BSE EXCELLENCE REPORT

High Casting Capacity with Spray cooled Molds on the Billet Casters at BSW.

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Excellence in Steelmaking

High Casting Capacity with Spray cooled Molds on the Billet Casters at BSW.

Technical Data and Machine Layout

BSW is a mini-mill built in 1970 with a design output of 400.000 tons per year of billets. It operates two 90 t EAFs, two ladle furnaces and two 5-strand billet casters at Kehl in Germany, producing cast billets for re-rolling to wire rods and rebars for concrete reinforcement.

The tundish and ladle car are all in line on each caster. This offers a high safety standard such that in the event of a breakout, the tundish or ladle can immediately and safely be removed from the machine.

There is no shroud preventing for steel oxidation neither between the ladle and the tundish nor between the tundish and the mold, as it is usually the case when making steel for concrete reinforcement.
The level of automation is rather high for ordinary billet casters. It allows operating each machine with one-first and three-second casters per shift.

Figure 1: *Ladle in casting position*

The secondary cooling of the billets is performed alongside of the 6,2 meter radius of the machine by water sprays arranged in three zones of spray risers representing a total cooling length of 8,5 meter. The specific water consumption for the secondary cooling is 2,1 l/kg.

The ground level of the casting machines starts with the straightener located just a short distance after the spray chambers. The billet cutting systems is either by oxy-gas torches or shears. There is one unique billet length at BSW of 13,8 m corresponding to a weight of 1.843 kg.

The dummy bars cover the distance between mold and straightener and are necessary for starting the casting sequence. The dummy bars are either rigid or flexible depending on the machine.

Both machines have a cooling bed but most of the billets are directly taken by the cranes equipped with a C-hook from the roller table and send to the reheating furnaces of the rolling mill. The average incoming temperature at the inlet of the reheating furnace of the wire rod mill was 617°C in 2006.

Ladle

To guarantee the correct and on-time logistics of the tapped steel between the EAFs, LFs and casters, BSW has 16 ladles in circulation. Of these, eight are in service in the steel plant and the other eight are in the refractory bay for repair or relining. All the refractory work is performed by BSW personnel. The main details are:

- Capacity 90 t
- Monolithic refractory lining
- Slide gate: Interstop CS 60
- Lifetime approximately 100 heats

Tundish

The 22 t capacity tundishes have a monolithic refractory lining offering a total lifetime of 235 heats corresponding to 5 multiples of 47 casts (average) in sequence.

Maximum sequence length is 55 heats. Tundishes are repaired between sequences by refractory spray and moved to and from the casting position by a car.
The tundish car is, like the ladle car, moved in the casting direction. The tundishes are equipped with quick nozzle changers, with nozzle diameters of 18,5 mm to 19,5 mm. Two nozzles are generally consumed per strand and per sequence. There are 11 tundishes available, but at any given time two are casting, two are on stand-by, with the rest being repaired or relined.

Figure 2: *Relined tundish*

Molds

All 10 strands are equipped with water spray cooled molds (see Figure 3). In the early 1980s the decision to use this technology was taken because of two main features; greater safety because of pressure-less cooling iNside the mold and one third less cooling water consumption compared to water-jacket cooling (60 m^3/h per mold compared to 90 m^3/h).

The molds have the following features:

- Copper with chromium surface
- 11 mm wall thickness
- 130 x 130 mm^2, 1.000 mm Length; Parabolic tapered
- 32 nozzles on 4 risers for lateral mold surface and 28 nozzles on 4 risers for mold corner cooling with a total water consumption of 1.000 l/min at 8 bar supply pressure
- 200 strokes/min with an amplitude of 11 mm. Two strands have hydraulic oscillation with 9,2 mm stroke with 65% NSR (Negative Strip Ratio) and sinusoidal oscillation
- Mold lubrication with 0,18 l/tgb of rape seed oil
- Mold level control with RONAN X 96 N / Cs 137. A low energy gamma ray emitting source, detector and micro processor.

Mold oscillation is performed by conventional mechanical design via a motor, gearbox, an eccentric and a rod on eight strands. The all-oscillating system is mounted in a removable frame. Every frame is preventively changed twice a year for checks and repair if necessary at the central mechanical workshop. In order to improve operations BSW reconsidered the mechanical oscillating system and defined three targets in order to develop a new system by BSE:

- To improve the equipment reliability and, consequently, reduce the maintenance cost and ensure a long sequence rate without any disturbance
- To produce a compact design in order to make the all-oscillating system exchangeable so as to secure a long sequence rate by enabling molds to be exchanged during casting since tube lifetime is not easily predictable
- To stay with the copper tube water spray system so as to profit from our 25 years of experience in this field

BSW has now been operating with two strands using the BAmold system developed by BSE and BSW. The BAmold is a spray cooled, removable mold system in which the oscillating function is performed by hydraulic cylinder.

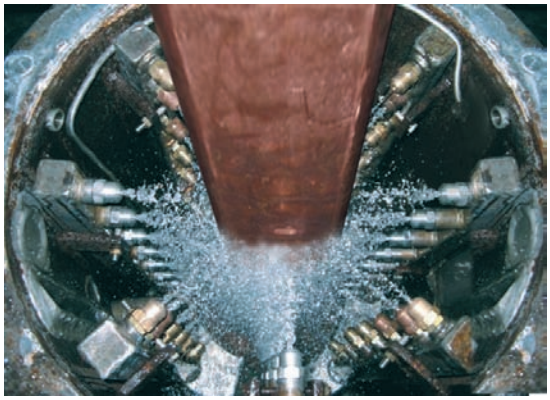


Figure 3: *Water-spray mold without top flanges*

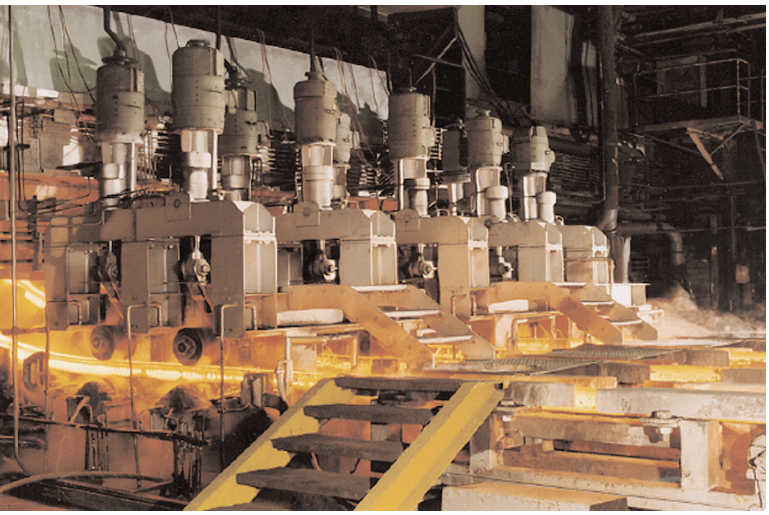


Figure 4: *Straightening unit at CCM 1*

CCM 1&2

Caster No. 1 was built in 1968 and upgraded in 1986 with state-of-the-art instrumentation and control. The main technical data are as follows:

- 5 strands with 130 x 130 mm² billet size
- Radius: 6.200 mm
- Distances between strands: 1.200 mm for strands 1 to 4 and 900 mm between strand 0 and 1
- Average Casting speed: 3,7 m/min
- Average Casting time with 5 strands: 37,7 min
- Electro-mechanical straightening units
- Oxy cutting for strand No. 0 and shears at strands No. 1 to 4
- Flexible dummy-bar

Secondary Cooling is separated in 3 zones with a spec. water consumption between 1,8 and 2,1 l/kg.

The zone 1, direct under the mold, generates an intensive cooling on a length of 250 mm with 28 nozzles and a total water flow rate of 300 up to 450 l/min at a supply pressure of 17 bar. In zone 2 the same water flow rate is used, but on a length of 2,4 m through 72 nozzles with a supply pressure of 12 bar. At zone 3, 64 nozzles are arranged on a nominal length of 5 m between spray chamber and straightener (see Figure 4). The water flow rate for this zone is between 120 and 200 l/min at a supply pressure of 6 bar.

The last determination of the solidification constant for RSt 37, a simple low carbon steel grade, was done in November 2004 with the following boundary conditions:

- Super heat 37 K
- Apparent heat from mold: 962 kW/m²
- Spray cooling 1,77 l/kg
- Air temperature: 10,1 °C
- Billet temp. 33,75 m from meniscus: 996 °C

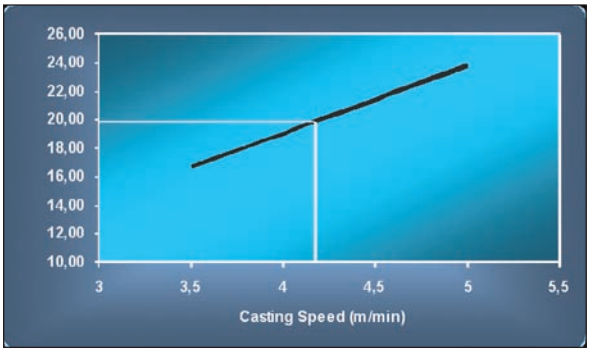


Figure 5: *Metallurgical length of CCM1*

This determination showed a solidification constant of KS = 30,47 mm/min1/2. As a consequence of this constant the metallurgical length is shown in figure 5.

In 1999 a major revamping of the caster No. 2 at BSW was made. The target was to build a caster with the latest and most reliable technologies for billet casting. The main features of the caster are listed below:

- 5 strands with 130 x 130 mm^2 billet size
- Radius: 6.200 mm
- Distances between strands: 1.200 mm for strands 1 to 4 and 900 mm between strand 0 and 1
- Average Casting speed: 3,7 m/min
- Average Casting time with 5 strands: 37,7 min
- Electro-mechanical straightening units with 2 driven and 3 idle rolls
- Oxy cutting for all strands
- Rigid dummy-bar
- Secondary Cooling is separated in 3 zones with a spec. water consumption between 1,7 and 2,1 l/kg

At CCM 2 the secondary cooling is done in the following different zones: zone 1, 2a, 2b and 3. The set-up of each zone is specified in the following paragraph.

The maximum water flow rate of Zone 1 is 440 l/min with a supply pressure of 12 bar through 4 nozzles direct under the mold. In Zone 2a 12 nozzles provide 120 l/min with a supply pressure of 15 bar. Zone 2b, with a length of 2 m, consists of 12 nozzles with a flow rate of 400 up to 900 l/min at a supply pressure of 15 bar. The zone 3 (3m before straightener) consists of 16 nozzles with a total water flow rate of 220 l/min at 5 bar supply pressure. All the nozzles at CCM 2 in the secondary cooling are mounted in square frames which each frame carrying 4 nozzles. The nozzles are rectangular wide-angle nozzles, which allow a relative big distance between nozzle and billet surface, with the benefit of reduced nozzle numbers and less nozzle clogging.

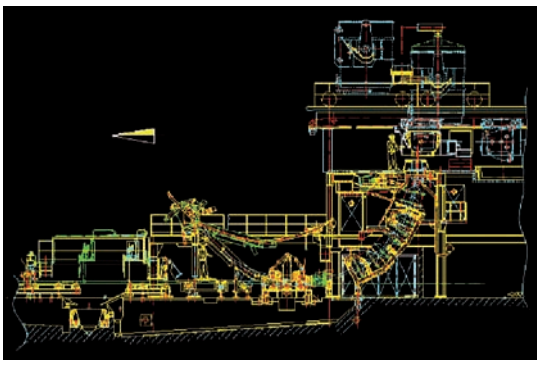
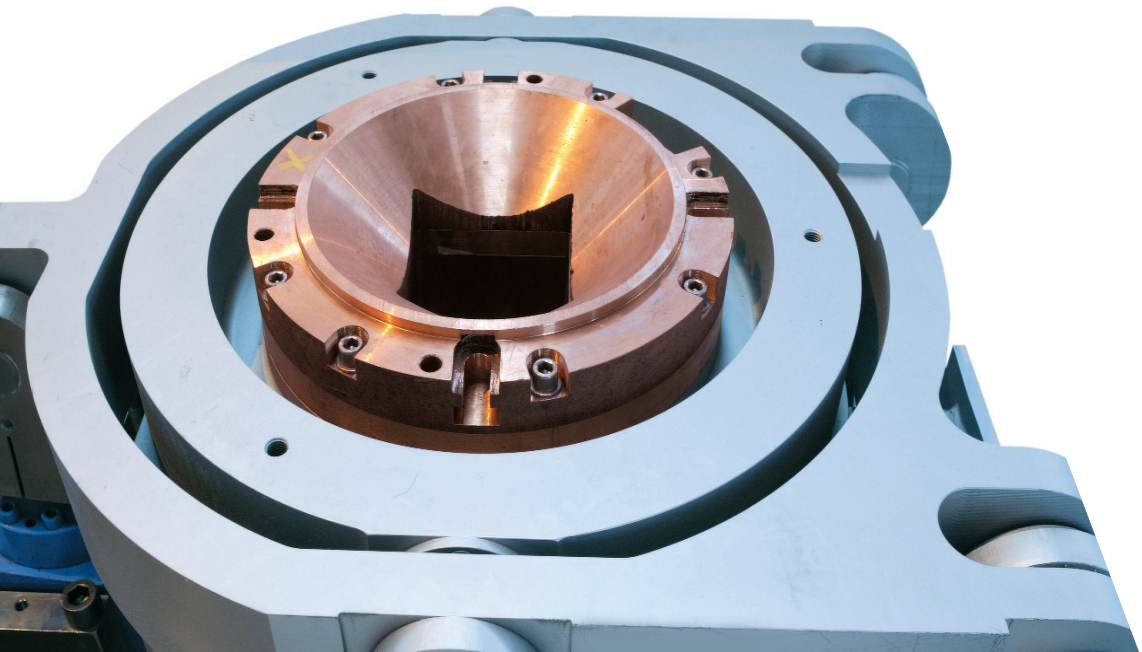


Figure 6: *Side view of CCM 2*



Also in November 2004 at CCM 2 the solidification constant was determined. In this case it was for the steel grade IV B/2, which means a simple medium carbon steel grade, with the following boundary conditions:

- Super heat 45 K
- Apparent heat from mold: 1.276 kW/m^2
- Spray cooling 1,69 l/kg
- Air temperature: 8,6 °C
- Billet temp. 32,85 m from meniscus: 993 °C

This determination showed a solidification constant of KS = 32,74 mm/min1/2. As a consequence of this constant the metallurgical length is shown in figure 7.

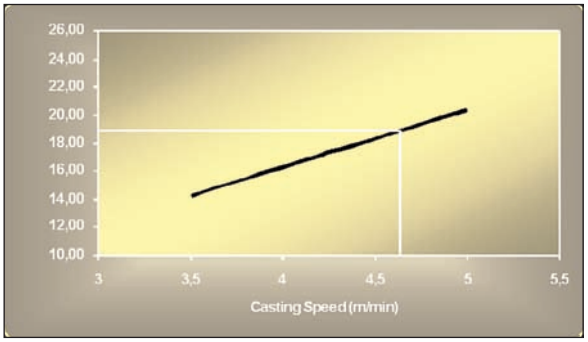
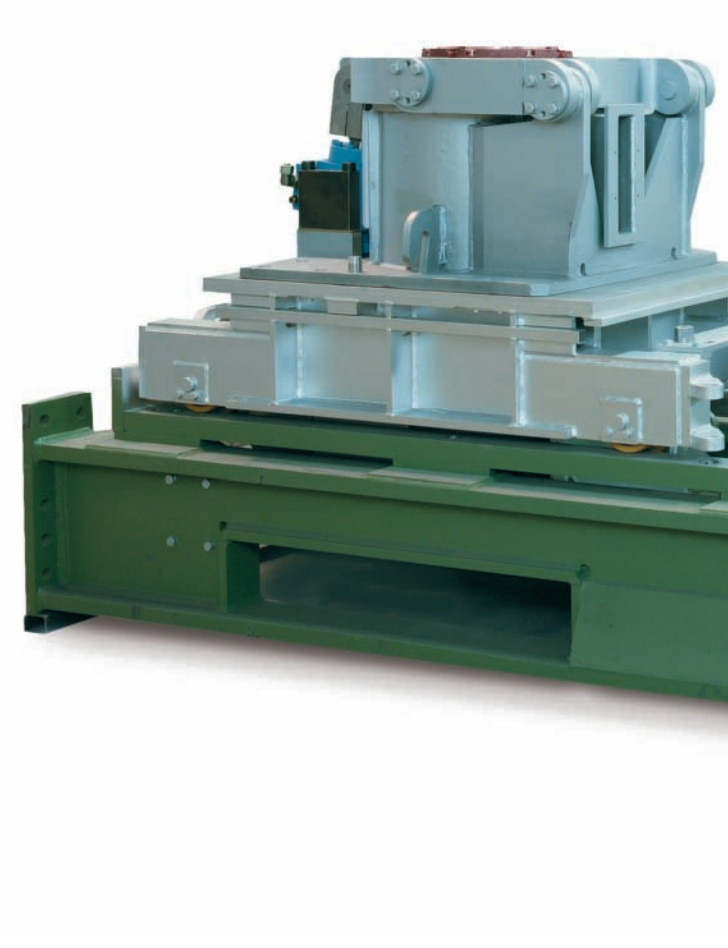


Figure 7: *Metallurgical length of CCM 2*

Performance & Consumption Data

As a result of the continuing developments to increase plant efficiency the plant achieved an annual production in 2006 of 2,07 million tons of good billets with a net annual operating time of 321,3 days, caster availability of 90,8% and a delay rate of 1,6%. This equates to an average daily output of 6.436 t corresponding to an operating time per heat of 37,7 minutes and an average casting speed of 3,7 m/min. This speed represents an annual average value but, on request, this speed can be increased to 4,2 m/min for CCM 1 and 4,5 m/min for CCM 2. Average heat size was 93 t with an average yield (tgb /tons of scrap + alloys) of 87,23%.



The overall plant production figures are summarized in the following table:

Annual production 2006:	2.067.929 t
Av. daily production 2006:	6.436 t/day
Average heat:	93 tgb/heat
Av. yield (tgB/t(scrap+alloys)):	87,23%

The data-records for the BSW-casters show the following total numbers for the year 2006:

Operating time:	15.332,6 h
Net operating time:	13.926,0 h
Set-up time:	473,9 h
Waiting time:	690,6 h
Delays:	242,1 h

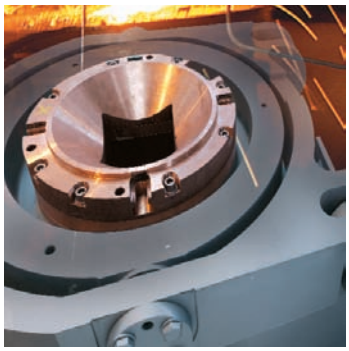
With these numbers the following casting operating data were calculated:

Caster operating availability:	90,8%
Delay rate:	1,6%
Operating time / heat:	37,7 min
Average casting speed:	3,7 m/min
Max. speed CCM 1:	4,2 m/min
Max. speed CCM 2:	4,5 m/min

Conclusion

From commissioning of the plant in 1970 to the present day BSW has embarked on a strategy of continuous improvement and optimisation which has resulted in an output of 2,07 million tons of good billets in 2006 at low production cost. The success of BSW is guaranteed by highly motivated and educated people who develop and optimise technologies to produce steel as cheaply and efficiently as possible. BSW has had an advantage of utilising the expertise of BSE engineering and consultancy services. These services are now available to other steel producers.

The advantage for BSW and of course steelmakers all around the world is, that through BSE, engineering and consultancy services for steel-mills, the "BADISCHE philosophy and technology" is available for other steel plants. The adaptation of the Know-How to other processes closes again the loop to reach continuous optimization.



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