lifting/ lowering, weighing
- T-shaped tundish with optimised design for flow-pattern, 13.5 tons capacity
- Casting systems:
  - Open metering with or without bellows-type gas shroud for constructional steels (Si-killed)

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- Submerged pouring by electromechanically activated tundish stopper control for special steels (Al-, Al / Si-killed)

- Cartridge-type Convex® moulds
- Radiometric mould level control
- Externally mounted electromagnetic mould stirrers
- Precision oscillation system (300 cpm)
- Dynamic secondary cooling
- Concast continuous straightening system
- Strand insulation/equalisation tunnels before, within and after withdrawal/straightening units
- Rigid dummy bar system
- Diagonal hydraulic shears with sample-cutting facility

A sophisticated state-of-the-art automation system (Level 1 and Level 2) monitors and controls all machine activities and all casting process parameters (**Fig. 6**).

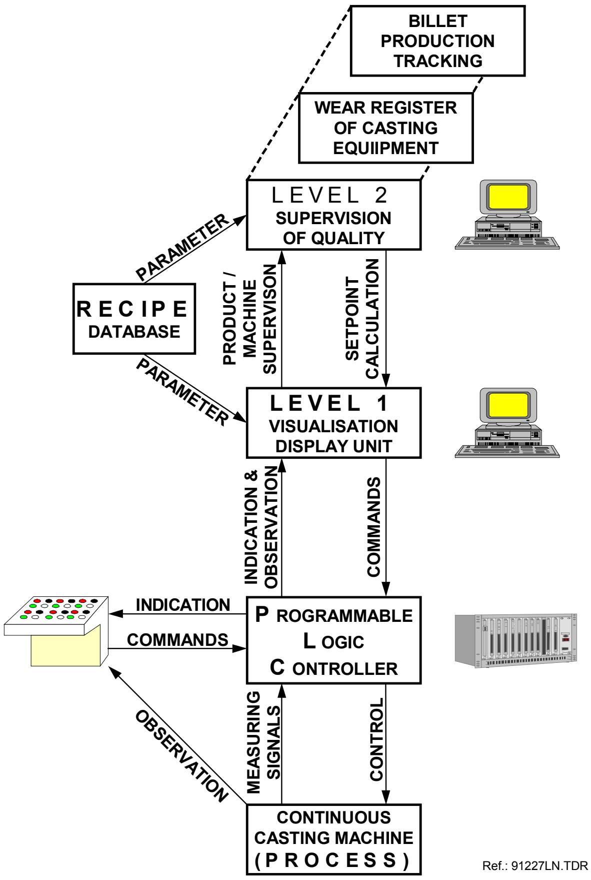

Fig. 6: Automation schematic of the SBQ billet caster

The Level 1 system (PLC plus visualization) is the primary system to control the casting process and serves as the interface between operator and machine.

All relevant metallurgical and machine parameters are stored in a recipe system. This stand-alone program is accessible from both Level 1 and Level 2.

The Level 2 system features the following functions:

- Supervision of product quality: any event or any significant deviation from established parameters that could lead to a quality defect is monitored and allocated to the exact relevant position within the billet length. This tool enables operators responsible for quality control to make decisions for further processing with high accuracy.

- Registration, tracking and summarising of wear or life-time of machine components and operational spares

- Production tracking in conjunction with billet identification

- Reporting system: generates various reports for quality assurance, productivity and management purposes

- Parameter set-point calculations according to specific algorithms
- Communication with other computers or networks within the steel plant (Level 3, Host, etc.).

5. OPERATIONAL EXPERIENCES

5.1 Productivity

Fig. 7 shows the start-up curve in terms of production for the new caster at von Moos Stahl. The target capacity was reached after two months, with a product mix of greater sophistication and complexity than originally foreseen. Four months after start-up, an even higher production rate (expressed in tons per hour) was attained, producing the full QEA steel grade spectrum of von Moos Stahl AG.

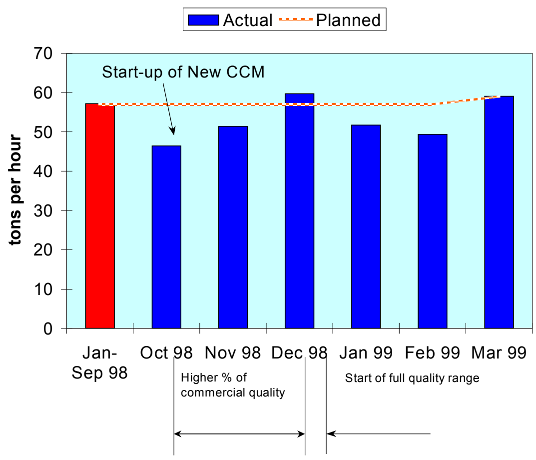

Fig. 7: Start-up productivity of the new billet caster

One of the big advantages of the new caster is the large range of casting speeds, up to even 3.8 m/min. for some particular steel grades. This allows all grades to be run at least at the same speed, presently 3.2 m/min, and results in great flexibility for production planning and furnace coordination. with great potential for future increases in productivity.

5.2 Product Quality Control

The aim of the new casting facility at von Moos Stahl AG was to maintain the existing, already quite high, quality levels of the old caster as a first step, and secondly, to increase quality levels step-by-step. To achieve this end, a considerable amount of quality testing and checking was methodically planned and performed.

Samples were taken from the beginning, middle and end of each strand and, after shotblasting, visually inspected for:

- oscillation marks: appearance and depth
- laps, double-skins
- pores, pinholes
- dimensional accuracy (rhombus, size).

Billet-slice samples were checked after preparation (macro-etching) for:

- micro- and macroscopic cleanness
- internal cracks
- surface pores
- center cavities
- center porosity
- amount of equi-axial (globular) structure
- amount and pattern of sulphide distribution (assessed by utilising K-4 values)
- type of sulphides

5.3 Surface Quality

With the new caster a wide range of steel grades can already be produced, achieving the same good billet surface quality in comparison to the old one (**Fig. 8**).

The old caster was using tundish slide gates and submerged entry shrouds (SES); whereas the new caster operates with electromechanically actuated tundish stoppers and monobloc submerged entry nozzles (SEN). **Fig. 9** shows the principal difference in terms of the negative pressure within the flow channel for the two systems.

The SES approach can allow air to enter the flow channel, whereas the monobloc SEN is effectively airtight. This fundamental design weakness of the SES has several negative consequences:

- Inconsistent flow resulting in bath-level perturbations leading to mould-powder entrapments and, thus, surface defects on the rolled product or deterioration of cleanness
- Air in the flow channel can lead to increased pinhole formation (e.g., in resulphurized grades) or macro-inclusions for aluminium-killed steels.

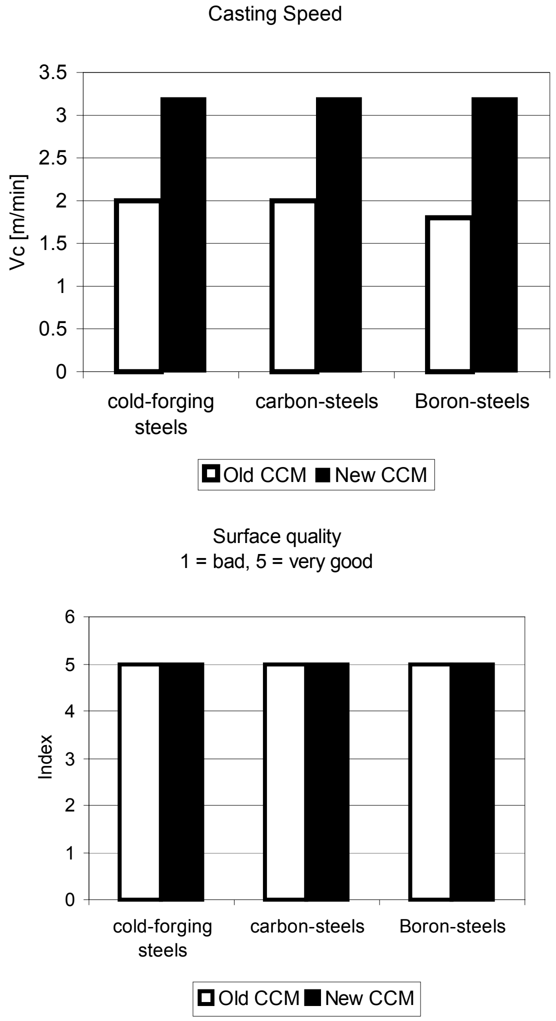

Fig. 8: Casting speed and surface quality for the old and the new caster

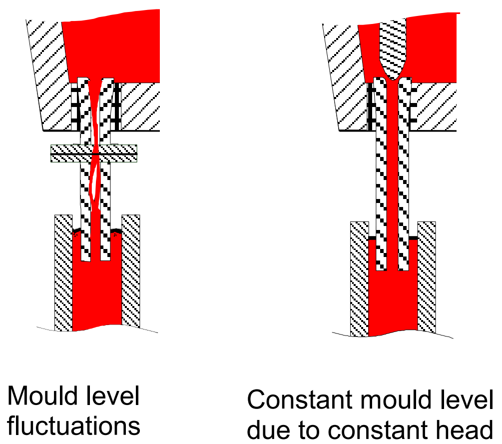

Fig. 9: Advantages of stopper-controlled tundish flow compared to slide gate control

The improvement realized with stopper-controlled tundish flow, as compared to the slide gate control, is quite dramatic (**Fig. 10**).

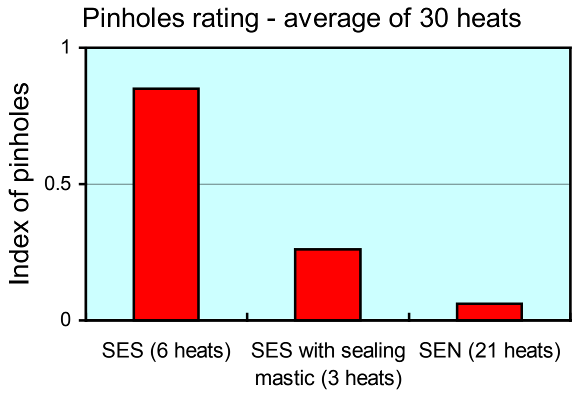

Fig. 10: Pinhole / pore formation for various casting systems

Another possibility to improve internal cleanness is the optimisation of the flow pattern inside the tundish. For this purpose extensive water modeling, on an 1:1 scale, was performed at the Swiss Federal Institute of Technology in Zurich (ETH) /2/. **Fig. 11** shows the principle design of the tundish and its simulated construction in plexiglass. For flow-pattern optimisation, the tundish was divided into imaginary "units":

- turbulent flow brake zone
- plug flow zone
- inactive zone.

The tasks of this optimisation activity included:

- minimizing inactive zones
- optimizing the plug flow for best inclusion flotation eliminating by-pass flows.

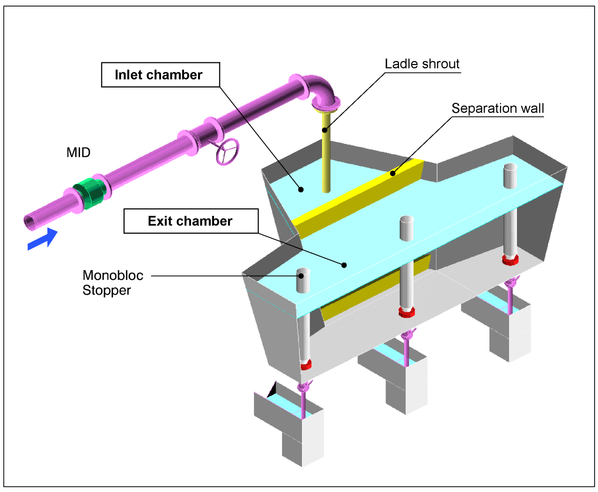

Fig. 11: Tundish water modelling

Despite the much larger volume of the new tundish, it was possible to achieve an assimilation in terms of analysis of two-sequence heats in a steel volume which is 25% smaller (**Fig. 12**). This is an indication that the mixing zone of the new tundish has been reduced compared to the old one, while at the same time the targeted plug flow in the exit chamber has largely been realized.

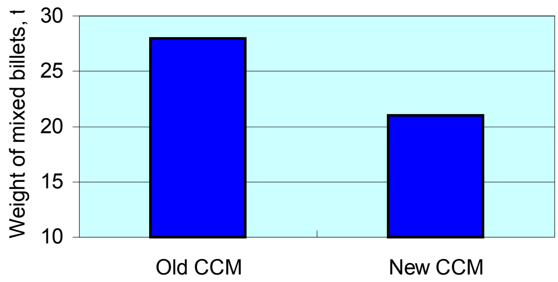

Fig. 12: Influence of optimised tundish flow pattern on mixed billets

5.4 Equi-axial (Globular) Structure

Fig. 13 represents the equi-axial zone in the billet centre for the steel grade family 16MnCrS5 and shows an increase of approximately 35% for the new caster over the whole tundish superheat region.

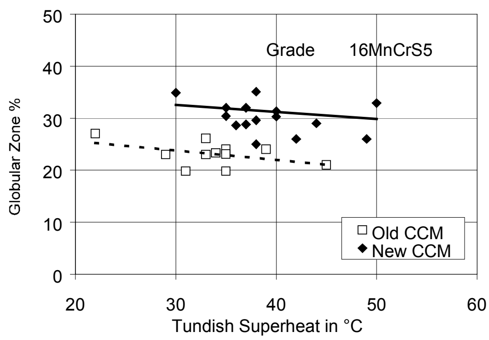

Fig. 13: Amount of equi-axial (globular) structure

A possible explanation of this behavior is the high heat transfer of the Convex® mould (on average +25%), the improved electromechanical mould stirring system (power and coil position) and the sophisticated secondary cooling. On top of this the globular zone also exhibits improved symmetry (**Fig. 14**). The relationship of the area F_o above the symmetry axis to F_u, the one below it, nears the ideal value of 1. Symmetry, as well as the amount of the equi-axial structure, may be further improved by lowering the tundish superheat step-by-step.

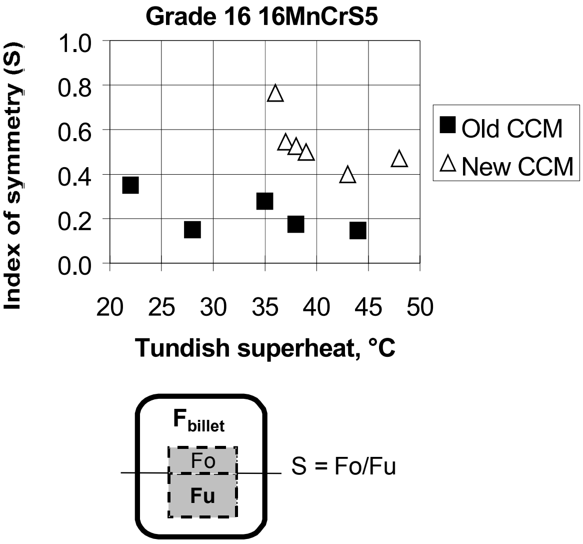

Fig. 14: Symmetry of equi-axial (globular) zone

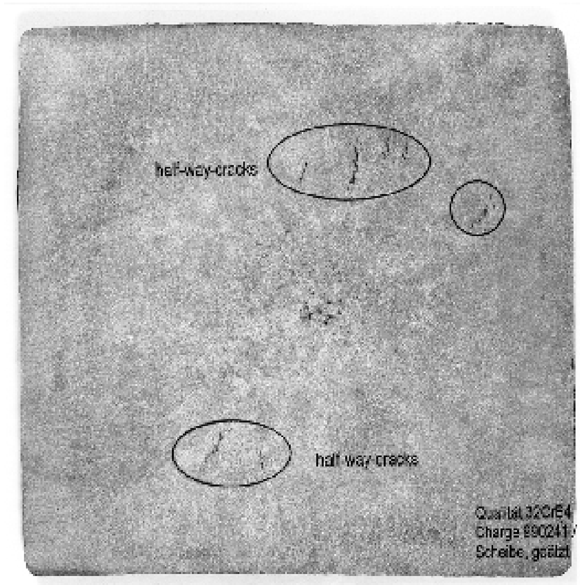

Fig. 16: Halfway cracks

5.5 Segregation

For the range of <0.40% Carbon, the tendency for C-segregation to diminish is pertinent for the new caster. For 0.40% C and above, there are no significant differences. Regarding sulphur segregation, there is no detectable difference **(Fig. 15).**

Beside strand-shell thickness, **Fig. 17** (lighter line) shows the computed course of the strand surface temperature and the strand center temperature as a function of the solidification length for cases with increased half-way cracking. Due to their position, it was concluded that reheating after a 5-m casting length was the primary reason. An unfavorable Mn/S ratio (inherent to most re-sulphurized steels) may also contribute /4/.

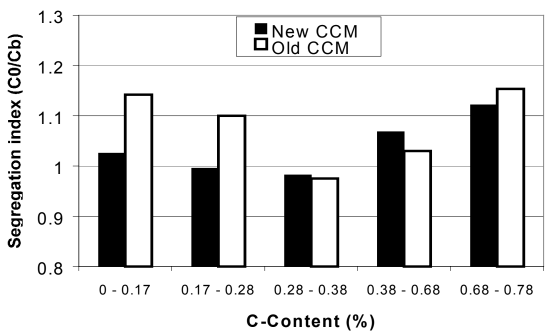

Fig. 15: Segregation comparison

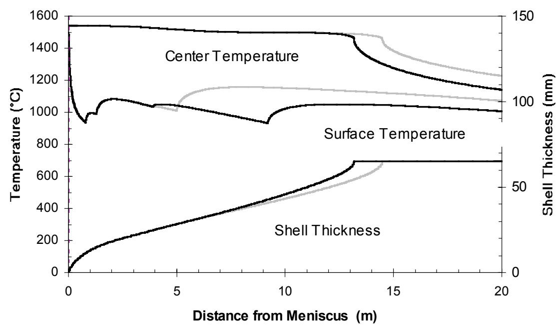

Fig. 17: Optimised strand temperatures for the surface and core

5.6 Halfway Cracks

During early commissioning, halfway cracks were experienced, e.g. for some Boron steels like 30MnB3. **Fig. 16** shows the typical appearance of these cracks. As a first measure, the influence of electromechanical stirrer (EMS) was investigated.

Both stirred and non-stirred material exhibited these cracks on the inside and the outside radii, but the non-stirred cases were coarser and longer compared to very fine and more "networked" cracks for the stirred material.

Two measures to counteract the halfway cracks were implemented:

a) Investigation of Mn/S Ratio

In principle, an already very low S-content can result in quite pronounced embrittlement. The adjustment of the Mn/S ratio influences this phenomenon, which was investigated by correlating the Mn/S-ratio with the appearance of halfway cracks under consideration of tundish superheat and secondary cooling patterns. The findings correlate with the statement in /4/ that above an Mn/S-ratio of 100, the ductility approaches 100% (**Figs. 18, 19**).

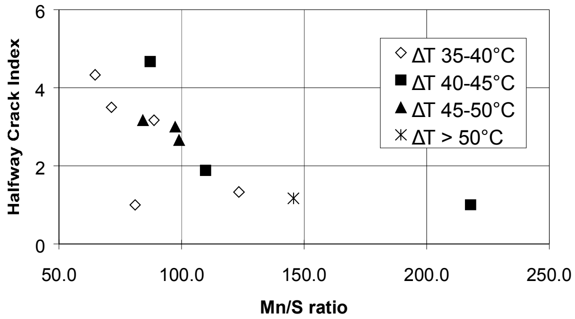

Fig. 18: Influence of Mn/S Ratio on halfway crack formation for steel 32CrB4

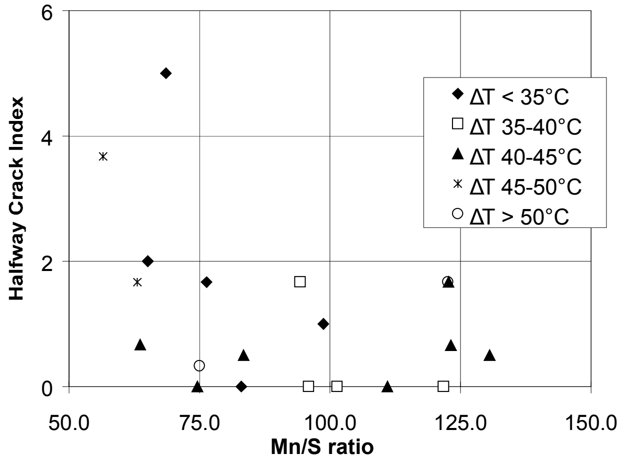

Fig. 19: Influence of Mn/S-Ratio on halfway crack formation for steel 30 MnB3

b) Modified Secondary Cooling Pattern

As a further consequence, a surface and core temperature pattern has been computed (Fig. 17, darker curve), which resulted in the following change of reheating (at the same super-heats):

- It was shifted from 5 to 9.3 m solidification length
- The amount was reduced from 141 to 113 °C

Consequently, the critical area for halfway cracks has been shifted to lower temperature regions close to the straightening zone.

After implementing the new secondary cooling curves, the halfway cracks could be completely eliminated, e.g. for 32CrB4 (**Fig. 20**).

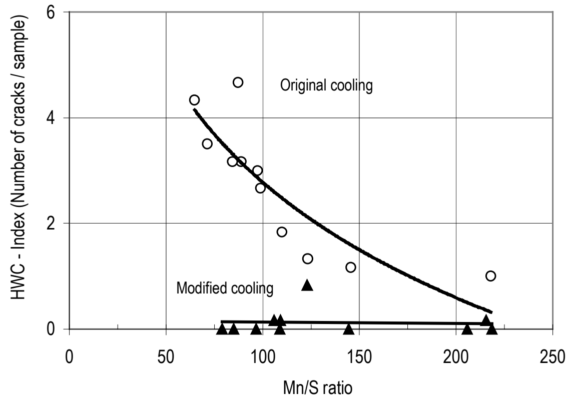

Fig. 20: Halfway crack elimination

6. CONCLUSIONS AND OUTLOOK

In 1997 a new strategy was implemented within the scope of reengineering of von Moos Stahl AG. In accordance with the Swiss Steel concept of centers of competency, the focus of von Moos today is on production of high quality steels. The market segment of constructional steels will be suspended on a short-term basis and taken over by sister company Stahl Gerlafingen AG.

A very important step towards realizing this concept was the installation of the new SBQ billet caster supplied by Concast Standard AG Zurich. The caster was commissioned exactly on schedule, 12 months after contract signature. All main steel grades of von Moos Stahl AG `s product-mix were produced within the first four months, as planned.

The three-strand caster concept, utilising high-speed casting technology with Convex® moulds and a new submerged casting system, has proven to be successful. The switchover from the old to the new caster was performed within less than one week.

Five months after commissioning, the quality of the production on the new installation, following extensive investigations, can be summarised as follows:

- reduction of index for pores/pinholes
- enlargement of equi-axial zone
- improved equi-axial zone symmetry
- slight improvement of center segregation
- maintaining satisfactory surface quality at casting speeds 60 – 90% higher than with the old caster.

This level of quality can be safely achieved with present casting speeds 3.0 to 3.5 m/min for the 130 mm-square section.
The flexible solutions of the secondary cooling arrangement allowed halfway cracks to be completely eliminated.

The plan is to constantly improve the quality of products at von Moos Stahl by continuous optimisation of the process technology, exploiting the computerized quality assurance system of the new caster.

Furthermore, additional investments are planned on the steelmaking side. For example, Concast Standard AG has been selected to supply a new electric arc furnace in 1999.

Such carefully planned and executed innovations will assure customer satisfaction and thus strengthen market share in the future.

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