



CUNOVA



Textured Mould Tube

INNOVATION & TECHNOLOGY



MELTING & CASTING
TECHNOLOGIES

CONTENT

The Company	03
Textured Mould Tube	04
Function of the Textured Mould	05
Report: Textured Mould for improved Casting Performance	08

The Company

cunova's corporate goal is to develop and manufacture products that meet customer demands, finding solutions for their specific applications, and providing services as a long-term partner. cunova's strategy for accomplishing this goal is based on a highly skilled and experienced workforce. cunova has the ability to invent and develop new materials and innovative production processes via ongoing advancement and training of our employees and the continual improvement of its organisational structures.



CUNOVA

AMT® ADVANCED MOULD TECHNOLOGY

Textured Mould Tube

Challenge

- Controlling mould heat removal to improve billet shape and product quality

Solution

- Macro texturing on mould hot face in upper zone

Application

- All mould tube types

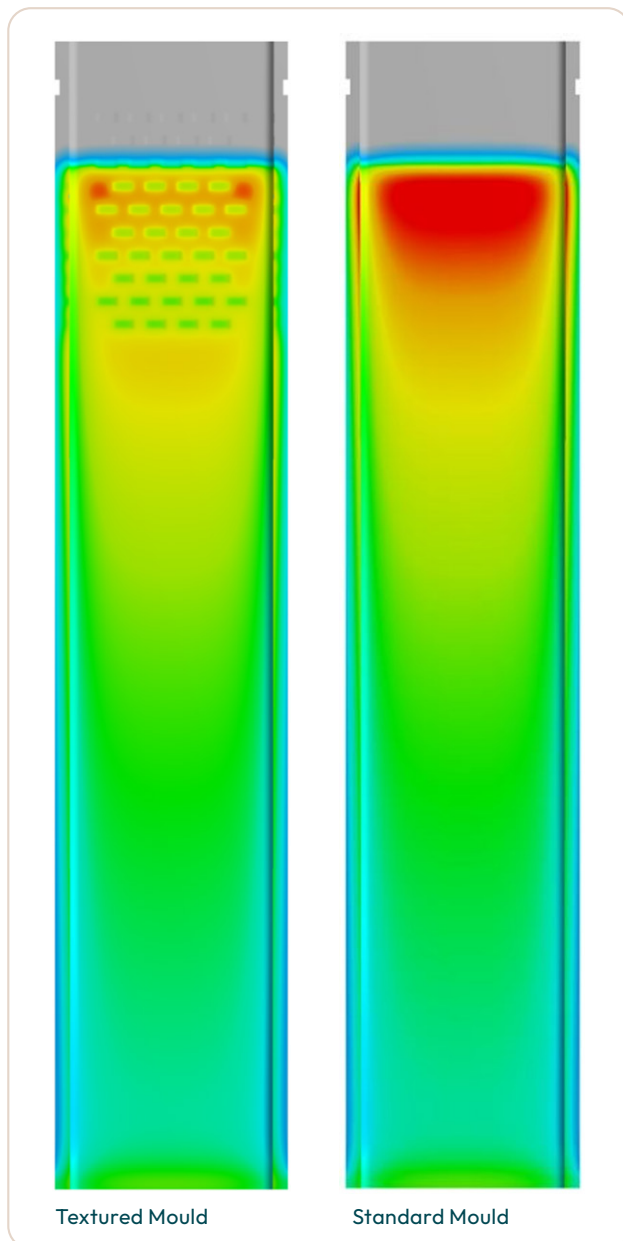


Function of the Textured Mould

An inhomogeneous shell growth inside a mould could be one reason for uneven wear and will have a negative influence on the billet quality.

The heat transfer of a standard mould tube is not linear over the whole mould length. Consequently, the shell growth is inhomogeneous as well.

The textured mould tube has been developed in order to achieve a homogeneous heat transfer with the target to produce a high quality billet. The textured structure improves the effect of lubrication. During casting, the slots are filled with cracked oil or casting powder. Moreover, the texture itself reduces the heat transfer and harmonizes the shrinkage of steel from top to bottom. Please see attached graph.



Advantages

- Moderated heat transfer in specific areas of the mould
- Improved product quality due to more uniform shell growth
- Reduced billet rhomboidity
- Increased mould life due to reduced thermal load

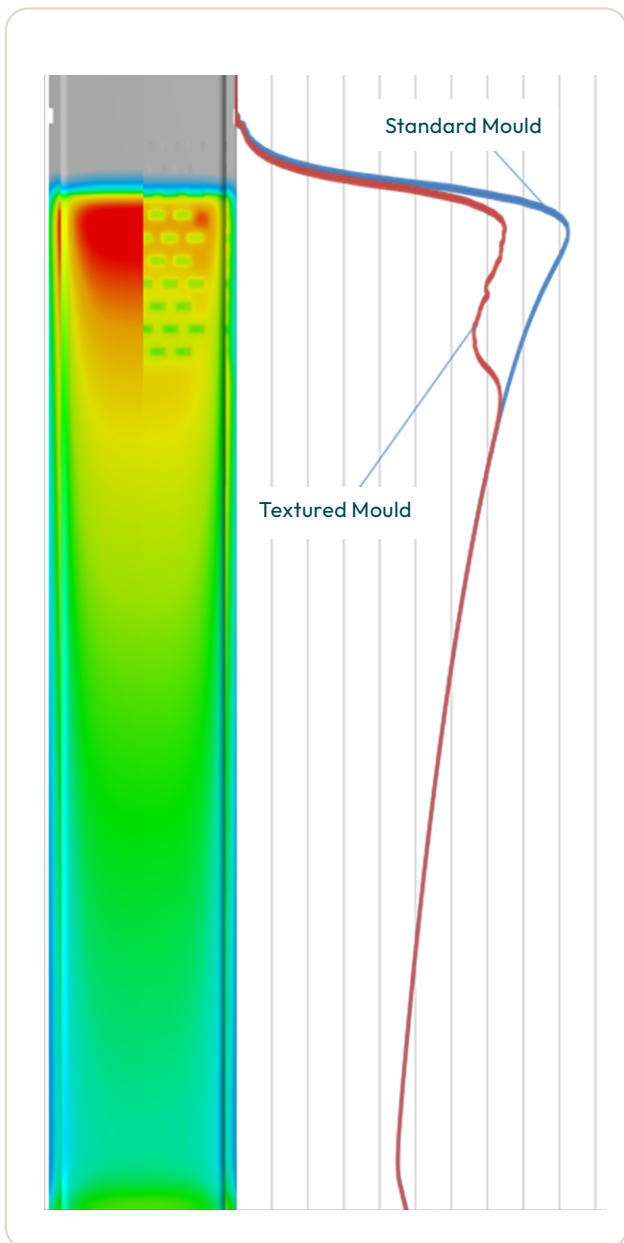
Results

Due to the isolation effect, the thermal stress of the mould at bathlevel area is reduced. Therefore, the negative effect of harmful elements (Zn, S) will be reduced as well, resulting in a substantial higher lifetime.

Billets show much lower rhomboidity; less hinge cracks have been detected. On top, the improved billet shape consequently results in less mechanical wear of the mould tube, i.e. in increased mould life.

More than 90 steel plants worldwide are presently using cunova textured mould tubes with more than 100 section sizes.

Function of the Textured Mould



Extract of achieved Casting Results:

Russia	150 mm sq + 60 %	Standard Texture	Ø 550 heats Ø 885 heats
USA	140 mm sq + 20 %	Standard Texture	Ø 1400 heats Ø 1700 heats
Brazil	130 mm sq + 60 %	Standard Texture	Ø 750 heats Ø 1200 heats
South Korea	130 mm sq + 140 %	Standard Texture	Ø 350 heats Ø 850 heats



Textured Mould for improved Casting Performance

Arndt Thiele / Dietmar Kolbeck- cunova GmbH

A new mould hot face topography that incorporates specific areas to moderate heat transfer and control the shrinkage of steel has been developed and tested for steel continuous casting applications. This new design, called the Textured Mould, utilizes an agglomeration of low conductivity material in key zones in the mould for heat transfer moderation. As a result, improved billet quality and mould life are obtained. The new design can be used with all standard copper alloys as well as coatings and is compatible with existing billet or bloom casting equipment.

Introduction

Since the initial days of continuous casting, a major quality concern for long products are geometry problems such as rhomboidity and depressions. These geometry defects result from inhomogeneous heat transfer affecting the shell growth. Literature and calculation had already proven the observation of caster operators, that the cooling in the mould is different in certain areas³. These different heat extractions especially from top to bottom result in an inhomogeneous shell growth along the length of the mould tube and in case of rhomboidity in a non-uniform shell growth over the cross section.¹

Casting flux is a proven tool for changing the heat extraction in the top part of the mould as is needed. Casting powders with different properties are available to adopt the heat transfer to the steel grade and its shrinkage behaviour^{2,3}. Considering this, mould powder casting is superior with respect to the billet or bloom and steel quality. However, the lower cost of oil lubrication, which was the lubrication since the start of continuous casting makes it still used all around the world.

¹ Definition and causes of continuous casting defects. ISI publication 106

255 pp 262-279

² Metallurgie des Stranggießens Prof. Dr.-Ing K Schwerdtfeger pp.242-

³ Stranggießen von Stahl Hans Schrewe, pp. 104-109

Texture Design Concept

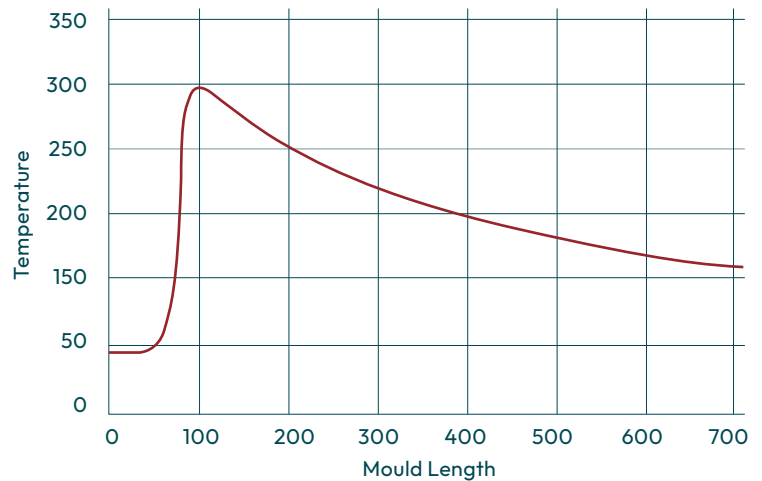
The heat transfer of a standard mould tube is not linear over the mould length. Consequently, the shell growth is inhomogeneous along the casting direction as well. In case of oil casting, the hot melt is provided via open stream pouring, resulting in a high thermal load in the meniscus and therefore the highest copper temperatures below the meniscus. The reason for this thermal load peak is the thin shell with its good contact to the wall, giving very good heat transfer.

The attached graph of a thermal calculation shows the copper temperature over the length of a standard mould tube during casting including the extreme temperature peak below the meniscus level.

Figure 1

Hot face temperature of standard mould tube vs. the mould length

— Standard mould tube



An inhomogeneous shell growth inside a mould is one reason for the negative impact on billet quality. A billet with such uneven shell thickness and its tendency for twisting creates an uneven wear inside the mould tube so that its lifetime will not reach the maximum potential.

Out of this knowledge, the task was generated to develop a mould tube with a moderated heat transfer in specific areas, in order to achieve a more homogeneous shell growth over the mould length. Therefore, the target is to produce a high-quality billet by smoothing the heat peak in the top part of the mould, without influencing the total shell thickness at the exit of the mould tube.

The physical properties of copper alloys (such as CuAg) with its drop in hardness at high temperatures is taken

into consideration. For protecting the copper against overheating, all design changes of reducing the heat transfer have to be made on the inner surface of the mould tube. Otherwise, with a significant reduced heat transfer from the mould into the water, the copper temperature will increase and might reach the softening or recrystallization temperature when copper changes its physical properties. For example, the hardness will drop and a plastic deformation will occur much earlier. A worst-case safety scenario would be a collapsing mould with water penetration into the liquid steel. Therefore, the target of heat transfer reduction at the hot face is reached by creating specific areas for moderation. This changed heat transfer from the steel to the mould improves the mentioned problems like the heat peak and the resulting inhomogeneous shell growth.

Texture Design Concept

Using the texture, the idea is to influence the heat transfer by working with the material available in the mould such as air, lubrication (cracked oil) and FeO₃ etc. The thermal conductivity of this combined material is much less compared to copper.

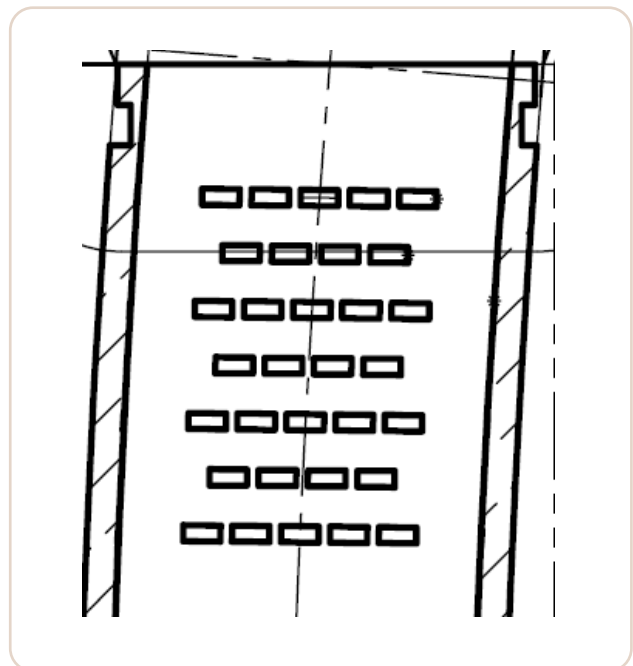
To utilize this resource of low conductivity material as an active heat transfer moderating tool in casting, cunova brought in areas of specific topography at the mould top (Fig. 2). By thus changing the heat transfer directly at the steel shell, an increase of the copper temperature can be avoided.

For example:

CuAg	≈ 377 W/(m·K)
Casting Oil	≈ 0.16 W/(m·K)
Casting Powder	≈ 1-2 W/(m·K)
Air	≈ 0.025– 0.081 W/(m·K)

Figure 2

Agglomeration areas in the top of a textured mould tube



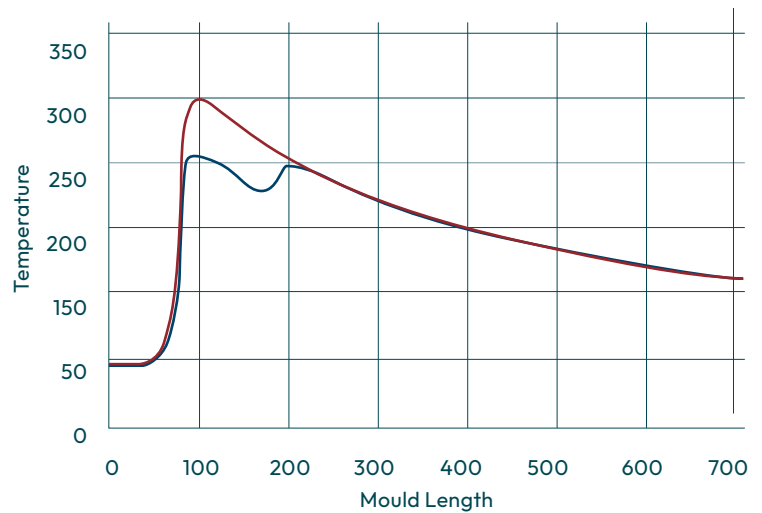
This deliberated zone of low conductivity material reduces the heat transfer and the heat absorption of the mould in such areas respectively and moderates the shrinkage of steel from top to bottom. In calculating the overall thermal conductivity, the heat peak is smoothed and the grown shell is created with less inner stress.

Please see below the graph of a thermal calculation comparing a standard mould tube and a textured mould tube (Fig. 3).

Figure 3

Hot face temperature in the middle of the faces of the mould tube vs. mould length (textured & standard)

- Textured mould tube
- Standard mould tube



Reducing the heat peak shown on the calculated graph above results in a low stress steel shell with less geometrical defects with a more homogenous contact to the mould and consequently the overall heat transfer will not drop significantly. For this reason, when looking at the cross section, the shell thickness at the exit of the mould tube is more homogenous.

The hot face temperature and the thermal stress of the mould at meniscus level decreases and prevents the copper mould tube alloy (such as CuAg) from overheating. In addition to the temperature reduction, the textured structure improves the effect of lubrication during casting as the slots are amongst other things filled with cracked oil, working as an oil/lubrication reservoir.

A calculation of standard mould tube with and without the texture (filled with oil) shows a decrease of approx. 25° C (from 300° C to 275° C which is about 10 %).

Texture Design Concept

Mould tube

Size: 160 mm x 160 mm
 Height: 800 mm
 Casting radius: 9000 mm
 Wall thickness: 13 mm
 Material: CuAg-GS
 Coating: neglected

Filler material inside the texture:

Casting oil: $\lambda = 0.16 \text{ W}/(\text{m}\cdot\text{K})$
 Air: $\lambda = 0.025 - 0.081 \text{ W}/(\text{m}\cdot\text{K})$

Thermal boundary conditions:

HTC (mould - strand): $6.43 - 2.7 \text{ kW}/(\text{m}^2\cdot\text{K})$ at $(1500 - 900 \text{ }^\circ\text{C})$
 Cooling water velocity: $\sim 10 \text{ m/s}$
 Cooling water temperature: $35 - 40 \text{ }^\circ\text{C}$

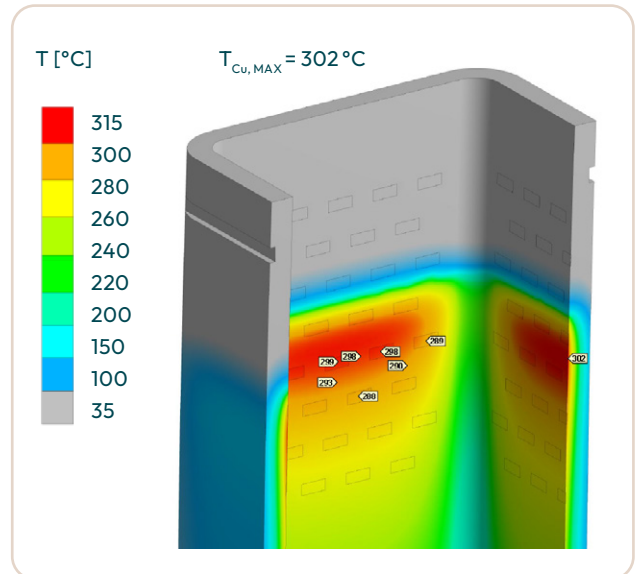


Fig. 4: Thermal calculation without texture

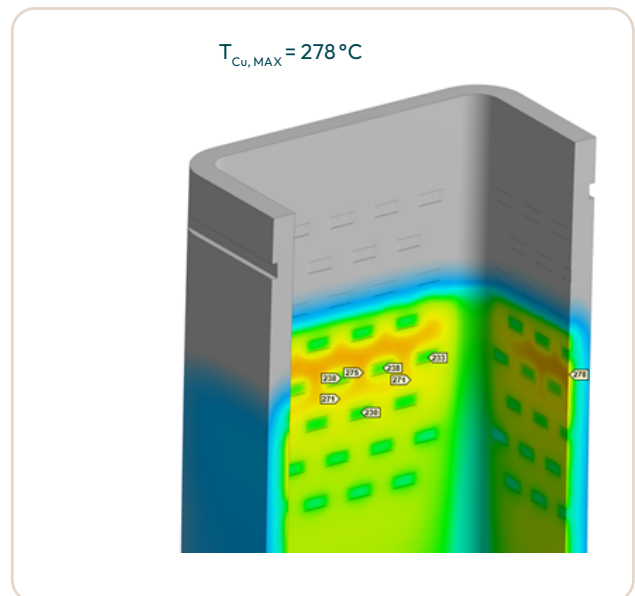


Fig. 5: Thermal calculation texture filled with oil

Another positive effect of a cut heat peak is the reduction of the diffusion process of harmful elements into the copper. The negative effect of harmful elements such as Zn and S is due to their behaviour in combination with copper. Zinc is a "tramp" element coming from the steel (scrap) that diffuses into the copper when exposed to high temperatures for a prolonged time. To reach the copper these harmful elements have to pass the

inner coating of the moulds. Most of the moulds for long product and open stream casting in use worldwide are only Chrome coated. This layer of about 0.1 mm thick electroplated hard-chrome does not stop the harmful elements because it contains a dense network of micro cracks. Due to the presence of these micro cracks, the zinc can diffuse into the copper quite easily.

Figure 6

Hard chrome with micro cracks

After penetrating the copper, the base material is damaged: Higher zinc levels in the steel and higher local temperatures lead to the development of hard and brittle (bulky) brass phases at the copper surface, which accelerate the development of chrome chipping and cracking to the ductile copper.

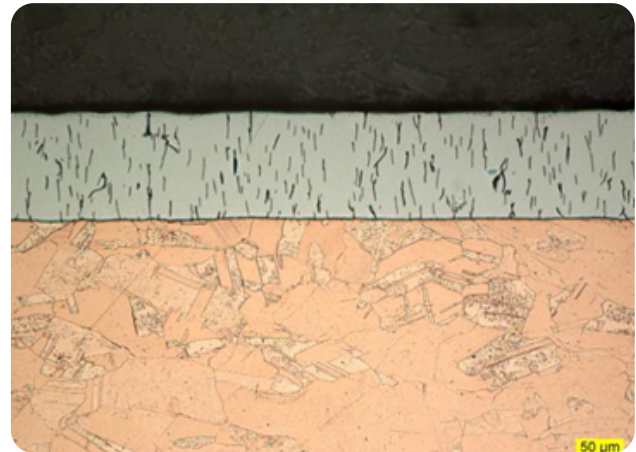
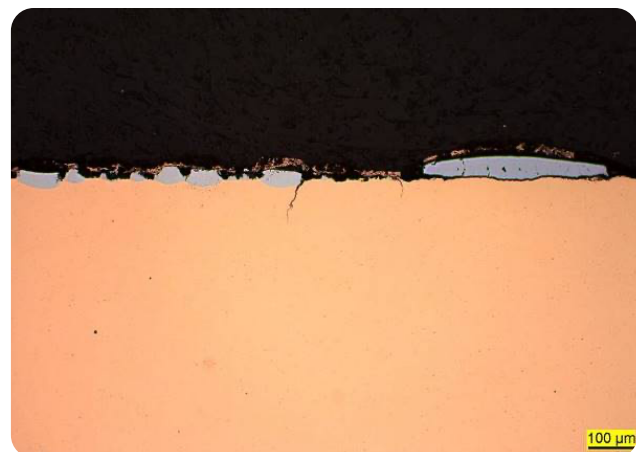


Figure 7

Slight brass formation on the exposed surfaces

Additionally, sulphur from the steel, or very often from mineral or synthetic casting oil, can penetrate through the chrome micro cracks into the copper. This penetration of sulphur in the copper damages the chrome due to the forming of voluminous, brittle copper-sulphides at elevated temperatures. Additionally cracks due to sulphur corrosion are generated.



Texture Design Concept

In addition, the very different coefficients of thermal expansion of Cr (~ $6 \times 10^{-6} 1/K$) and Cu (~ $17 \times 10^{-6} 1/K$) make things more complicate. Therefore, you can often find an enlarged macro cracking in combination with high thermal stress. That is the reason why low quantity of heats might be sufficient for this type of damage if the temperature is high enough.

Appreciable diffusion in solid material starts around $0.4 \times T_s$ (T_s = melting temperature in Kelvin) and increases exponentially at higher temperatures⁶. The most common mould material for long product casting is CuAg

with a melting point of $1083 \text{ }^\circ\text{C}$ ⁷. The resulting appreciable diffusion start temperature for this copper alloy is theoretically $269 \text{ }^\circ\text{C}$. The exponentially increasing diffusion is the reason that the damage of the mould tube in the meniscus area speeds up very fast at higher temperatures. Due to the lower copper temperature in the texture zone, the diffusion process is slower in that area, resulting in higher lifetime especially for scrap-based steel production. The combination of both factors, the reduced copper temperature and the moderated heat transfer in the top part of the copper mould, results in an excellent mould performance in continuous casting.

The delayed attack in the meniscus area can be seen by comparing a standard mould and a textured mould from the same machine in a mini mill after casting 1500 heats.

Size:	160 mm x 160 mm
Strands:	5
Radius:	6 m
Casting Speed:	approx. 2.8 m/min
Steel Grades:	Rebar
Ladle weight:	100 to

Thus both improved billet quality and increased mould lifetime are the reasons that the cunova textured mould is growing popularity around the world.

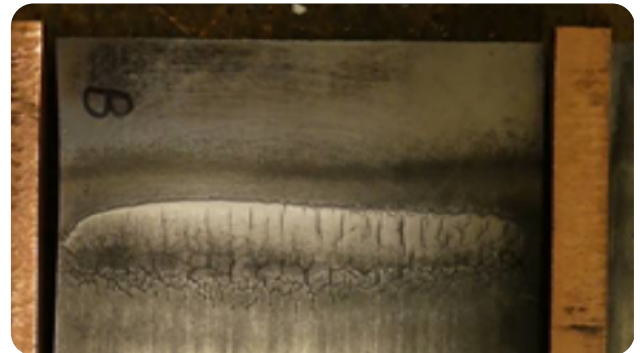


Fig. 8: Meniscus of moulds after 1500 heats

⁶ Handbuch Hochtemperatur Werkstofftechnik, Prof. Dr. Ralf Bürgel pp 18-19

⁷ DKI (Deutsches Kupfer Institut) Datenblatt





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