VAI Beam-Blank Casting Technology— Fundamentals and Examples of Plant Installations

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Near-net-shape beam-blank casting offers similar advantages for the production of heavy and medium sections and beams as thin-slab casting does for the production of flat products, namely lower rolling costs, higher productivity and reduced energy consumption. Beam-blank casting is therefore an excellent alternative to the more conventional bloom-casting route for the production of beams and sections. This paper outlines the fundamental design aspects of beam-blank casting and presents several examples of VAI-supplied beam-blank casters.

INTRODUCTION

The economic advantages of beam-blank casting for the production of beams and sections can be mainly attributed to the reduced (or eliminated) rolling costs at the roughing stand of the hot-rolling mill. These are summarized as follows:

- Approximately 30% lower investment costs
- Approximately 15% increased productivity
- Fewer rolling passes at the roughing stand
- Approximately 1.5% higher yield
- Lower operating costs
- Approximately 55% reduced energy consumption at the roughing stand
- Approximately 55% lower maintenance costs at the roughing stand
- Reduced man-hours per ton of steel
- No intermediate storage for blooms required.

To gain the highest benefit from beam-blank casting technology a direct coupling of the caster to the rolling mill is necessary. A comparison of the time-temperature profiles of beam-blank casting with the conventional production route via cold charging of blooms with subsequent rolling to the respective beam sizes is shown in Figure 1.

The above benefits have contributed substantially to the rapid increase of beam-blank casting in recent years. During the past six years, six out of the eighteen new beam-blank caster installed worldwide were supplied and commissioned by VOEST-ALPINE Industrieanlagenbau GmbH & Co (VAI), Linz/Austria.

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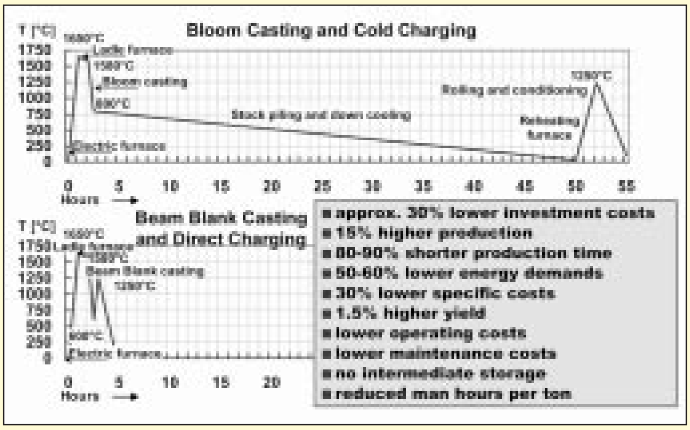
Figure 1: Advantages of Beam-Blank Production



BEAM-BLANK-CASTER DESIGN

Mold Design—Tube vs. Plate

There are two basic designs for beam-blank molds. The first is the tube mold, which is mainly used for beam-blank formats up to 300x400mm outer cross section dimensions. Depending on the beam-blank size, the copper tube wall has a thickness of up to 25 mm and the primary cooling water is guided between the outer surface of the copper tube and a special baffle tube. For manufacturing reasons it is not possible to design the mold with a negative taper on the shoulder area or with variations of the copper-wall thickness for the temperature homogenization over the beam-blank-strand circumference.

For larger beam-blank sections a plate mold is more suitable. Here individual copper plates are fixed on support plates and connected via screws to form the cross section. Primary cooling water is guided through cooling slots and holes. With this design a negative taper in the shoulder area to compensate for web shrinkage and an improved arrangement of the cooling holes for homogenization of the copper-surface temperature is possible.

Taper Design

The geometric and thermal mold conditions for the initial solidification of the strand are extremely important in order to obtain a strand with outstanding surface and internal quality. A properly designed primary cooling system and mold taper are, therefore, necessary preconditions to meet these requirements. VAI has developed a 2 dimension (2D), fully coupled thermo-mechanical finite-element model to calculate the temperature and displacement fields of the strand during initial solidification in the mold. This type of simulation provides a better understanding of the complex shrinkage behavior of a particular beam-blank section, enabling the shape and taper of the mold inner contour to be accurately determined.

These 2D finite-element models have been successfully verified at ARBED, Stahlwerke Thüringen, Germany with respect to shell growth, internal and surface beam-blank quality and mold wear.

Figure 2 illustrates the 2D finite-element model results for the beam-blank size 800x440x130mm (the last dimension is web thickness), as produced with the beam-blank caster at PEINE Salzgitter Works in Germany. A transient analysis, neglecting heat flux in the longitudinal direction, provides the temperature and displacement fields. The influence of different mold tapers on the shell growth, temperature fields and contact pressures due to the shell shrinkage can easily be studied. The internal ferrostatic pressure is increased as the strand shell moves through the mold.

Strand-Support Length

For the design of the strand-support length a transient heat-transfer analysis of the beam-blank section is performed. This type of analysis provides the necessary information about the shell growth within the strand support and the exact metallurgical length. A web-strand support that is too short may cause bulging or even an opening of the web center. This can lead to steel segregation and web-thickness variations. A flange-strand support which is too short may cause bulging and interface cracks. A typical strand support arrangement is shown in Figure 3.

Due to the unique shape of the beam-blank section, four different areas on the surface of the beam-blank section have to be individually supported, as follows:

Web. In order to prevent bulging of the web, and hence more pronounced center segregation, the web of the beam-blank section needs to be supported until sufficient solidification over its width is achieved. 2D thermal analysis provides the information for the necessary supporting length.

Flange. The flange has to be supported in order to prevent bulging and internal cracking. A 2D thermal analysis yields the temperature field and the corresponding shell thickness. A subsequent stress analysis displays the stress/strain and displacement fields, which results from the internal ferrostatic pressure from the liquid steel core. The criterion for the support length in this area is the generated interface strain due to the ferrostatic pressure at the liquid/solid transition of the flange inner surface.

Flange Tip. Similar criteria apply to the flange tip as for the whole flange and in general the supporting length depends on the casting size and on the casting speed. In many cases, particularly for lower casting speeds and small beam-blank cross sections, no additional support other than the mold foot rollers is necessary.

Shoulder. Due to its physical shape, the shoulder area acts like an arch, and therefore no support is normally necessary. A 2D finite-element analysis shows the stress and displacement field.

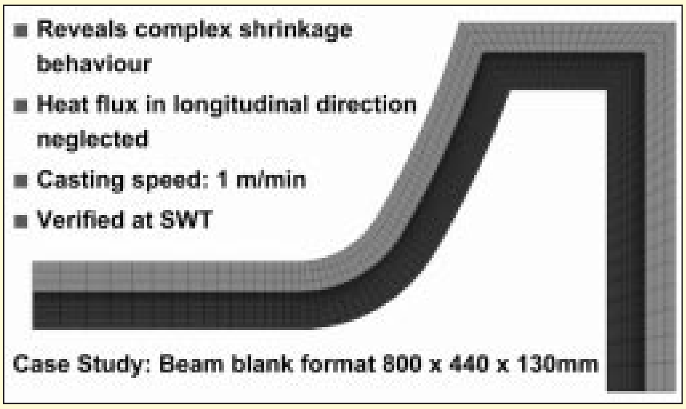


Figure 2: Finite-Element Model for Fully Coupled Temperature-Stress Analysis

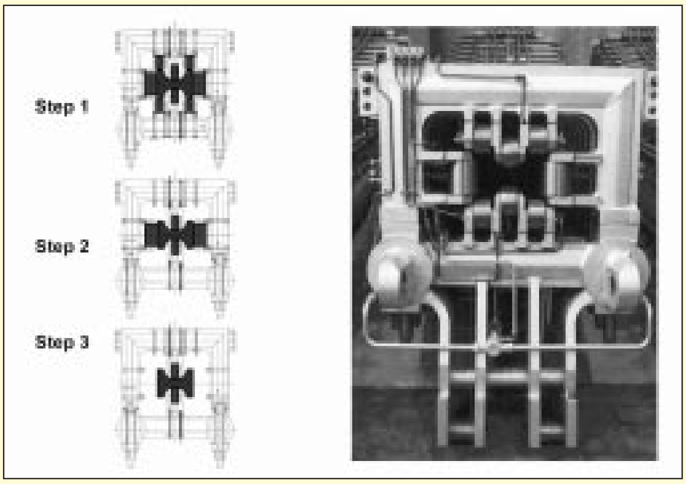


Figure 3: Typical Strand Support Arrangement

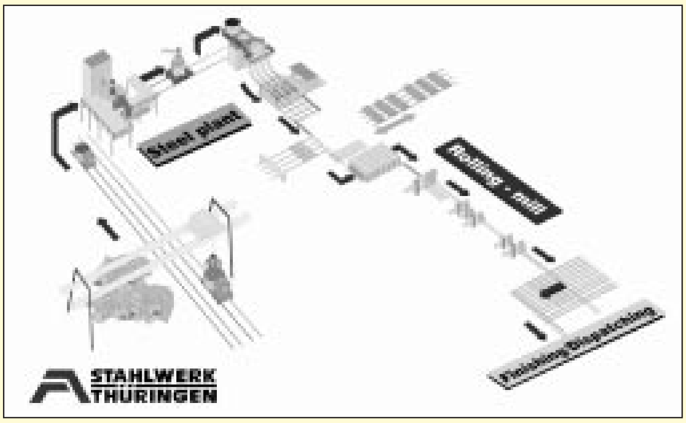


Figure 4: Steel Works Layout, Stahlwerk Thüringen (ARBED Group), Germany

OPERATIONAL RESULTS

Stahlwerk Thüringen, Germany

In September 1993, Stahlwerk Thüringen, a company of the ARBED Group, awarded VAI a turnkey contract for the supply of a 120 t DC electric arc furnace, a ladle furnace and a four-strand beam-blank caster. The plant was started up in February 1995 and a general layout of the plant is illustrated in Figure 4.

Two remotely controlled transfer cars carry the scrap buckets from the 45,000 t capacity scrap yard to the 120 t DC electric arc furnace with an installed transformer capacity of 120 MVA. Seven 3.5 MW natural-gas/air/02 burners are installed in the EAF. The tap-to-tap time is roughly 50 minutes. The ladle with the tapped steel is treated in an inline ladle furnace with a transformer capacity of 18 MVA, giving a heating rate of 4oC/minute in approximately 35 minutes. The steel is then transported to the beam-blank continuous caster. Meanwhile the ladle transfer car is free for the next cycle. The products from the continuous caster can be directly charged to the pusher-type furnace or intermediately stored in the stock yard.

The annual production of beam blanks has continuously increased since the start up of the caster in 1995 and reached 952,000 tons in 2001 (nominal capacity is 630,000 tons per year) See Figure 5.

This high production output is a result of the introduction of a third beam-blank size in 1997, 20 shifts per week production instead of the planned 17 shifts per week, and an increased cast-to-cast connection speed with a high utilization time. A production of 5 million tons was achieved in October 2001.

The casting rate is also higher than planned. For instance, for beam-blank size BB-1 the planned production rate was 114 t/hr, whereas the actual rate in 2000

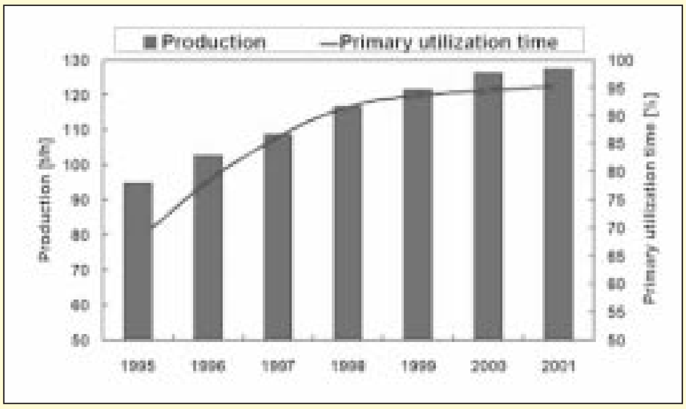


Figure 5: Average Hourly Production Rate and Primary Utilization Time at Stahlwerk Thüringen, Germany

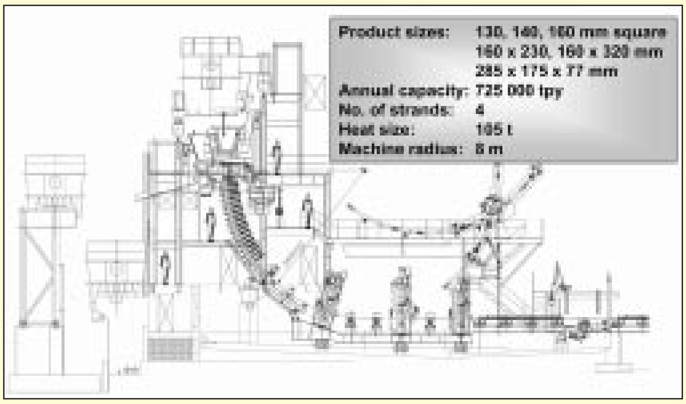


Figure 6: Cross Section of the Beam-Blank Caster at AmeriSteel, Cartersville, GA/USA

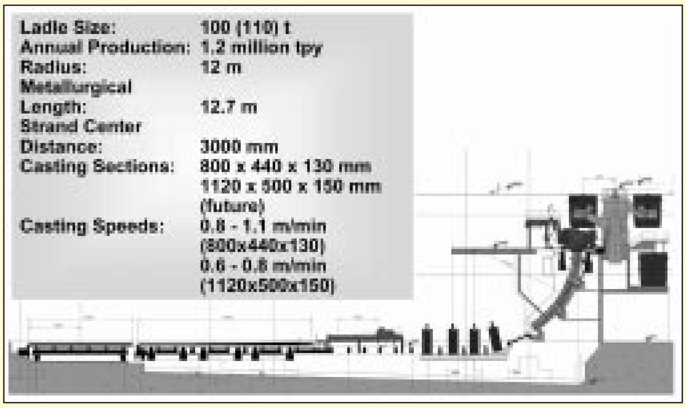


Figure 7: Cross Section of the Two-Strand Heavy-Section Beam-Blank Caster at SALZGITTER AG, Peine Works, Germany

was 11% higher at 126.4 t/hr with an average of 3 section sizes. The plant average figure further increased in 2002 to more than 130 t/hr as a result of a higher casting speed for the BB-3 size, introduced in September 2001.
Since start up the number of casting sequences has been decreasing continuously down to 285 in 2000 and the number of flying tundish exchanges has increased to 366. These figures are a result of optimal timing of the DC arc furnace with the caster in combination with a high utilization time and fewer maintenance interruptions. The average sequence length is approximately 29 heats.
The maximum sequence length achieved at Stahlwerk Thüringen was 204 heats in 195 hours, which was terminated for a planned maintenance outage.

AmeriSteel, Cartersville, GA/USA

In 1999 VAI commissioned the 4-strand combination caster at the former Birmingham Southeast LLC, Cartersville, GA/USA, now a plant of AmeriSteel. The caster is capable of casting 725,000 t/a of high-quality billets, blooms and beam blanks. The flexibility of casting various section sizes (billets; 130 mm sq., 140 mm sq. and 160 mm sq., blooms; 160x230 mm and160x320 mm, beam blanks; 285x175x77 mm) allows AmeriSteel (Cartersville) to meet the demand of its structural mill and its external billet customers. The machine casts a wide range of steel grades, including low-carbon silicon grades, alloy steels and resulfurized steels. The combi-caster employs open-stream casting, a mold length of 700 mm and has an 8-meter radius. Regular linear taper is used for the beam blanks (Figure 6).
The first heat was cast on January 13, 1999 in the 140x140 mm square section size for a structural steel grade. The caster was then commissioned to cast different section sizes during the following months depending upon the production requirements. The beam-blank size was commissioned on September 16, 1999. An additional new size of 130x130 mm square was commissioned on June 24, 2000.
No surface defects such as cracks, depressions and inclusions have been detected on the beam blanks. The oscillation marks are uniform and have no detrimental effect on the product's surface quality. The internal quality of the products has been satisfactory.
The beam blanks are rolled into 10” and 12” wide flange beams and 12” channels.

Nizhnij Tagil (NTMK), Russia

NTMK, the 4th largest steel producer in the Russian Republic, awarded VAI a contract for the supply of a unique two-strand beam-blank, bloom and mini slab caster to the joint venture VAI and Uralmash in 1994. The combi-caster is designed to cast a variety of sizes, from the smallest beam-blank size of 530x355x165mm, up to the largest size of 1050x450x130 mm. In addition, bloom sizes of 200x500 to 520 mm and mini-slabs of 160x620 mm can be produced. Presently, the machine is equipped for casting mini slabs and the beam blank size 530x355x165mm.
In order to accommodate the above sizes the strand center distance is 3,500 mm and an air-mist cooling system optimizes the strand temperature for the variety of steel grades and cast sizes.
The caster was commissioned with the 200x500 mm mini slab size on December 25, 2000. The first beam-blank format 530x355x165 mm was cast on August 1, 2001.
The surface and internal quality of the beam blanks fully satisfied the requirements of the end user.

Salzgitter AG, Peine Works, Germany

In May 2000 VAI was awarded a contract from SALZGITTER for the supply of a two-strand beam-blank caster for the production of heavy sections at their Peine Works in Germany. The new caster, with a production capacity of 170 tons per hour, was successfully started up in October, 2001. The beam blank quality was excellent from the start.
The machine is equipped with a plate-type, high-performance beam-blank mold, a DYNAFLEX hydraulic oscillator and a modern 3-segment stand-guide system. The beam-blank caster casts heavy sections in a size of 800x440x130 mm and is designed for a future extension to produce the largest beam blanks in the world (Figure 7).
The short project implementation time was made possible by extensive preassembly and testing work of the mold,

oscillator and strand guide segments in Linz, Austria (Figure 8).

The cast semi-finished products are rolled to heavy beams in an adjacent two-stand heavy-section rolling mill. (Previously, slabs were rolled to produce the required large-sized sections.) The rolling of near-net-shape beam blanks has drastically reduced the number of required roughing passes with a corresponding major decrease in overall operational costs.

JINDAL Steel & Power Ltd.

On March 16, 2001 VAI received an order from JINDAL Steel & Power Ltd., Raigarh, India (JSPL) to supply a new 2-strand beam blank/bloom/round casting machine (Figure 10).

The 2-strand machine will be designed to cast blooms on both strands for rail grades (285x390 mm), rounds (140, 162, 200, 220 mm) and for seamless pipe grades. One strand is designed to additionally cast beam blanks for standard structural steel grades with a cross section of 480x420x120 mm. The total annual production of the casting machine will be 400,000 t/a. In order to enable an annual production of 810,000 tons in the future, the caster is designed to allow for the installation of two additional strands.

The machine is equipped with a plate-type, high-performance mold for the casting of beam blanks and blooms, a tube mold for rounds, a DYNAFLEX hydraulic oscillator and a modern 3-segment stand-guide system. The beam blanks will be further processed in the JSPL rolling mill to standard structural steel products.

Following start-up up in the first quarter of 2003, this will be the world's first caster capable of producing beam blanks, blooms and rounds.

Figure 8: Preassembly and Testing of the Beam-Blank Caster in the Workshop at Linz, Austria

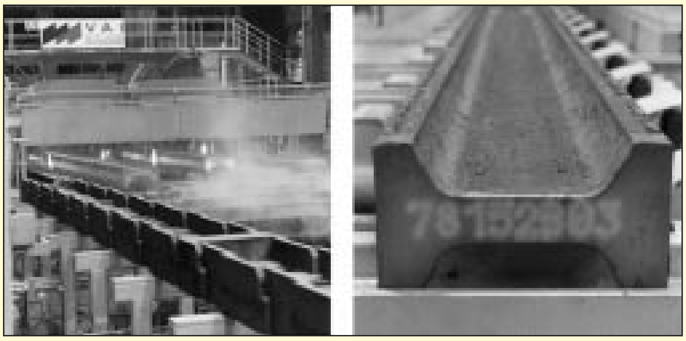


Figure 9: Start-up of the Beam-Blank Caster, Peine Works, Germany

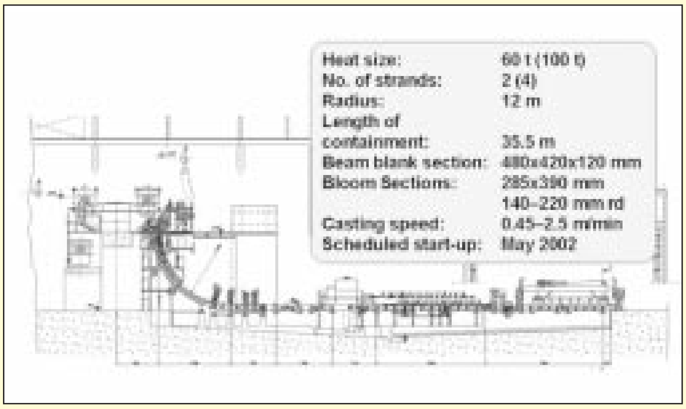


Figure 10: 2 (4) Strand Bloom Beam-Blank Round Caster, JINDAL Steel & Power Ltd., India