High productivity billet casting at BSW

BSW is a mini-mill built in 1970 with a design output of 400ktpa of billets. It operates two 90t 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. Since 1970 the plant has been revamped on a number of occasions to provide ever increasing productivity and product quality such that today the plant achieves an annual production of more than 2mtpa of billets with a net annual operating time of 321 days.

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MACHINE LAYOUT

The plant layout is shown in *figure 1*. The tundish and ladle car are 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.

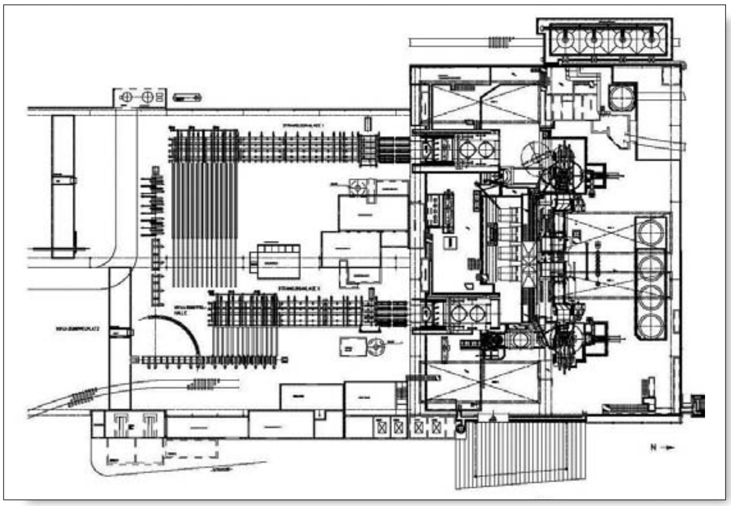

Fig.1 BSW steel plant layout

CASTER FEATURES

Caster No. 1 was built in 1968 and upgraded in 1986 with state-of-the-art instrumentation and control. Caster No. 2 underwent a major revamp in 1999 *(see Figure 2)* to provide a caster with the latest and most reliable technologies for billet casting. The main technical data are as follows:

- 5 Strands per machine with 130 mm billet size
- Radius: 6,200mm
- Distances between strands: 1,200 mm for strands 1 to 4 and 900 mm between strands 0 and 1
- Average casting speed: 3.7 m/min
- Average casting time with 5 strands: 37.7min
- Electro-mechanical straightening units
- Oxy cutting for CCM 2 and CCM 1 strand No. 0, and shears at strands No. 1 to 4
- Flexible dummy-bar for CCM 1 and rigid dummy bar for CCM 2
- Secondary cooling is separated into three or four zones depending on machine, with a specific water consumption between 1.7 and 2.1 l/kg

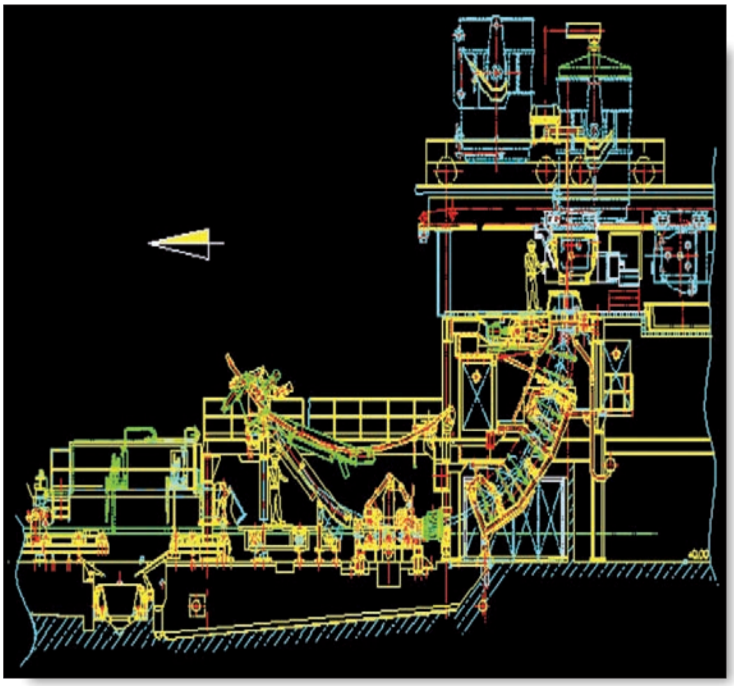

Fig.2 Side view of CCM 2

AT CCM 1 secondary cooling is split into three sections. Zone 1, directly under the mould, generates intensive cooling on a length of 250mm with 28 nozzles and a total water flow rate of 300 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. In zone 3, 64 nozzles are arranged on a nominal length of 5m between spray ▷

Fig.3 **Straightening unit at CCM 1**

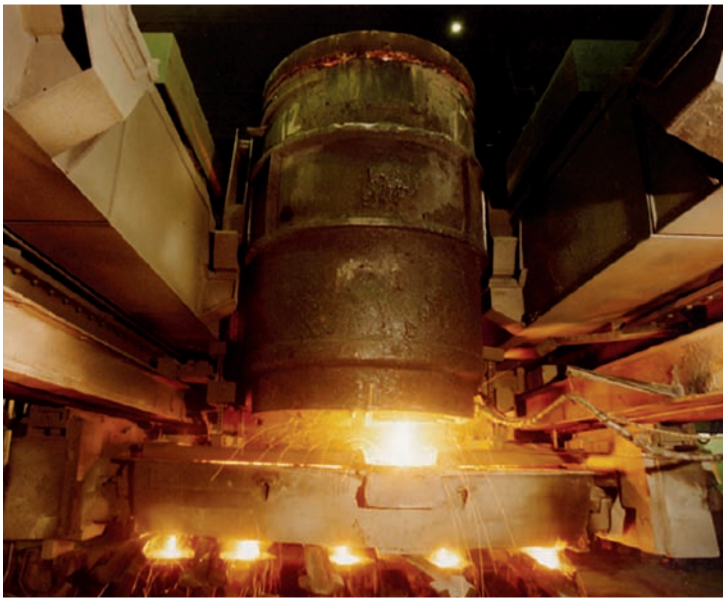

Fig.4 **Ladle in casting position**

Fig.5 **Relined tundish**

chamber and straightener. The water flow rate for this zone is between 120 and 200 l/min at a supply pressure of 6 bar.

At CCM 2 secondary cooling occurs in four zones: zone 1, 2a, 2b and 3. The maximum water flow rate in zone 1 is 440 l/min with a supply pressure of 12 bar through 4 nozzles directly under the mould. In zone 2a 12 nozzles provide 120 l/min with a supply pressure of 15 bar. Zone 2b, with a length of 2m, consists of 12 nozzles with a flow rate of 400 up to 900 l/min at a supply pressure of 15 bar. 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 are mounted in square frames with each frame carrying four rectangular wide-angle nozzles which allow a relatively large distance between nozzle and billet surface, with the benefit of fewer nozzles and less nozzle clogging.

There are no shrouds preventing steel oxidation between the ladle and the tundish or between the tundish and the mould, as is usually the case when making steel for concrete reinforcement. The level of automation is rather high for ordinary billet casters, allowing operation with only four caster operators per shift.

The ground level of the casting machines starts with the straightener located just a short distance after the spray chambers *(see Fig. 3)*. Billet cutting 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 1,843kg. 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.

LADLES

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, with the other eight in the refractory bay for repair or relining. All the refractory work is performed by BSW personnel. The main details are:

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

Figure 4 shows the ladle in the casting position.

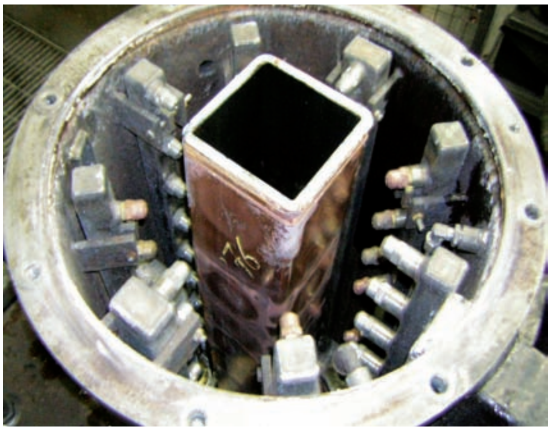

Fig.6 **Water-spray mould without top flanges**

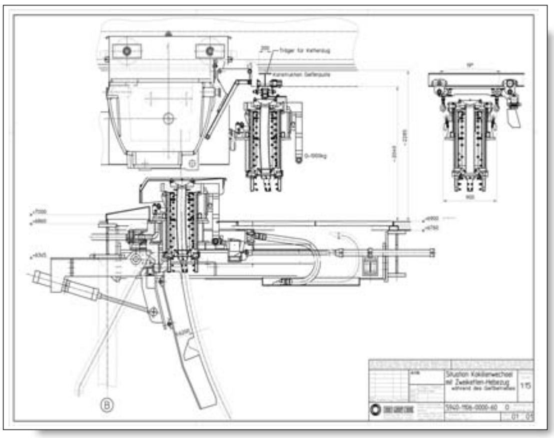

Fig.7 **BAmold layout for one strand**

TUNDISHES

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 *(see Fig. 5)*. 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 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.

MOULDS

All 10 strands are equipped with water spray cooled moulds *(see Fig. 6)*. 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 mould and one third less cooling water consumption compared to water-jacket cooling ($60m^3/h$ per mould compared to $90m^3/h$).

The moulds have the following features:

- Copper with chromium surface
- 11 mm wall thickness
- $130mm^2$, 1,000mm length
- Parabolic tapered
- 32 nozzles on 4 risers for lateral mould surface and 28 nozzles on 4 risers for mould corner cooling, with a total water consumption of 1,000 l/min at 8 bar supply pressure
- 200 strokes/min with an amplitude of 11mm. Two strands have hydraulic oscillation with 9.2mm stroke with 65% negative strip ratio and sinusoidal oscillation
- Mould lubrication with 0.18 l/t billet of rape seed oil
- Mould level control with RONAN X 96N / Cs 137, a low energy gamma ray emitting source, detector and microprocessor

Mould oscillation is 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 which 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 moulds 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 new BAmold system developed by BSE and BSW since 2001. The BAmold is a spray cooled, removable mould system in which the oscillating function is performed by hydraulic cylinder *(see Fig. 7)*. ▷

METALLURGICAL LENGTH

CCM 1 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 mould: 962 kW/m^2
- Spray cooling 1.77 l/kg
- Air temperature: 10.1°C
- Billet temperature at 33.75 m from meniscus: 996°C

This determined a solidification constant of KS = 30.47 mm/min$^{1/2}$. As a consequence of this constant the metallurgical length is shown in *figure 8*.

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

- Super heat 45K
- Apparent heat from mould: 1,276 kW/m^2
- Spray cooling 1.69 l/kg
- Air temperature: 8.6°C
- Billet temperature at 32.85 m from meniscus: 993°C

This determined a solidification constant of KS = 32.74 mm/min$^{1/2}$. The resulting metallurgical length is shown in *figure 9*.

PERFORMANCE AND CONSUMPTION DATA

As a result of the continuing developments to increase plant efficiency the plant achieved an annual production in 2006 of 2.07Mt 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 4.2m/min for CCM 1 and 4.5 m/min for CCM 2. Average heat size was 93t with an average yield (tonnes good billets/tonnes of scrap + alloys) of 87.23%

Table 1 shows the specific refractory consumptions at BSW for the last four years. The tundish and ladles are totally monolithic relined. The permanent optimisation at BSW results in a steady decrease of the specific values.

SUMMARY

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 2.07Mt 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.

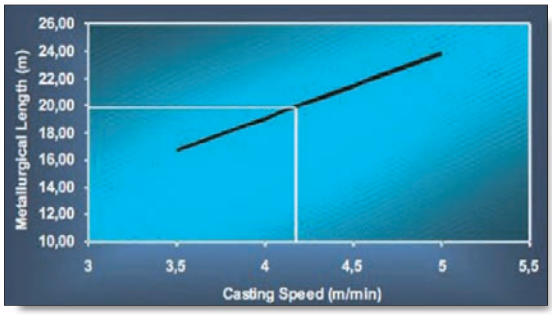

Fig.8 **Metallurgical length of CCM 1**

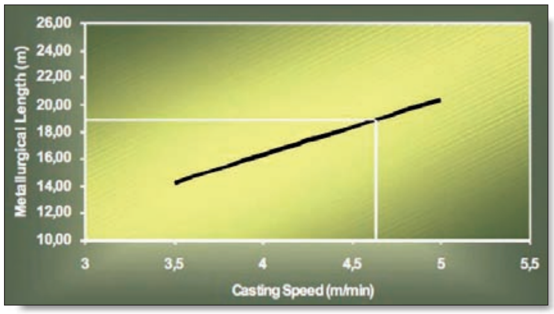

Fig.9 **Metallurgical length of CCM 2**

Year	**2002**	**2003**	**2004**	**2005**
Casting				
Monolithic lining	0.44	0.46	0.45	0.45
Nozzles and other various	0.01	0.01	0.01	0.01
Gunning	0.34	0.32	0.35	0.32
Total	0.79	0.79	0.81	0.78
Ladles				
Monolithic lining	1.38	1.53	1.13	1.43
Gunning	1.26	1.42	1.74	1.64
Porous plug	0.03	0.02	0.04	0.02
Slide gate	0.12	0.14	0.12	0.11
Total	2.79	3.11	3.03	3.20

Table1 **BSW Refractory consumption, kg/t**

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