

The application of KALPUR* direct pour technology in the production of safety critical steel construction castings

Introduction

The Olympic Stadium in Berlin is being renovated in readiness for the Football World Championships in 2006. Its design will be in keeping with that of a cultural monument yet at the same time cater for all the demands placed on a modern stadium. After completion, the stadium will have 76,000 covered seats. Until now the stadium has had a capacity of 75,000 seats but only 27,000 of these are covered by a roof (figure 1).



Figure 1: Model of the Berlin Olympic Stadium after reconstruction

The new roof has been intentionally designed to have a different tone to the existing architecture of the historic stadium; and will consist of a filigree steel construction with a roof membrane over it.

Only the roof over the Marathon Gate remains open so as not to obstruct the view of the bell tower.

The main supports of this steel construction are steel casting clusters welded together with either pipes or solid material.

The key advantages of steel castings over welded and screw-fixed components for construction are:

- ❑ The accurate production of even the most complicated geometrical cluster shapes is possible

- ❑ Steel casting components can be optimised in their shape and wall thickness in accordance with load bearing requirements.
- ❑ Sharp corners and edges and variation in wall thicknesses can be virtually eliminated, thereby reducing stress concentration to the lowest levels. This is a decisive advantage for construction components subject to material fatigue.

For these reasons, steel casting construction components are normally used for cable net structures, roof supports, pedestrian bridges, road and railway bridges as well as stadia such as the Berlin Olympic Stadium as described above.

Steel castings were originally used in the roof of this stadium for the Olympic Games of 1972. The castings for the new roof are being manufactured by the Friedrich Wilhelms-Hütte (FWH) steel foundry in Mülheim, Germany, who have been manufacturing castings for bridge, hangar and roof constructions for many years.

FWH produced the first casting clusters for railway bridges in 1998/99 for the Humbold-Harbour Bridge in Berlin. Further major projects are the Lerther Railway Station in Berlin, the Nesenbachtal Bridge in Stuttgart, the Traunstein Bridge and hangars at the airports of Stuttgart and Leipzig.

Roof construction

The Berlin Stadium project comprises the supply of 254 different casting configurations with up to nine different exits and up to three additional connecting latches. The alloys used for the castings are G20Mn5V and G18NiMoCr3.6V (figure 2).

Alloy G18NiMoCr3.6V with a wall thickness of 290 or 350 mm was chosen for the casting clusters of the uprights and the connecting exits of the cluster numbers 1 and 2. All other exits have a wall thickness between 14 and 45 mm (figure 3).



Figure 2: Initial roof construction. Architects: von Gerken, Mang and Partner. Photo: Heiner Leiska

The following case study concerns a cluster with 6 exits – 3 latches and a wall thickness of 14 – 45 mm.

Pattern and Casting Data – Conventional Casting System

Several parts had already been produced with a conventional feeding and running system.

General Data:

Part description:	Node
Alloy:	G 20Mn5V
Dimensions	(mm) 1100 x 800 x 685
Nett weight:	(kg) 792
Poured weight:	(kg) 1298
Running/Feeding system:	(kg) 506
Moulding system:	Furan resin (quartz/chromite sand) Coating: MOLCO* 246FA4 – CERAMOL* 58
Cores:	alkali phenolic resin (quartz/chromite sand) Coating: MOLCO 246FA4 – CERAMOL 58



Figure 3: Casting cluster with cross-struts

Gating and Feeding Data:

Downsprue:	1x dia 80mm
Runner:	1x dia 80mm
Ingates:	2x dia 60mm
Filters:	none
Feeders:	KALMINEX* X 12 - 500mm high (Modulus = 9.4)
sleeves	

Casting Data

Casting temperature:	1610°C
Casting time:	24-25 seconds
Casting vessel:	4t and 6t bottom pouring ladle – nozzle diameter 70mm
Melting furnace:	Arc furnace followed by VARP converter

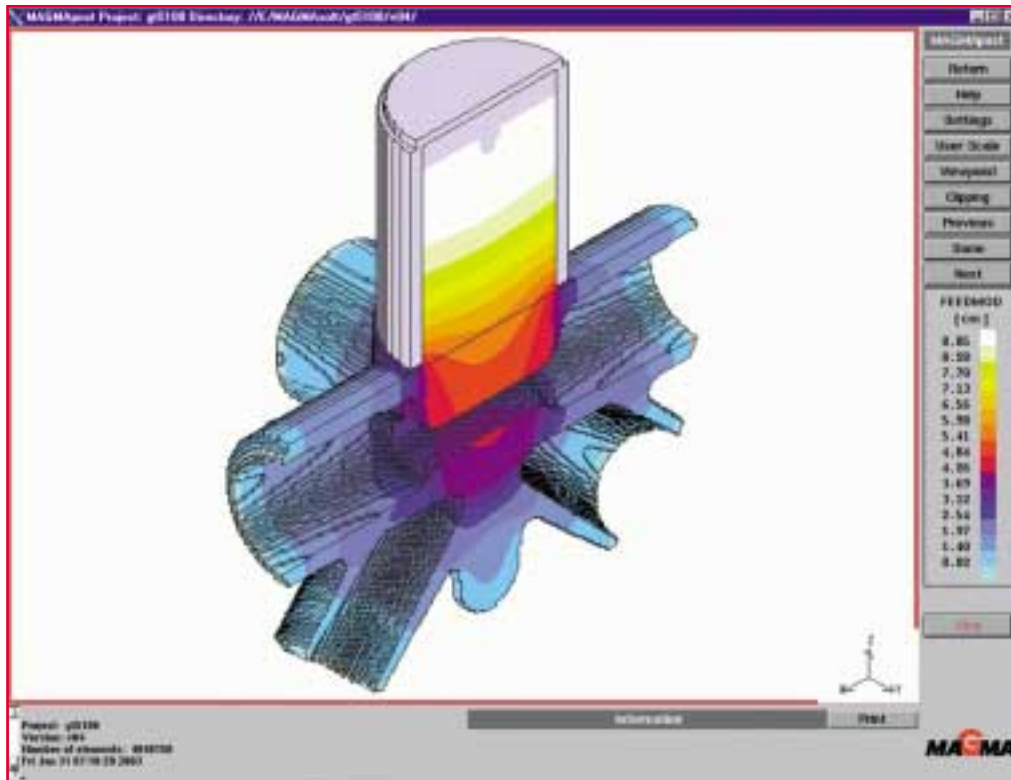


Figure 4: Computer simulation of solidification

A computer simulation of solidification was carried out before production, which resulted in the feeding method described above (figure 4).

Alternatives to the Conventional Casting System: KALPUR* Direct Pour Technology

It was suggested to cast the aforementioned cluster with the FOSECO patented KALPUR direct pour technique. The following is the technical data of the KALPUR direct pour casting product incorporating a STELEX* PrO filter.

Application of KALPUR direct pour units:

The FOSECO KALPUR product combines the use of feeders and filters and can replace the entire conventional casting runner system, as the mould is filled directly via the feeder. Because ingates are not necessary and filling is carried out into a suitable section of the casting, a directional or controlled solidification of the casting is achieved or improved.

KALPUR direct pour units can either be positioned on top of the casting or used as a side feeder head.

1. Hand moulding and simple moulding machines

Open, neck-down shaped KALPUR direct pour units are used for this purpose and have a supporting surface on which the filter is located. They are either placed on the pattern or inserted later into the cavity created by an insert dummy. KALMINEX 2000 exothermic-insulating feeders are used for iron and steel castings up to a modulus of 4.3 cm. The neck-down KALMINEX TA feeding range is

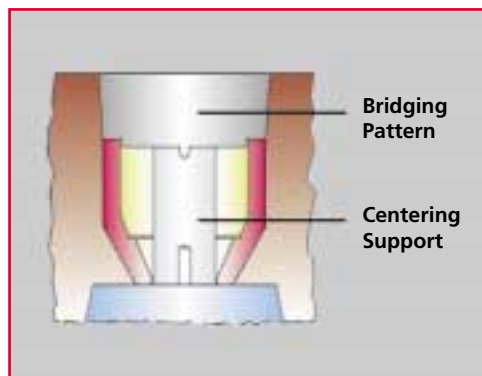


Figure 5: Ram-up style with a fixed centering peg and a loose dummy reaching up to the cope

suitable for larger castings produced with the KALPUR direct pour units (figure 5).

2. Automatic moulding line with horizontal and vertical parting

Use of the insert sleeve method enables highly-automated repetition foundries to take advantage of KALPUR direct pour unit technology but will not be described here.

STELEX PrO Steel Filter

STELEX PrO is a new generation of ceramic foam foundry filters which have been developed especially for the filtration of carbon and low-alloy steels. Even materials such as manganese steel can be cast without problems. However, it is not recommended for steels with a carbon content below 0.15% or for high alloy stainless steels (figure 6).

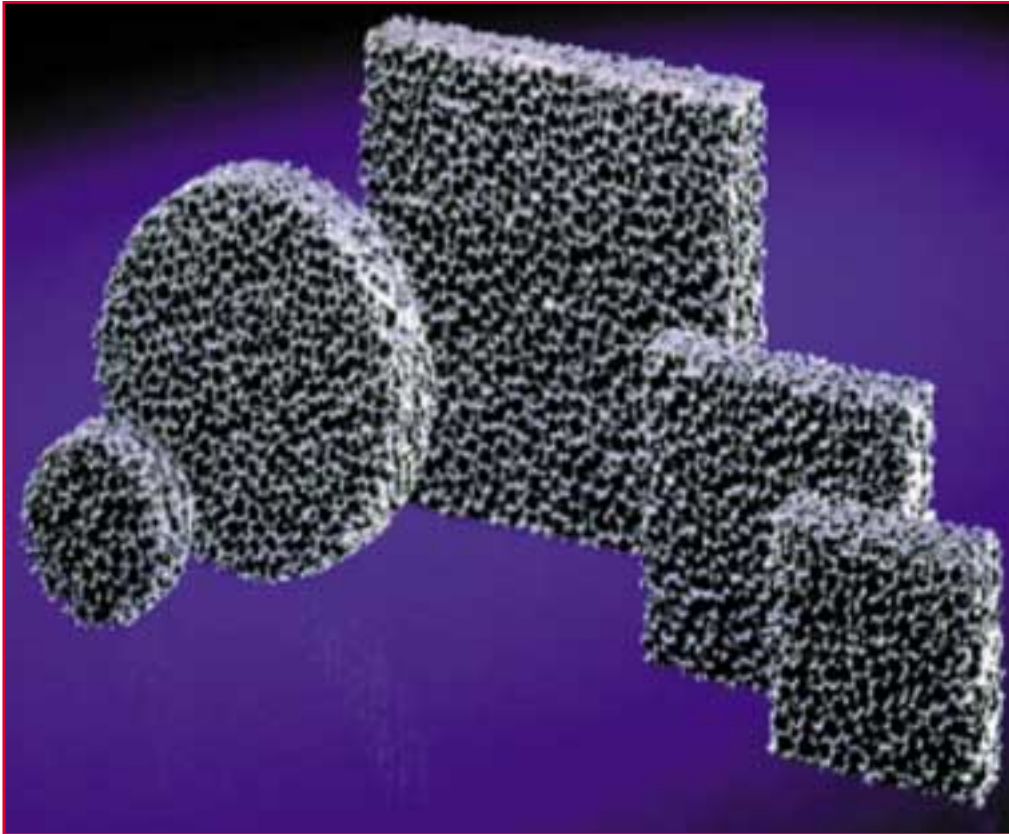


Figure 6: The STELEX Pro filter

Some of the advantages of the STELEX Pro filters include:

- Consistent "Priming" even when pouring temperatures are low such that pouring temperatures normal for conventional gating systems are possible.
- Reduction of temperature related inclusions.
- Higher filtration capacity
- Excellent flow rate characteristics compared to zircon ceramics
- Flexible filter positioning - the filter can be placed horizontally and vertically and is ideally placed at the ingate
- The use of finer porosity filters is possible.
- When used in the KALPUR direct pour system the filter will easily float to the feeder surface after pouring, reducing the risk of secondary shrinkage and maximising feeding efficiency
- No difficulties during remelting of returns containing STELEX Pro filter material
- Lower energy costs
- Lower refractory materials costs

Clusters cast with KALPUR Direct Pour method

Because of the positive experiences with the KALPUR direct pouring unit, the suggestion to try to produce the cluster using this method was accepted.

The first step was to create a computer simulation of the mould-filling and solidification in order to ascertain its feasibility. The simulation results indicated a successful result and casting trial was planned (figure 7).

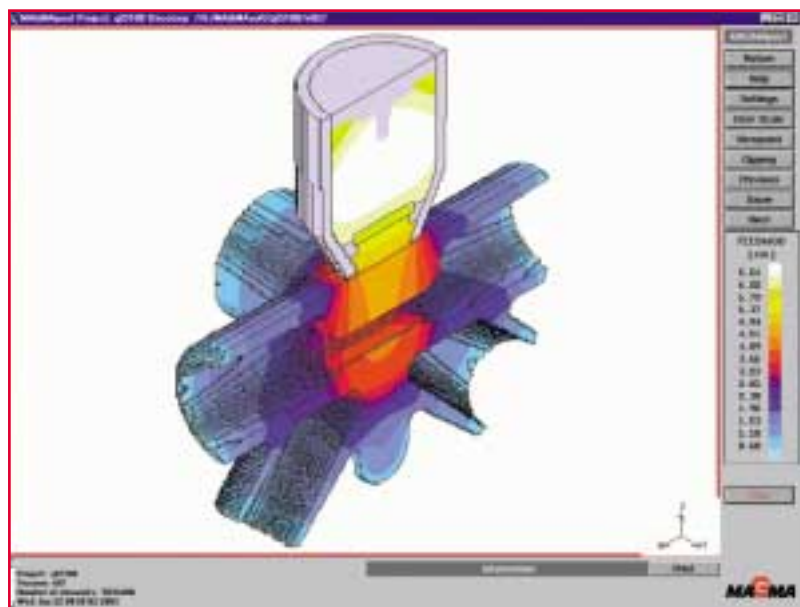


Figure 7: Computer simulation for solidification

KALMINEX TA 11 feeder sleeves were chosen as the feeder, but since the height of feeder was not sufficient a KALMINEX X 12 feeder sleeve was placed on top of it. A STELEX PrO 200 dia x 40mm /10ppi filter was used.

The neck aperture of the feeder sleeve posed the risk of the filter being washed into the mould by the high ferrostatic pressure. To prevent this a shell sand core was used to provide a defined base for the filter.

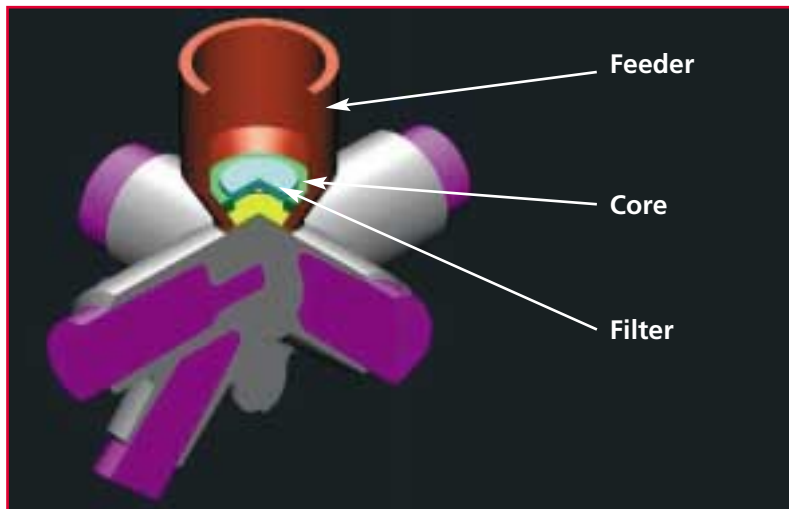


Figure 8: CAD illustration of casting method

The pattern was specially designed for use with the KALMINEX TA 11 feeder sleeve. This sleeve has the advantage of a base area four times less than the KALMINEX X 12 feeder sleeve – this also means that cutting and fettling costs are significantly reduced (figure 8).

Casting Data KALPUR- Direct Pour Method

Casting temperature	1612°C
Casting time:	23-24 seconds
Casting vessel:	6 tonne bottom pouring ladle 70mm nozzle diameter
Moulding/Core practice	no change

The filter floated upwards immediately after casting and could be removed. Figure 9 shows the upper side of the filter after casting.



Figure 9: Filter after casting

The filled feeder, open at the top, was covered with FERRUX* 707G – an exothermic, expanding powder. Covering the feeder with a suitable material is of prime importance for the KALPUR direct pouring system. Using FERRUX exothermic expanding powder, the dual effect of heating and insulation of the feeder surface facilitates the longest effect of the atmospheric pressure on the molten feeder metal. This leads to optimum use of the feeder, improvement of the later interdendritic feeding and consequently to a reduction of secondary shrinkage.

After removal, shotblasting and fettling of the cluster, a cost comparison – conventional casting method vs. direct pour method – was carried out.

Costs	Conventional Method	KALPUR Method
Molten material	100.0%	87.4%
Core-shop	100.0%	100.0%
Moulding	100.0%	97.3%
Pre-fettling/sandblasting	100.0%	80.1%
Manual cutting	100.0%	65.1%
Arc Air	100.0%	88.1%
Initial grinding	100.0%	81.1%
Final fettling	100.0%	94.7%
Tolerance grinding	100.0%	100.0%
Heat treatment	100.0%	100.0%
Finishing	100.0%	29.6%
Production costs of raw casting	100.0%	82.9%

Figures 10 and 11 show the cluster after sandblasting, fettling and heat treatment.



Figure 10



Figure 11

The finished casting passed the customary ultrasonic inspection tests.

Conclusions

The example described above illustrates a significant reduction in production costs, most noticeably in the fettling shop.

Furthermore a significantly better casting surface can be achieved compared with conventional casting methods, especially where the new STELEX PrO ceramic foam filter is used.

Depending on the geometry of the casting and the arrangement of the patterns in the mould, not all castings are suitable for the KALPUR direct pour technique, and a feasibility study should be carried out beforehand.

The ability to manufacture high-quality castings whilst paying attention to economic and environmental pressures is a pre-requisite for a successful position in the market for many manufacturers. Demands are placed, especially in industrial Europe, for continuous improvement in productivity and the development of new and innovative production processes.

The KALPUR direct pouring technique is just such an innovative production process, offering the foundry industry the following advantages:

- direct pouring of the casting
- complete elimination of conventional running systems
- directional solidification is improved or achieved
- increased yield
- reduction of fettling and grinding costs
- reduction of casting temperatures
- removal of fine inclusions

References:

Herion Mang Stahlbaukalender, Guß im Bauwesen S. 641 / Ausgabe 2001

Karl-Josef Müller, The stadium roof for the football World Cup consists of 254 cast nodes.

Glück auf – Internal magazine of the Georgsmarienhütte Group; Edition: April 2002, page 20

STELEX PrO brochure, June 2003

KALPUR Direct Pour brochure, May 1999