Upgrading of long product steel casters with low CAPEX

Current steel market conditions require low capital expenditure upgrades of existing casters to improve quality and/or productivity, while lowering operational costs. SMS Concast has developed some new solutions to suit this difficult market, including a non-radioactive mould level measurement system, improved control software for electromagnetic stirrers, which provides enhanced stirring at lower energy cost, and an internally cooled strand guiding roll which significantly extends roll lifetime and improves process control, with less water being sprayed on to the strand.

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Three new products will be described:

- **CONSAFE** For reliable and precise mould level measurement without the use of radioactive equipment.
- **CONSTIR-MWS** Control software for electromagnetic stirrers which varies the set points of current and frequency during stirring. This modulation gives enhanced stirring effect at lower energy cost.
- **CONCOR** An internally cooled strand guiding roll which significantly extends roll lifetime and improves process control, with less water being sprayed onto the strand.

CONSAFE

Introduction and benefits Radioactive mould level height measuring systems for continuous casting machines (CCM) are still common. However, despite its advantages, the use of radioactive devices adds several layers of cost including licensing, security, operating practices and disposal of radioactive sources after use. SMS Concast has developed CONSAFE, a safe, radiation-free, reliable and less expensive alternative to conventional systems. Especially when a plant needs to replace its radioactive devices or the sensors, then the return on investment (ROI) becomes very short.

Working principle CONSAFE uses a patented array of four thermocouples which is attached to the mould tube (see *Figures 1 & 2*). The tips of the thermocouples are inserted into holes in the mould tube which ensures optimal thermal contact and best dynamic response. As the steel level rises in the mould tube, temperature changes due to heat transfer are sensed by the sensor array and an advanced algorithm evaluates the thermocouple signals to determine the level of the liquid steel inside the mould. The raw thermocouple signals are converted into highly noise-immune 4-20mA temperature data, which is then

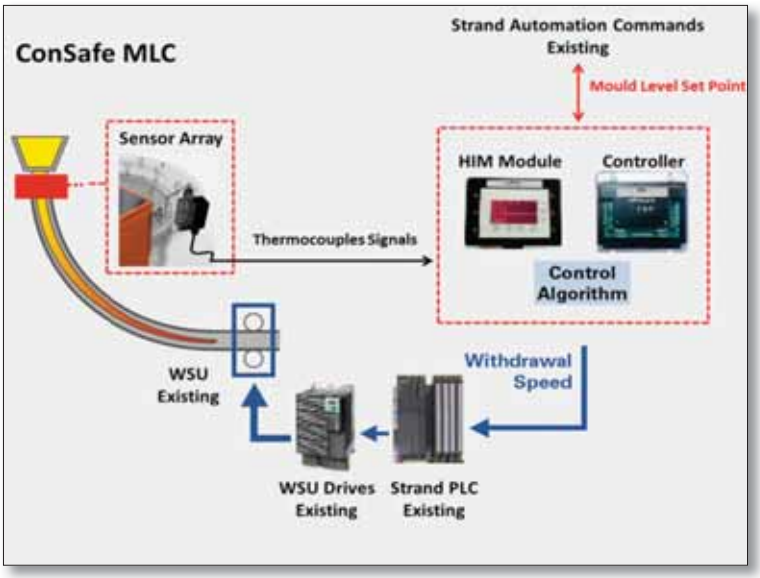

Fig 1 **CONSAFE system components and layout**

Fig 2 **Scheme of sensor array mounted on a mould tube with cabling from wet side to dry side**

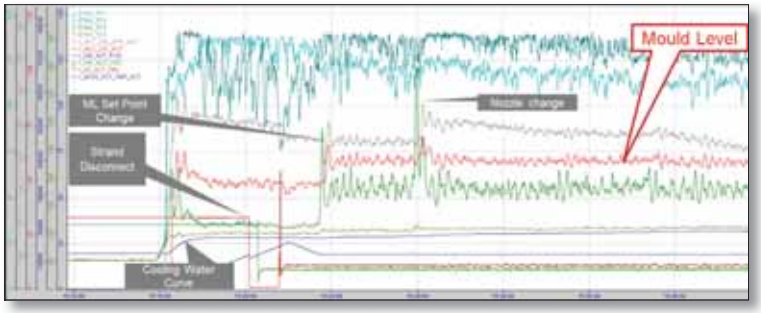

Fig 3 **The red line shows the mould level controlled by CONSAFE**

applied to a thermal model in the controller, producing a representation of the actual steel level in the mould tube. A plant example is shown in *Figure 3*.

At the start of the cast, CONSAFE is capable of recognising the rising steel level within the mould before the steel reaches the control range of the thermocouples. This allows the proportional integral derivative (PID) to take control of the strand at a very early stage and also allows starting every cast in automatic mode. This steel level pre-view function provides for a safe and reliable auto start. The steel level within the mould tube does not overshoot the set-point.

Application in the plant The CONSAFE sensor can be fitted into practically every open stream caster. Attaching a sensor array is a fairly simple and quick operation. The water jacket is not affected. The lower top plate of the mould cartridge requires a threaded hole to safely guide out the cable. No re-calibration is required after the initial system calibration during commissioning. The system is maintenance-free. Even in the unlikely event of two thermocouple failures, it would still sense and hold a level to operate the strand until the end of the cast.

Learning to operate the system is easily accomplished by the intuitive design of the interface screen. Online operational data across all strands is available on the same display. The controller is capable of storing operational data for one year of production, giving extensive diagnostics and data trending capabilities. Communication is via Ethernet. Field network connection is adaptable to Profibus, Profinet, etc.

Operating results The first installation in 2001 was under its previous brand LevelTherm®. SMS Concast bought the intellectual property of LevelTherm® in 2015 and the product's successful history is continuing under the new brand name CONSAFE. Ten long product mills in the USA and three mills elsewhere use the system. Two examples are described below.

NUCOR STEEL SEATTLE, USA

Nucor Steel Seattle converted from an older radioactive mould level control system, being driven primarily by safety and reliability and to provide a radioactive-free work environment on the caster. After ten years of operation, Nucor are of the opinion that the system has proven to be very reliable and they have not encountered any known thermocouple failures. Commissioning was simple and the system provided a liquid steel level accuracy within +/- 4mm. They have found that the system works continuously and independently of casting section size, steel grade or casting speed, and have realised their goals of improved caster reliability, improved billet quality and a radioactive-free working environment.

CASCADE STEEL ROLLING MILL (CSRM), USA

CSRM converted from an electromagnetic system due to issues with mould level stability. They wanted a redundant system with two sets of sensor arrays which provides both a 'hot backup' in the rare event of a thermocouple failure and a much more stable mould level as the values from both arrays are averaged. This increased mould level stability also decreased the turbulence previously experienced. The start of cast with the old system was made manually whereas today all starts are in automatic mode, even after a 'flying tundish' change. CSRM has indicated that they are very satisfied with the CONSAFE system.

CONSTIR-MWS

Introduction and benefits CONSTIR-MWS is part of SMS Concast's electromagnetic stirrer product family and

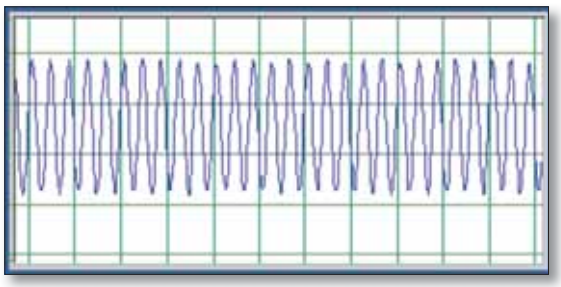

Fig 4 **Conventional sinusoidal magnetic field**

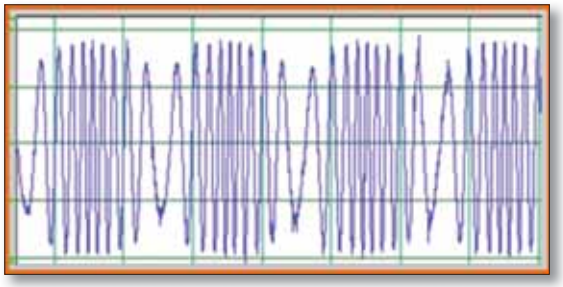

Fig 5 **CONSTIR-MWS modulated magnetic field**

Plant	Type	Stirrers	Country	Measured saving %
1	6-strand billet	MEMS	Russia	34.4
2	8-strand billet	MEMS	Turkey	36.1
3	3-strand billet	MEMS & FEMS	Poland	33.3
4	3-strand bloom	MEMS & FEMS	Italy	35.5
5	6-strand bloom	MEMS	England	37.2
6	4-strand billet	MEMS & FEMS	Switzerland	41.4
7	3-strand bloom	MEMS	USA	30.0
Average measured electrical energy savings				**35.4**

MEMS is mould electromagnetic stirring, FEMS is Final (ie, at metallurgical length) Electromagnetic Stirring

Table 1 Electrical energy savings with CONSTIR-MWS on seven CCMs

stands for Modulated Wave Stirring. The new product is software that modulates the current and frequency of the stirrer and consumes 35% less electric power than conventional systems. Such savings generate a ROI of less than one year in many cases.

The lower energy input also reduces the angular velocity of the steel meniscus, which is an advantage for the casting operation itself, but also provides improvement to carbon segregation and potentially also for porosity.

Working principle The CONSTIR-MWS technology intensifies the heat and mass transfer processes of the liquid steel inside a continuously casting strand. The conventional sinusoidal magnetic field (see *Figure 4*) is replaced by a multi-frequency magnetic field, generated with amplitude and frequency modulation (see *Figure 5*). The modulated wave carries less energy, hence the power savings are achieved. The modulation changes the melt circulation pattern in the vicinity of the solidification front and provides positive metallurgical effects for shell growth.

A proprietary mathematical model is used which calculates how the conventional sinusoidal current input for an EMS is to be modulated in its amplitude (AM) and frequency (FM). The calculation variables are steel grade- and section-specific and operational inputs.

Application in the plant The software can be implemented on most CCMs, even those equipped with existing mould stirring units. *Figure 6* shows the layout of an industrial implementation. In both cases, the frequency converter is controlled from the CCM control room with the metallurgical recipe system. A CONSTIR-MWS controller is integrated into the overall system. The modulation control of the EMS system is realised by a special algorithm installed in the new CONSTIR-MWS controller which generates the amplitude and frequency modulation set-points, and transmits the data to the frequency converters. The original EMS system now performs a fast and reliable AM/FM operation.

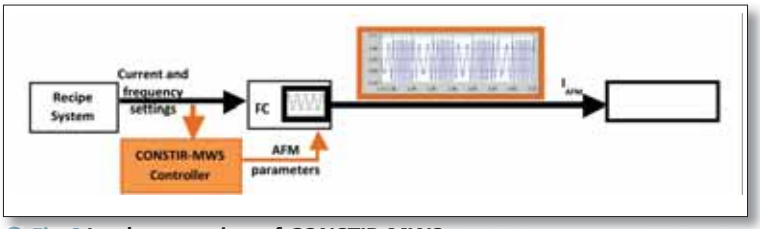

Fig 6 Implementation of CONSTIR-MWS

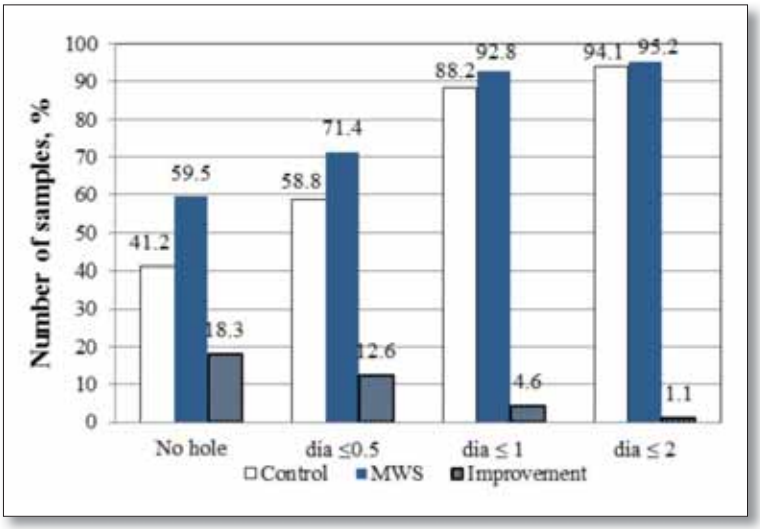

Fig 7 Central porosity of steel P52 in 200mm square billets

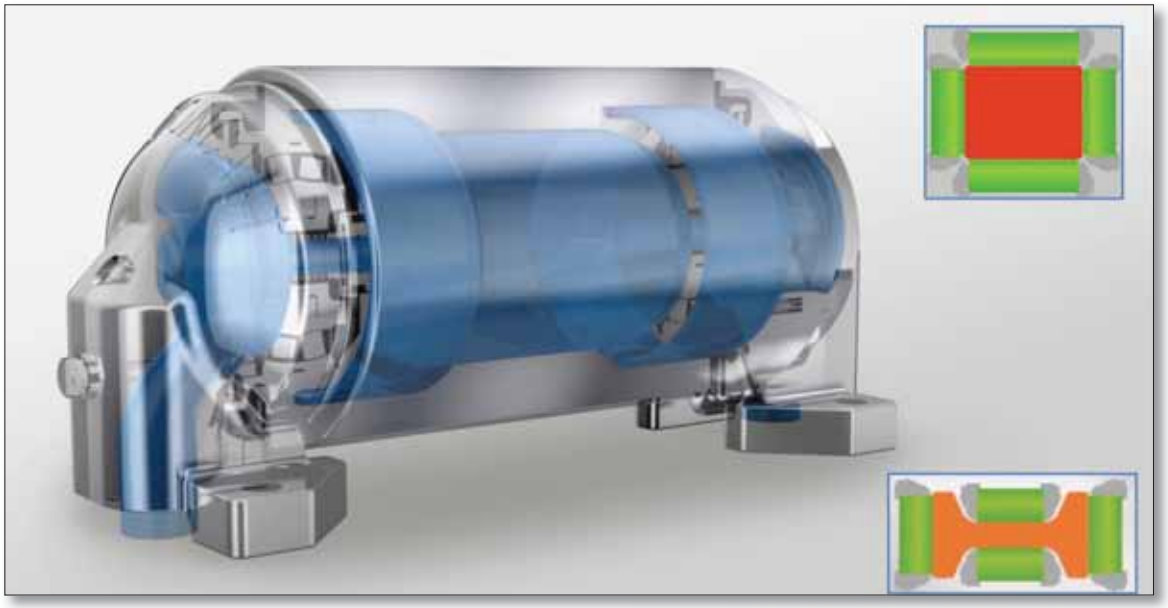

Fig 8 **Smartly cooled CONCOR® roll. It is applicable for bloom and BBL**

Operating results Several industrial implementations exist and many trials have been performed to gain clear evidence on the superiority of this technology.

Energy savings The average energy saving achieved on seven CONSTIR-MWS installations is 35.4% (see *Table 1*). Such power consumption savings are quite an achievement, especially if considering that the stirrers are often the largest energy consumers on a CCM. In some countries, such as Italy, plants receive governmental advantages if they can present energy consumption savings in this range. The energy savings are easily measured during commissioning. All energy savings figures presented in *Table 1* were evaluated as the difference between CONSTIR-MWS switched off and on.

Centreline porosity *Figure 7* shows an impressive statistical result of central porosity improvement achieved in a steel plant casting peritectic steel P52 (steel analysis wt%: 0.18-0.2C, 0.15-0.25Si, 0.85-1.05Mn, <0.15Cr, <0.15Ni, Mo<Cu<0.18) in a 200mm^2 section. It can be seen that the size of the pores (hole) is reduced if using CONSTIR-MWS.

Carbon segregation, white band and equiaxed zone Carbon segregation and its standard deviation generally decreased in the statistical analyses. The carbon coefficients of all strand sample slices produced with CONSTIR-MWS ranged in a smaller band (from best to worst) as compared to the band of all strand sample slices stirred in the conventional way. The positive impact of CONSTIR-MWS on impurity segregation can be explained by the resonance condition effects and with the decreasing of the average angular velocity of the melt. This action may lead to a reduction of the white band, together with reduction of the dendritic structure. There are few methods to increase the size of the equiaxed zone, but in some cases, the equiaxed zone is positively affected by applying CONSTIR-MWS.

CONCOR

Introduction and benefits With one patented innovation, SMS Concast has resolved several major process issues for beam blank (BBL) casting, namely uneven cooling resulting in shape and cracking problems, as well as higher maintenance costs for BBL plants. The internally cooled CONCOR® strand guiding roll (see *Figure 8*) enables considerably less water to be used on the strand, so that the risk of unbending cracks in the shape-critical web zone is remarkably reduced.

Less maintenance is required to produce the same amount of steel so helping productivity and reducing costs.

Working principle CONCOR® strand guiding rolls feature a compact design and intense internal water-cooling. This innovative design makes it possible to place up to eight internally cooled rolls in each roll layer of a BBL segment, including the flange tips. The machine cooling water enters through one bearing support and leaves through the other one, so even the bearings are water cooled (see *Figure 9*). This allows installation of lifetime-lubricated bearings hence the rolls require no grease piping on the roll segments. The rolls remain operational much longer than conventional rolls and maintenance

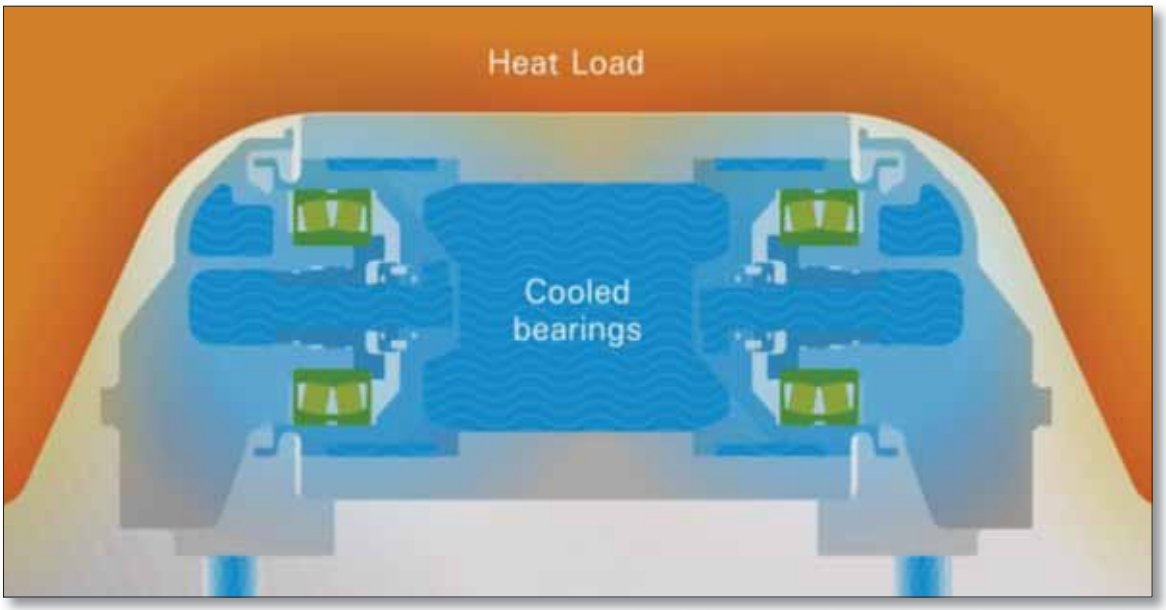

Fig 9 **The web of a BBL is supported on its full length. The bearings and bearing supports are water-cooled**

times and costs are drastically reduced. It can also be used on conventional square or rectangular products.

Application in the plant A CONCOR® roll segment looks simpler than a conventional segment as no grease pipes are required to lubricate the bearings and machine cooling water channels are integrated into the segment, for both roll and segment cooling. The machine can operate with less secondary cooling, which follows the new trend of 'dry casting'.

As there is no grease, there are no pumps to maintain and no grease is washed away with the secondary cooling to end up in the water conditioning plant. The compact design of the roll and of the bearing supports makes the roll comparably light and so eases handling in the segment work shop and in the alignment of the segments.

OPERATING RESULTS IN TWO PLANTS

TimkenSteel Corporation, Faircrest, OH, USA 1,200 CONCOR® rolls have been installed on the vertical caster where a large 460mm x 610mm section is cast. Thanks to the inclined design of the bearing supports, the strand can be supported with the rolls along its full width and height. The strand cooling and hence product shape are excellent. Bloom surface defects due to blocked rolls are uncommon.

No CONCOR® rolls have required replacement or maintenance after 15 months of operation. When roll maintenance does eventually become necessary, the rolls will only require body refurbishment and new bearings and new carbide sealing plates. The bearing supports remain without any maintenance needs.

Karabük Demir Celik (Kardemir), Karabük, Turkey Kardemir uses CONCOR® rolls on its BBL segments on a 5 strand, 12m radius caster producing 400mm x 500mm x 110mm (W x H x web thickness). Kardemir appreciates the CONCOR® design because the BBL can be cast without the excess water usually required to cool conventional rolls used to support a BBL section. The result is that the flange tips are still warm enough when they undergo straightening, meaning that flange tip cracks are no longer an issue.

When compared to a conventional solution, there is little water which has to be blown out of the upper/inner part of the strand and so provides equal strand cooling conditions on both inner and outer side of the BBL.

There is clear evidence that the CONCOR® rolls, with their internally cooled bearings, have significantly lowered the need for maintenance, and roll adjustment needs to be done less often, so helping to reduce costs.

CONCLUSIONS

The three technologies described are examples for innovative products by SMS Concast. Each one has a thoroughly sustainable positive effect on the operating cost of a steel plant. These products can be implemented with a comparably low CAPEX, and ROI time is short. MS

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