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CAST SHOP for ALUMINUM PRODUCTION

Grain Refinement, Alloying, Solidification and Casting

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Hycast ™ Gas Cushion (GC) Billet Casting System

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Abstract

The Hycast™ Gas Cushion Billet Casting System (Hycast ™ GC) for casting of extrusion billets has been used in Hydro Aluminium casthouses (both primary and remelt) for more than 20 years. The technology is based on a patented mould construction utilizing dual graphite rings for optimal distribution of oil and gas into the mould and increasing graphite ring lifetime. Annual production capacity in existing casthouses equipped with Hycast™ GC is more than 2 million tons per year. The diameter ranges from 152mm up to 405mm (6"-16"). The Hycast™ GC produces excellent and consistent metal quality in combination with high productivity, excellent metal recovery and low maintenance cost.
The technology is now available for the aluminium industry also outside Hydro Aluminium. This paper describes the main technical achievements of the technology with focus on operational issues such as Health, Safety and Environment (HSE), metal recovery, metal quality and productivity. The focus on HES in Hydro Aluminium casthouses has been a driving force for developing a reliable casting technology with a high automation level. The casting control system has been designed to minimize manual operation during start and stop of cast, maintaining exact control of all important casting parameters including a proven and documented emergency stop philosophy.

Introduction

Hycast AS was established in 1990 as a spin off company from the Hydro Aluminium RTD Centre (Research and Technology Development) in Sunndalsøra, Norway. During the years Hycast has developed and commercialized a range of production equipment for aluminium casthouses. Main focus area have been equipment for melt treatment and casting, but the product range today also covers launders for molten metal transfer, rod feeders for addition of grain refining, casting machines, automation systems and special maintenance equipment.

Development of a new casting technology for extrusion ingots started in 1985 when ÅSV (now a part of Hydro) bought a technology license from Showa Denko. The patent from Showa Denko (1) covered a technology for hot-top casting of extrusion billets where gas (air) were introduced into the mould. The casting system produced billets with a reduced segregation zone and an improved surface quality compared to the traditional open spout and float system based on open moulds or the hot-top moulds used in the casthouses.

The Hycast™ Gas Cushion Billet Casting System was introduced to Hydro Aluminium (and partners) casthouses in the beginning of 1990, and was included in Hycast product portfolio from 1991. Today the casting systems is used in both primary and remelt casthouses, and a total of more than 100 casting tables have been delivered. Total tonnage of metal casted with the system is more than 2 million tons per year. Figure 1 show a casting machine equipped with the Hycast™ Gas Cushion (GC) Billet Casting System.

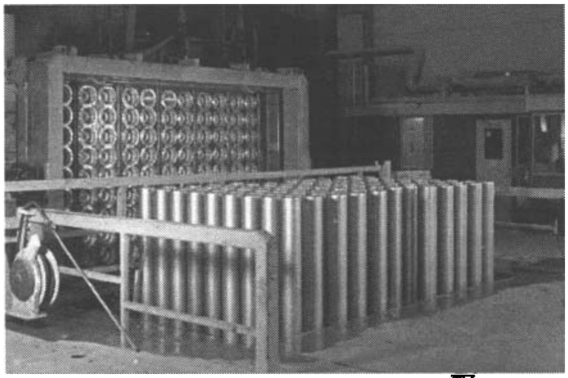

Figure 1. Casting machine equipped with Hycast™ Gas Cushion Billet Casting System in a Hydro casthouse.

Equipment design

The Hycast™ GC technology is based on a mould construction with patented dual graphite rings (2) for supply of gas and oil to the mould wall. The upper ring distributes the casting oil into the mould while the lower graphite ring distributes the casting gas. Special seals and surface treatment are used between the two graphite rings to eliminate oil penetrating from the upper oil-ring into the lower gas-ring.
By the use of this patented dual ring design, we avoid that casting oil disturbs the supply of casting gas to the mould. As a consequence the mould will produce a constant billet surface and sub-surface quality and the need for gas adjustment during or between casts is more or less eliminated. An assembled Hycast™ GC mould can be observed in figure 2.

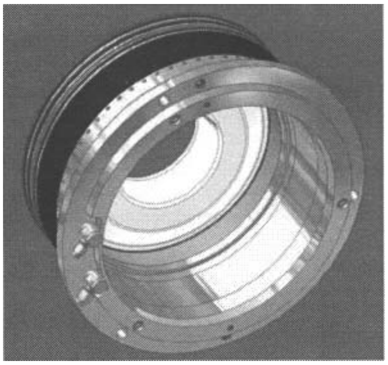

Figure 2. Hycast™ GC Mould.

When the mould is completely assembled with all its components, a pretest for oil and gas leakages is performed before the mould is mounted in the module based casting section. See figure 3.

Each casting section is equipped with a pneumatic dam that is automatically (or manually) opened during the start up sequence to ensure simultaneously filling of the moulds. Each casting section has a cabinet where the flow of gas and oil can be individually adjusted on each of the moulds.

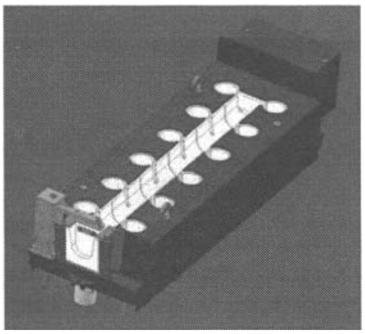

Figure 3. Module based Casting Section with moulds.

To build up the complete casting table, several of these casting sections are assembled on a common water-frame. Figure 4 shows the casting sections mounted on the water frame with metal distribution launder.

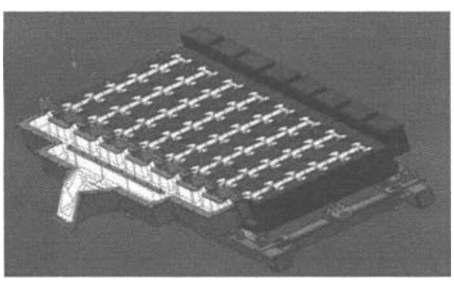

Figure 4. Casting table with casting section mounted on water-frame including metal distribution launder.

The distribution launder is used to control the flow of metal into each of the casting sections. This is particularly important on larger tables, where the design of the launder controls the metal flow into each of the casting sections, and thereby minimizes the metal temperature gradient between the moulds.
The mathematical model Alsim (3) has been used for optimizing casting parameters and mould design. Alsim has proven to be a powerful tool to simulate critical parameters effect on centre and surface cracks during casting, (4) and also to optimize launder design to minimize temperature gradients during casting startup and steady state. Figure 5 shows an ALSIM simulation of the temperature field in the distribution launder during casting.

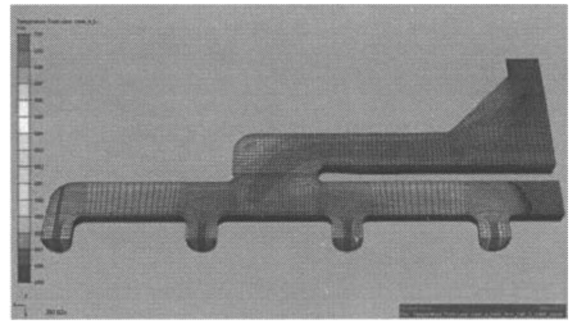

Figure 5. ALSIM simulation of temperature fields in distribution launder during casting (5).

Additionally the self centering starter blocks are assembled on a module based framework system. The starter block has a special design with a conical center part that effectively eliminates center cracks in the start up phase. (Figure 6)

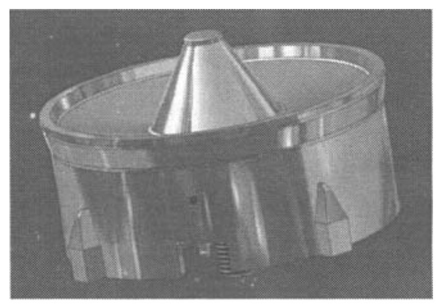

Figure 6: Hycast™ GC starter block

Due to the high automation level, the Hycast™ GC casting system is easy to use and very operator friendly. In combination with Hycast casting control system, both starting and stopping the casting sequence can be fully automated. Manual work during casting is reduced to inspections. After casting, manual work on the equipment normally includes cleaning of moulds / refractory and inspection of mould condition.

The open structure of starter block frame and base plate is designed to minimize metal buildup on equipment if a bleed out should occur.

To minimize downtime between casts the moulds can be equipped with an optional internal cooling circuit (6). This allows equipment cooling times down to 5 minutes before the table can be raised and the casting pit can be stripped for logs. Cooling will continue with the equipment in upright position to prevent damages on seals and o-rings.

Changing of casting table (from one diameter to another) may be a bottleneck in some casthouses. The Hycast™ GC is equipped with a quick exchange system allowing equipment to be changed within less than 20 minutes. The system is based on a combined lifting of casting sections and starter block frames by the overhead crane, and a "quick lock" system for fastening of both frames to the casting machine.

The diameter range for the equipment ranges from 152mm (6") and up to 405mm (16"), with standard diameter tolerances as defined in EN 486. Other tolerances can be delivered according to customer specifications.

The very dense packing of the mould allows for optimal utilization of the furnace capacity for all billet diameters. The normal setup is to empty the casting furnace in one drop. In some casthouses large capacity increases has been obtained when the number of drops pr furnace charge has been reduced from 2 to 1 by changing the casting equipment to the very dense packed Hycast™ GC casting system.

The highest number of moulds in one table delivered so far is a 152mm (6") casting table with 160 moulds.

HSE

When designing equipment for aluminium casthouses it is important to include "state of the art "knowledge regarding HSE. The recommendations given in "AA Guidelines For Handling Molten Aluminium" (7) have been extensively used to optimize both equipment design and procedures to minimize the potential for incidents during casting.

A main philosophy behind the equipment design has been to minimize operator's exposure to molten metal, and to minimize the risk for "bleed outs" during startup and stationary casting. Traditionally "casting start up" is the phase where most "incidents" take place. To minimize possible problems, it is important to minimize temperature gradients across the casting table, ensure even filling of all moulds and minimize the number of people close to the casting machine.

Mathematical simulations of the metal flow in the distribution launder and in the basin elements have been the basis for the metal distribution system used today. Validation in casthouses has proven that the short filling channels and the use of automated dams in the metal inlet are very effective to secure minimal temperature gradients during start up and casting. Typical filling times for the casting sections are < 5 seconds and the maximum temperature gradients in the stationary casting phase are reduced to < 10 °C.

Hycast has developed a standard safety philosophy for extrusion ingot casting which is included in the automation package.
Main principles are:

- Hard wiring of emergency functions
- Block and bleed of the liquid metal
- Fail safe function on all valves and critical components.
- Maintain cylinder downward movement in case of power outage.
- Emergency water from gravity tank.
- Use of explosion protective coating on all steel-frames below the casting moulds.
- Standardized precast checklist a prerequisite before startup.

Operational experience

Since the first implementation of the Hycast ™ GC Billet Casting System at Hydro Sunndal in 1989, the system is now implemented in 17 casthouses (both remelt and primary). The casting system and casting parameters have during the years been continuously optimized with regards to HSE, product quality, component lifetime, metal recovery etc., based on feedback from casthouses and input from Hydro RTD.

Pit recovery is a very important performance indicator for all casthouses. Minimizing casting scrap (surface scrap and internal cracks) has been a focus area for all casthouses in the Hydro group during the recent years. Today the average pit recovery when using Hycast™ GC casting system is above 99,5%, and plugging of moulds due to bleed outs is more or less non existent. Most casthouses has in fact completely stopped the practice of plugging of moulds during casting due to safety concerns.

The lifetime of refractory and graphite components in a casting system will have a large effect on the casthouse operational costs. It has therefore been an important issue to use component consumption data from the casthouses to optimize the design of all components included in the casting system.

Based on data from casthouses the average operational cost including all wear components and consumption items (casting oil, casting gas, refractory coating) is today less than 1 USD/ ton. Typical lifetime of hot-top rings is between 400-500 casts, while the graphite rings last for more than 1500 casts.

Operational experience from all users proves that maintenance routines are extremely important for maximizing pit recovery, minimizing operational cost and also for maintaining a consistent product quality. A well functioning mould maintenance workshop with a trained maintenance crew and equipped with the necessary tools is therefore one of the main keys to obtain consistant product quality and high casting line recovery.

Special training programs have therefore been developed to cover equipment operational practice, maintenance practice and operational trouble shooting. Based on feedback from casthouses these training programs are regularly updated and revised by Hycast.

Product Quality

It is well known that "State of the art" hot-top casting systems utilizing gas has several product quality advantages such as:

- Minimized surface segregation zone.
- Shallow shell zone.
- Even grain structure
- Smooth surface appearance
- Minimized oxide formation during casting
- Minimized/ no pre-solidification.
- Low surface porosity.

In the early days of hot-top casting, poor casting parameter control could lead to casting defects due to solidification towards the hot-top (Bergmann zones and cold shuts).
The casting speed for hot top casting is higher than open mould systems, and therefore the tendency of center cracking could also

be higher. With the automated systems for parameter control used at modern vertical DC casting machines in combination with high quality grain refiners and a maximum specification limit for Na contend in the liquid metal, these problems are now more or less none existing.

Typical average inverse segregation zone thickness for billet diameter 203mm (8") is ~100microns for a 6xxx-alloy. Due to the effect of the casting speed the inverse segregation zone will increase approximately proportionally with billet diameter.

Conclusions

The Hycast™ Gas Cushion Casting System has been in use in Hydro and Hydro partner casthouses for more than 20 years. The casting system has been continuously modified and improved based on input from the casthouses.
The Hycast™ Casting System produces high quality extrusion billets with an excellent surface quality and with excellent extrudability.
Annual production capacity on existing equipment is more than 2 million tons per year.
The casting system is characterized by:

- Patented dual graphite ring system for supply of oil and gas to the moulds.
- Superior safety track records.
- Very high pit utilization (Dense packing of moulds)
- Excellent pit recovery
- Excellent and consistent surface quality.
- Fully automated casting sequence is available in combination with Hycast Casting control system.
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The Hycast™ Gas Cushion Casting System is now available for casthouses outside the Hydro group.

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