Modern billet casting technology

The use of an innovative mould shape, high-precision oscillators and compact billet withdrawal unit provides steelmakers with a high-speed billet casting capability in combination with high billet quality, flexibility and low maintenance. The equipment can also be retrofitted to existing machines.

Josef Fuchshuber and Gerald Zederbauer
VAI Pomini GmbH

New technologies in the field of high-speed billet casting have been developed by VAI Pomini – the long product company of the VAI Group – leading to significant sales. DIAMOLD, a novel mould design for high-speed casting was introduced in 1995, followed in 1997 by DYNAFLEX high-precision mould hydraulic oscillation. Since product introduction, VAI Pomini has equipped and/or upgraded 47 billet casters (205 strands) with DIAMOLD technology, and nearly 40 billet/bloom casters (more than 160 strands) with DYNAFLEX technology.

The number of reference plants has grown progressively and several companies have modernised additional casters following satisfactory performance and benefits on the first. Both DIAMOLD and DYNAFLEX technologies are installed in open stream casters for plain carbon steel grades as well as in fully shrouded casting mode for high-quality carbon steels and stainless steels.

In 2003, a new compact withdrawal unit was also developed and sales have commenced.

**Diamold high speed casting technology**

**Technological features** During casting, steel shrinkage is greater in the upper zone of the mould than in the lower zone. Good contact can be enhanced by mould tapering, however, excessive taper leads to pressure peaks in the strand-edge areas – especially in the lower zone of the mould – resulting in unacceptably high frictional forces during strand withdrawal. In order to ensure optimum contact between the strand shell and the mould along its entire length, the DIAMOLD design has a highly pronounced parabolic concity of the mould taper. Also, because of the two-dimensional heat removal at the strand corners, the shell thickness of the edges in the lower part of the mould is already sufficiently thick to prevent tears and breakouts, so from a position about 300-400mm below the top of the mould it is no longer necessary to maintain a firm contact between the strand edges and the mould wall, and so open corner areas in the lower mould zone are used. This reduces friction. Figures 1a and 1b illustrate the mould shape and pressure distributions for a square mould with excessive taper and the DIAMOLD shape. The key features of DIAMOLD are illustrated in Figure 2 and can be summarised as follows:

- Appropriate selection of the mould-tube length to ensure sufficient residence time of steel in the mould for the product mix and related casting speeds

![Figure 1](image1) Mould shape and pressure distributions for (a) conventional and (b) the DIAMOLD shape
Mould design with pronounced parabolic taper at the strand mid-face along the entire mould-tube length to assure rapid and homogeneous strand-shell growth

Open corner areas in the lower part of the mould in order to prevent excessive frictional forces during strand withdrawal and to ensure homogeneous strand-shell growth.

**Advantages** This design optimises heat transfer, resulting in casting speeds up to 50% higher than standard mould tubes (see Figure 3), as well as increasing the lifetime of the copper tube. In all the reference plants a significant speed increase was achieved, while maintaining or improving quality and operational parameters. Because of the high productivity with DIAMOLD moulds, the number of strands, and hence the capital and operating costs, can be reduced. Furthermore, they can be inserted in any existing mould housing, hence reuse of existing equipment reduces capital costs. The production of a uniform strand shell growth also increases machine availability as there are fewer breakouts.

**Market acceptance** The market has responded very positively to the introduction of DIAMOLD technology by selecting it for plant upgrades as well as for new installations (see Table 1). Many major long product steel producers, such as Riva, Nucor, Arcelor and Gerdau, now use DIAMOLD moulds.

**The Dynaflex hydraulic oscillator**

**Technological features** In view of the disadvantages of using conventional oscillation equipment in billet casting, such as high wear on the bearings of the guidance system, mechanical backlash and the need for complicated procedures of stroke adjustment, VAI decided to develop a new type of hydraulic oscillator. The basic principle involving a wear-free leaf spring guidance system and hydraulic drive was derived from the

![Figure 2 Key features of DIAMOLD](image1)

![Figure 3 Casting speed comparison between standard and DIAMOLD designs](image2)

![Figure 4 DYNAFLEX cascaded leaf-spring guidance system](image3)

![Table 1 DIAMOLD installations](image4)
DYNAFLEX oscillators successfully used in slab casters.

Typical space restrictions in billet casters required the development of a new (patented) oscillator suspension system as that used for slab casters and big bloom machines would result in a strand centre distance, which would be unacceptably large. A schematic cross section is illustrated in Figure 4. For economic reasons (low operational and maintenance costs) the drive system applied to slab machines was reduced to only one cylinder and without any servo-hydraulic components. Instead, proportional hydraulic components are applied as standard. After intensive testing and optimisation in the workshop with a full-scale model, VAI Pomini installed the first billet caster Dynaflex oscillator in Lechstahlwerke, Germany in 1997 (see Figure 5).

**Advantages** Comparison of the old electro-mechanical and the new Dynaflex oscillators in terms of guidance accuracy is shown in Figure 6. At a stroke of 5mm and frequency of 300 strokes/min, the horizontal deviations were below 0.1mm. This superior standard of accuracy was maintained for a period of more than two years without any need for maintenance, apart from the exchange of a hydraulic cylinder because of overfilling a mould, which resulted in steel flooding over the oscillator.

The advantages of the modern actuator mechanism permit the achievement of ideal oscillation characteristics: waveform (sinusoidal,
non-sinusoidal, saw-curve, and so on), stroke (amplitude) and frequency (strokes per minute), can all be varied in order to optimise the positive and negative strip time as desired on-line and even during casting.

Typical options are:

- Use low negative strip time for shallow oscillation marks
- Use high positive strip time to promote mould powder consumption
- Use an inverse oscillation algorithm to adapt frequency and stroke to the casting speed in order to keep the negative strip time constant

Figure 7 shows the different oscillation practices which can be applied with the DYNAFLEX system.

Since the first installation, VAI POMINI has successfully equipped more than 160 billet and bloom strands worldwide with these oscillators, involving casters of many different designs. Each one was individually tailored, especially so for the modernisation projects where there was a need to minimise modifications to the steel structure, as well as to reuse existing mould housings. Box-type or cantilever-type design of DYNAFLEX oscillators can easily be installed in new or existing casting machines, and the modular automation system provides interfaces to all common electrical and automation components, systems and platforms.

**Advantages** The benefits of DYNAFLEX can be summarised as follows:

- Produces billets with the highest surface quality
- Excellent guiding accuracy
- No mechanical backlash of the drive and guidance mechanisms of the oscillator table
- Simple adjustment of stroke, frequency and waveform
- Smooth running over the whole frequency range
- Adjustment of stroke height, frequency and wave form during casting
- No servo-hydraulic components
- Highest flexibility in operating parameters and wear free operation resulting in better surface quality
- Nearly maintenance free

**Market acceptance** Figure 8 shows the steady growth of Dynaflex references in billet and bloom casting machines since 1998.

---

**Compact withdrawal unit**

Building on VAI’s successful continuous straightening technology for slab and bloom machines, VAI Pomini has developed a completely new withdrawal and straightening unit for billet casting machines. This development is aimed at producing high-quality billets by minimising strain and strain rate, together with minimum and simplified maintenance.

The design features are:

- Rigid frame, completely internally water cooled
- Internally water cooled rolls with highly wear resistant surface ensuring long life time
- Water cooled cooling tunnel covering the hot strand within the withdrawal unit to avoid harmful heat radiation towards electrical and hydraulic components
- Arrangement of motors on top of the frame with connection of the gears via universal joint shafts, allowing optimum protection of motors and sensors and easy access from the top
- Withdrawal units are fixed by four connecting
<table>
<thead>
<tr>
<th>Production features</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production</strong></td>
<td>approx. 500,000 t/yr</td>
</tr>
<tr>
<td><strong>Heat size</strong></td>
<td>48 t</td>
</tr>
<tr>
<td><strong>Radius</strong></td>
<td>9 m</td>
</tr>
<tr>
<td><strong>Metallurgical length</strong></td>
<td>25 m</td>
</tr>
<tr>
<td><strong>Casting mode</strong></td>
<td>SEN casting with stopper rod</td>
</tr>
<tr>
<td><strong>Steel grades</strong></td>
<td>Cold heading, wire rope, spring, automotive, electrode wire</td>
</tr>
<tr>
<td><strong>Billet size</strong></td>
<td>150 x 150 mm</td>
</tr>
<tr>
<td><strong>Casting speed</strong></td>
<td>max. 3 m/min</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design features</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mould</strong></td>
<td>DIAMOLD tube, electromagnetic stirring, LEVCON mould level control system</td>
</tr>
<tr>
<td><strong>Oscillator</strong></td>
<td>Hydraulic DYNAFLEX</td>
</tr>
<tr>
<td><strong>Secondary cooling</strong></td>
<td>4 zone spray cooling</td>
</tr>
<tr>
<td><strong>Withdrawal unit straightening</strong></td>
<td>Compact unit with continuous</td>
</tr>
<tr>
<td><strong>Automation</strong></td>
<td>Level 1 and Level 2 system with CAQA</td>
</tr>
</tbody>
</table>

**Table 2 Main production and design features of the Xingtai caster**

Figure 9 shows the units installed in the 4-strand billet caster in Xingtai, China.

In summary, the system is capable of secure long-term operation with minimal maintenance, ensuring best possible billet quality due to continuous straightening as well as the avoidance of negative metallurgical influences, which could be caused by uncontrolled open cooling.

**Combined technology application**

Recently ordered billet casters – either at the engineering/manufacturing stage or already in operation – are equipped with DIAMOLD, DYNAFLEX and the Compact Withdrawal Unit. Additional equipment is also installed depending on individual needs. This includes advanced secondary cooling – DYNASHELL, the LEVCON mould level control system and level 2 automation with
computer-aided quality assurance systems (CAQA). The 4-strand Xingtai billet caster in the PR of China, which commenced operation in December 2002 is illustrative of this new generation of billet casters. Figure 10 shows a longitudinal section through the machine and Figure 11 shows the caster in operation.

Main features of the Xingtai caster These are summarised in Table 2.

Product mix
With the start-up of the caster, Xingtai entered the quality steels market segment and is successfully producing a wide variety of steel grades, as illustrated in Table 2.

Conclusions
Steel producers must be able to deliver the product quality requested by their customers, but in order to remain competitive, this must be combined with high productivity, flexibility, and cost efficiency. In order to do this they must utilise the latest technology. Examples of this are DIAMOLD, DYNAFLEX and the Compact Withdrawal Unit, which, in providing high quality, high productivity and low maintenance, are benchmark indicators for both new and refurbished continuous casting machines.

Josef Fuchshuber is Managing Director and Gerald Zederbauer is General Manager Sales, both at VAI Pomini GmbH, Linz, Austria.