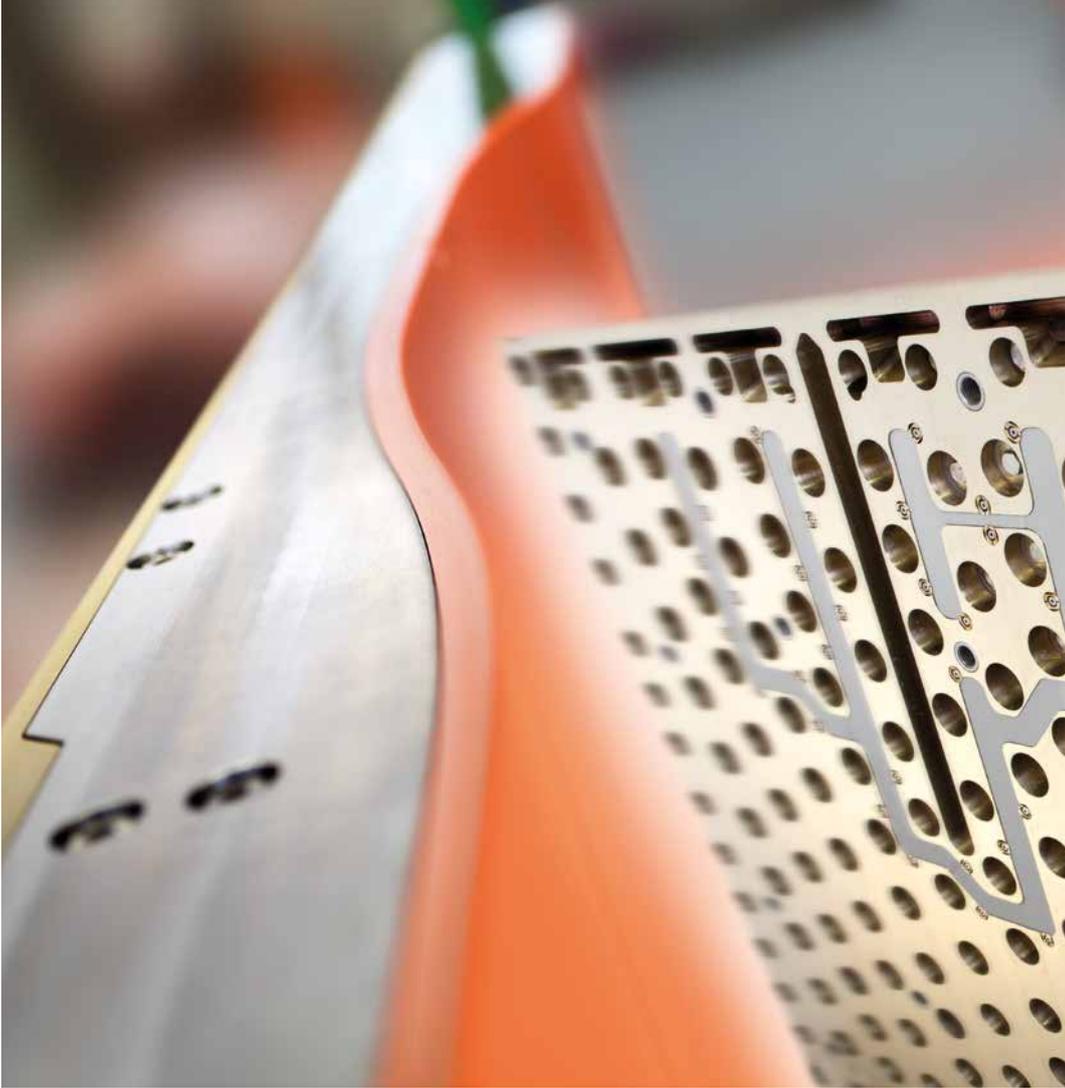


KME Germany GmbH & Co. KG
AMT® – Advanced Mould Technology
[GB]





AMT[®] – Advanced Mould Technology
AMM[®] – Advanced Mould Materials
AMC[®] – Advanced Mould Coatings



*KME offers a unique combination
of expertise and experience in all
key technologies for the production
of high-performance moulds for
continuous casting.*

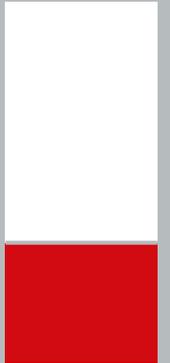
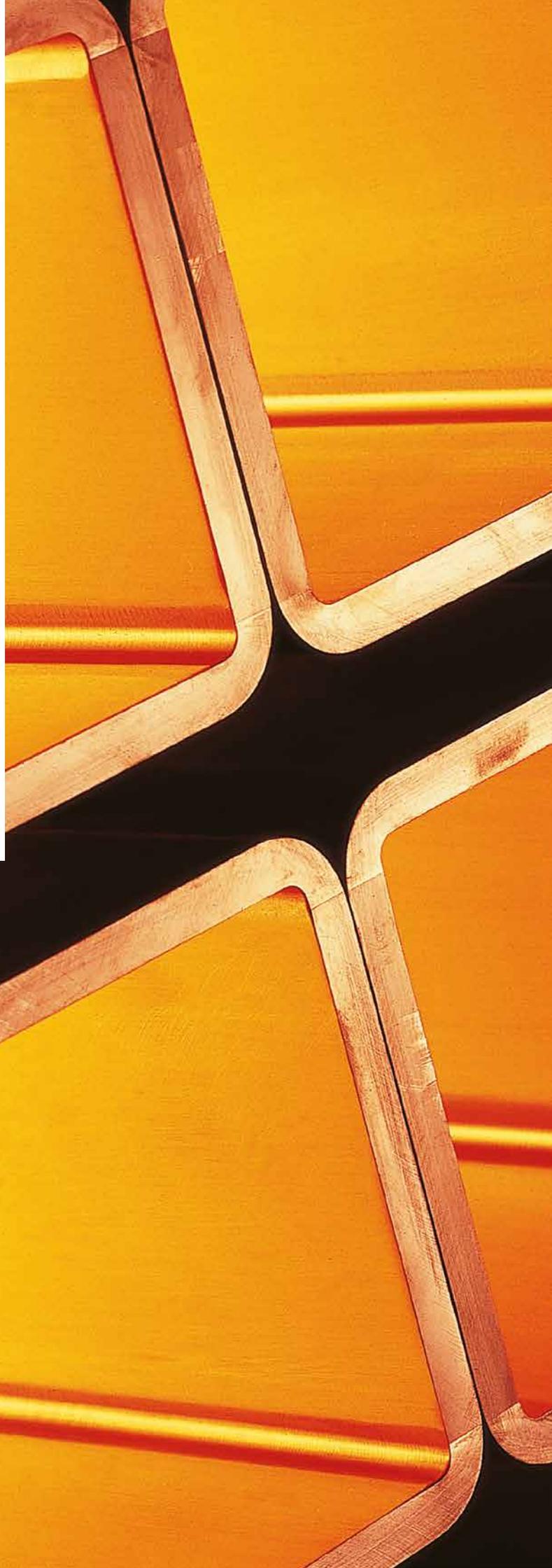


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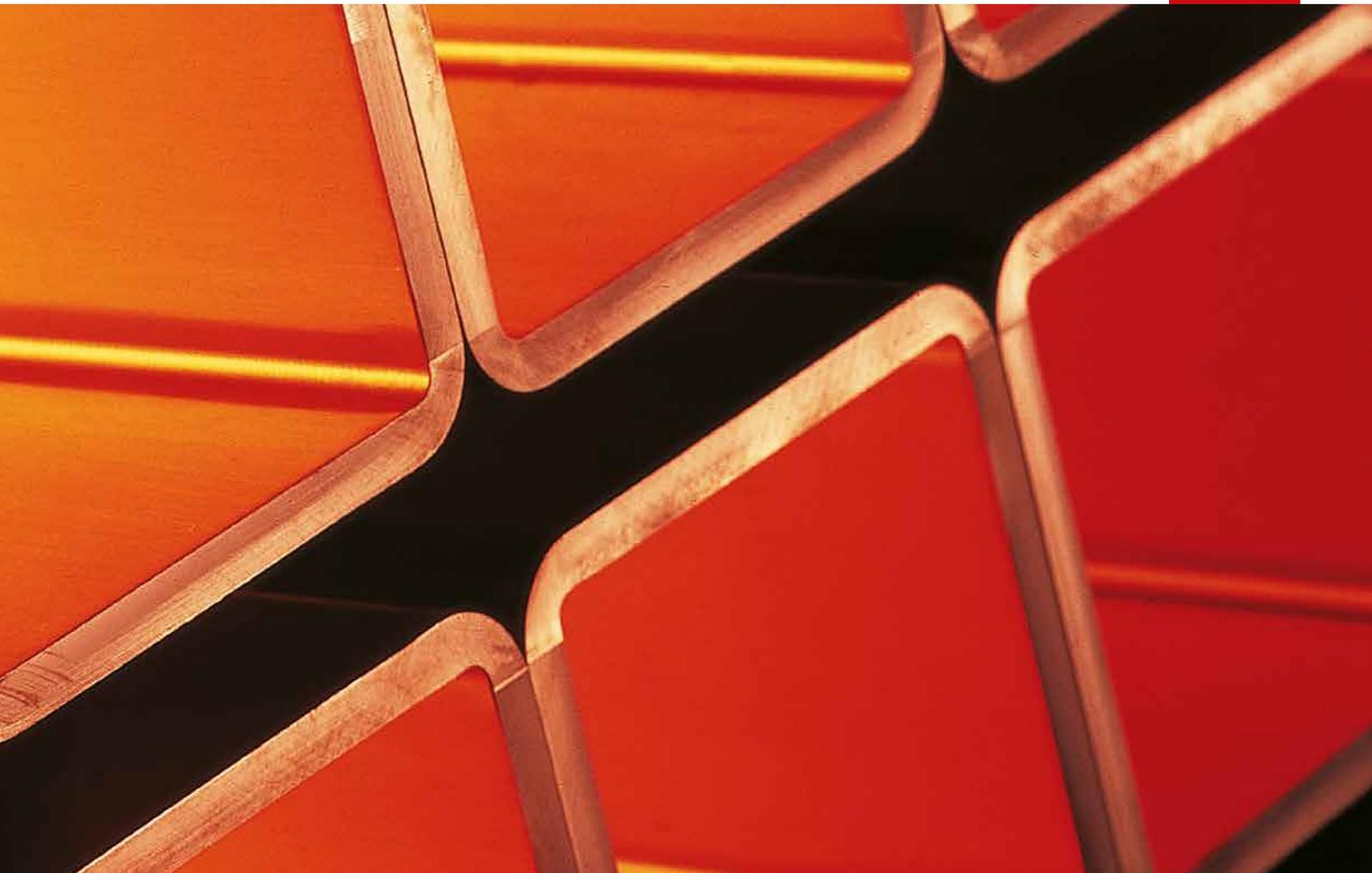


KME is one of the world's largest manufacturer of copper and copper alloy products. Today, KME employs nearly 4,700 people, manufacturing a wide range of semi-finished, finished and special products at locations across Europe and Asia.



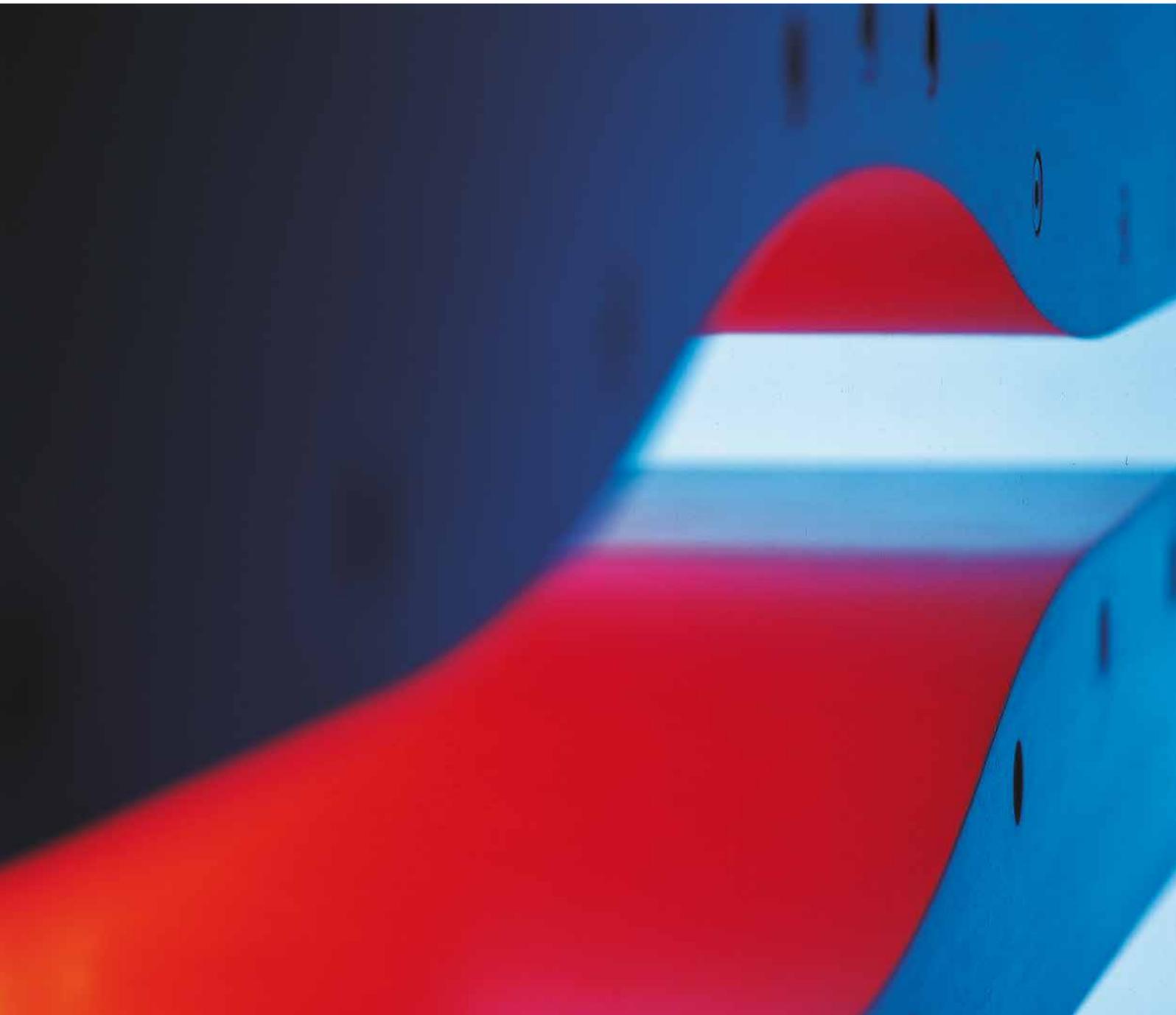
The Company

KME'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. KME's strategy for accomplishing this goal is based on a highly skilled and experienced workforce. KME 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 engineering capabilities.



Engineered products for melting and casting

The continuous casting of steel has seen major technological improvements over the past decades. This has led to considerable increases in productivity and product quality necessary to ensure survival in today's highly competitive environment. The Engineered Products Division of KME has been instrumental in achieving many of these process improvements.



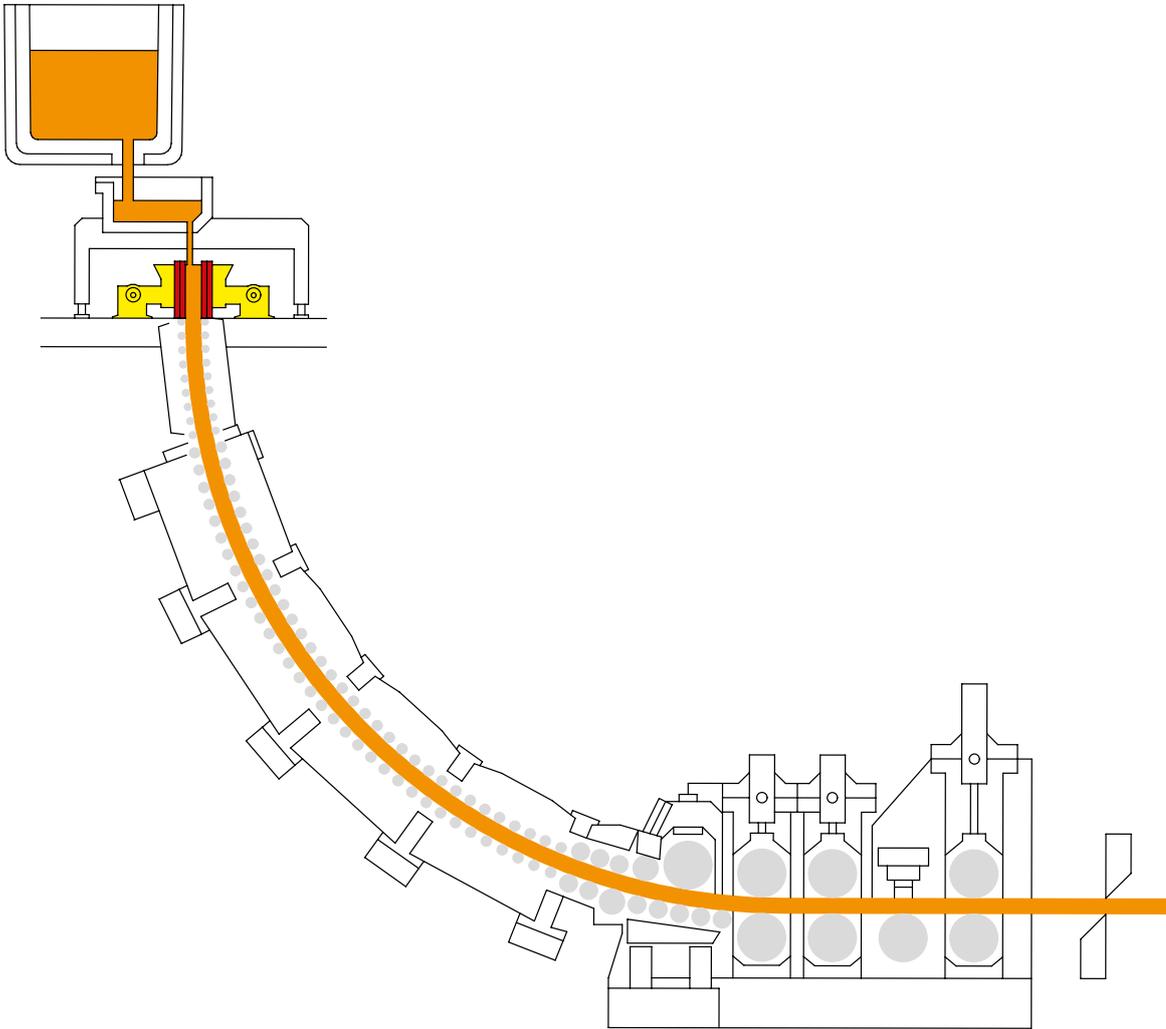


The advances in casting technology were made possible by the development of high-performance moulds made of copper materials. KME was involved in these activities right from the very beginning and has continued to set milestones in the development and production of copper moulds for the continuous casting of steel.

The Engineered Products Division was formed as part of a strategic reorganisation, with the aim of providing a flexible solution to market demands and improving the customer orientation of our business. Our customers are manufacturers of steel and nonferrous metals, casting machine builders and maintenance companies throughout the world.

The division not only serves our customers as a general contractor for the production of mould assemblies, but also as a partner in solving the many technological challenges in the field of continuous casting.

AMT® – Advanced Mould Technology



The performance requirements that have to be met by moulds and mould materials depend on the specific application and the levels of stress involved. These stress levels are mainly predetermined by the machine and casting parameters, which means that many different cast shapes are needed, depending on the type and construction of the mould. When designing a new mould, the correct profile must be chosen in order to achieve high product quality, optimal casting speeds, smooth casting operations and long service life of the moulds.



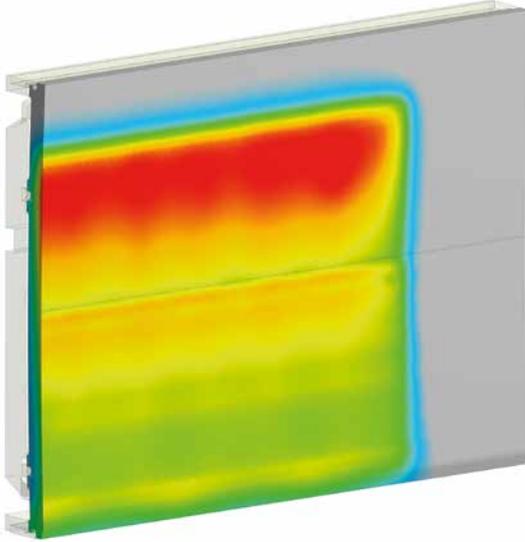
A good example of this are the requirements placed on modern mould materials for near-net-shape-casting processes which have been developed in recent years. Here, very high casting speeds are achieved and a much higher proportion of the liquid metal must solidify in order to form a sufficiently stable strand shell. The resulting extreme temperatures demand moulds with higher strength levels. At the same time, a high alternating thermal stress can occur, for example on casting rolls. This wide variety of requirements placed on moulds has to be met by highly developed materials and system expertise.

In order to be able to offer our customers future-oriented solutions for the wide variety of different casting technologies and taking into account the constantly changing requirements on moulds and mould materials, KME is conducting research in the following fields of mould technology:

- Mould engineering
- Mould materials
- Mould coatings
- Mould manufacturing

Unlike all other manufacturers, KME has all the key technologies for the production of high-performance continuous casting moulds under one roof. This unique combination of expertise, numerical simulation, calculation methods and long-standing experience in the field makes us a highly qualified partner in all mould related questions that arise.

AME – Advanced Mould Engineering & Design

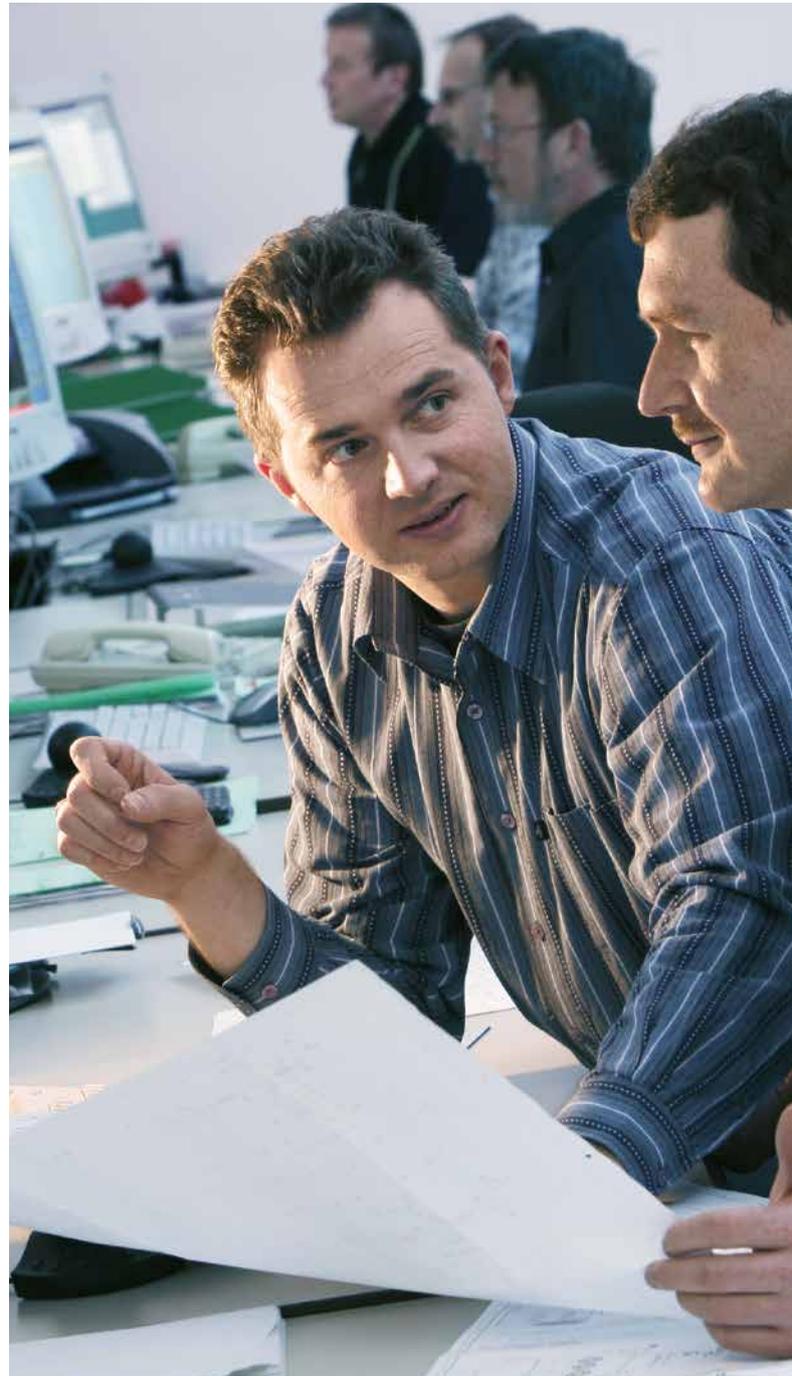


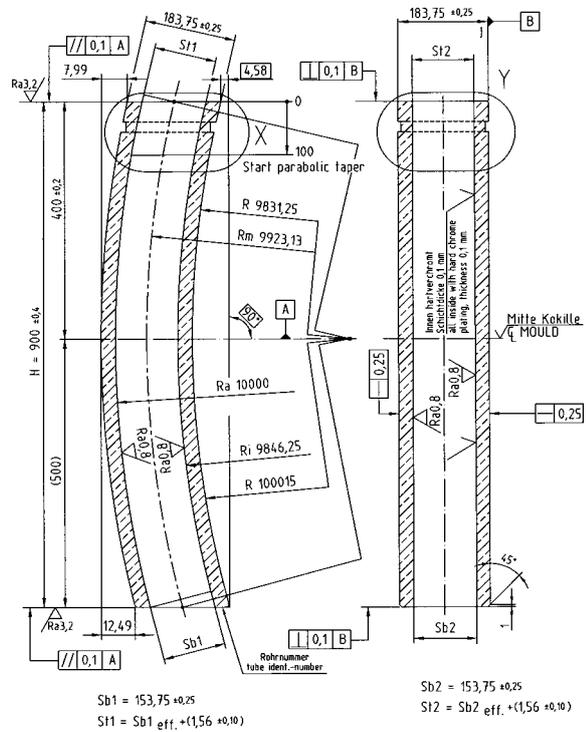
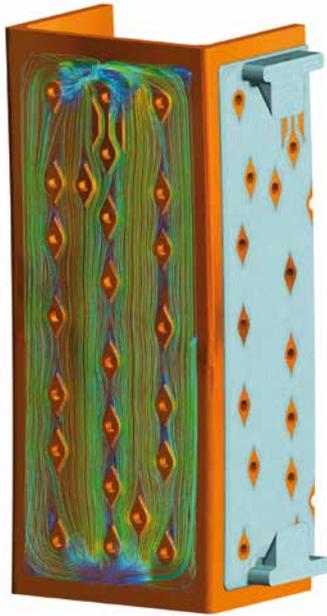
Finite element analysis

The range of mould materials developed and produced by KME allow appropriate selection of the optimum copper alloy for individual applications. However, in order to achieve high performance, optimum steel quality and a long service life of the moulds in the casting facilities, further engineering work is generally necessary – particularly when casting facilities are operated on system parameters that have been changed from the original concept in order to achieve higher casting outputs or produce special types of steel. This is where KME's mould engineering service comes into play, supporting its customers in upgrading continuous casting moulds and optimising system parameters and mould constructions.

Using FEA to calculate the mould stresses based on 3D CAD modelling allows accurate simulation of the mechanical and thermal stress factors involved in each case. Mould dimensioning, tapering and the specification of cooling conditions are based on the results of these calculations.

KME can provide detailed support on the design of new moulds. On request, KME will also do the entire detailed engineering based on the plant maker's design drawings.





Dimensioning

When designing the size of moulds for slabs, blooms or billets, each case must be considered individually. The main variables that play a role are the types of steel to be cast, the cooling conditions, and the desired casting speed.

Mould taper

The type of steel, the construction of the casting machine, and the casting parameters are the main factors that must be taken into account when specifying the mould taper.

From a theoretical approach, the optimal taper of a mould can only be specified for one type of steel and for one specifically defined casting conditions, i.e. superheat of the liquid steel, casting speed, etc. For this reason, there is always an element of compromise in the taper actually used, especially in the case of non-adjustable moulds.

Today a multitude of tapers are used in the design of mould tubes, these include a range of linear tapers with single, double and triple taper formats. In addition, the more modern trend is to use a parabolic taper which can be tailor-made to meet the casting parameters.

If a limited range of steel types with a similar chemical composition and similar shrinkage behaviour are to be cast, it makes sense to adjust the taper of the mould more closely to the shrinkage behaviour of the steel. Especially for billet and bloom mould tubes, it has been shown that parabolic tapers better conform to the shrinkage behaviour of the strand than linear tapers and thus contribute to an improvement in strand quality (off-squareness/oscillation marks).

Cooling conditions

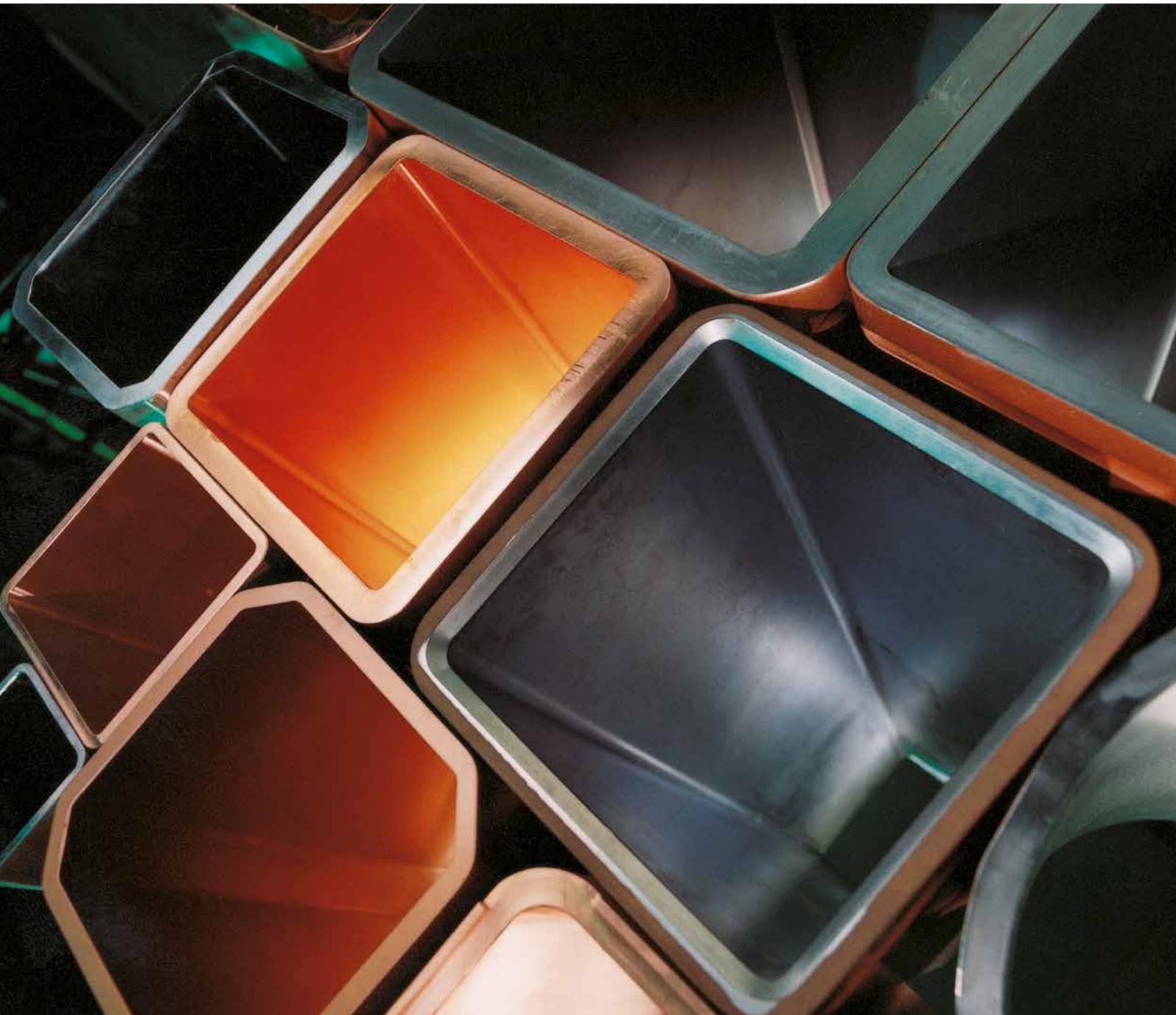
Another important factor is the adjustment of cooling conditions and casting parameters in order to ensure good system productivity and product quality.

For this purpose, KME performs CFD (Computational Fluid Dynamics) calculations of the water flow between cold face of the mould and the water box. In combination with the thermal load calculation of the hot face, this will give a detailed analysis of the thermal and mechanical stresses on the mould during the casting process.

Working in consultation with our customers, KME can offer a full range of technical services to optimise the mould, cooling and casting parameters to achieve improved productivity and product quality, together with long service life of the mould. The Advanced Mould Engineering Service is provided by experienced KME engineers as before and after sales service to our customers.

Mould tubes for billets and blooms

KME develops and supplies the whole range of mould tube geometries and dimensions in use today, from small rectangular tubes right through to large-format round mould tubes. Our customers can select from various tapers and special internal geometries, such as DIAMOLD® or AMT® solutions.





KME manufacturing range for mould tubes

Materials	Cu-GS, CuAg-GS ELBRODUR® G, ELBRODUR® GR
Design	<ul style="list-style-type: none"> - Square, rectangular, polygonal, round, beam blank - Straight or curved - Outer contour parallel - Internal geometries: parallel, tapered, part-tapered, multi-tapered or parabolic - CONVEX, DIAMOLD®, AMT®, AHE - WAVE mould tubes (Patent pending) - Textured mould tubes
Coatings	Chrome (recommended thickness 0.08-0.12 mm), Advanced chrome, TOPOCROM®
Sizes	Up to 450 mm square; larger sizes upon request; no limits on diameter for round sections
Wall thickness	Up to 30 mm; greater wall thickness upon request

Corner radius

The size of the internal corner radius has a major influence on solidification and uniform shell growth over the strand circumference. Depending on the size of the billet or bloom, mould tubes should be designed with the following nominal radii:

Internal corner radius

- R = 2 - 5 mm for sizes ≤ 100 mm square
- R = 4 - 6 mm for sizes ≤ 130 mm square
- R = 5 - 8 mm for sizes ≤ 160 mm square
- R = 8 - 10 mm for sizes > 160 mm square

However, the definitive design of the corner radius always has to be made taking into account the needs of the rolling mill using the cast shape.

AMT[®] tubes

To optimise the casting process and product quality even more, KME offers innovative detailed solutions that can be combined to suit the customer's specific needs for solving metallurgical or process-related technical problems.



WAVE tubes

The WAVE mould has a patented design that superimposes a series of undulations onto the hot-face side of the mould, causing a mirror image to be formed on the billet surface as it begins to solidify. These two surfaces will interlock and the shell will be guided through the length of the mould while restraining any movement from side-to-side.

The mould and shell are thus “coupled” together to such a degree that a more equal heat extraction, and hence uniform shell growth, occurs during this critical time. The result is improved billet shape and internal quality, as well as increased mould life.





AHE tubes

As the optimisation and efficiency of the casting machines increases, heat removal in the mould will become critical. To increase the heat removal in round and rectangular formats, KME supplies AHE (Advanced High Efficiency) mould tubes. These have been specially developed to optimise heat removal at higher casting speeds.

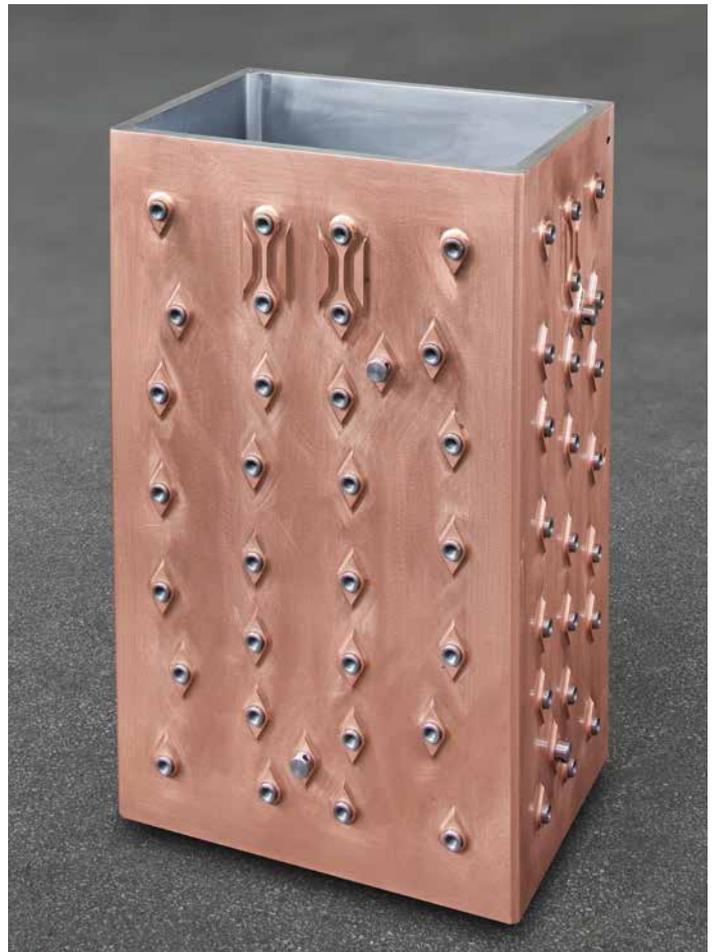
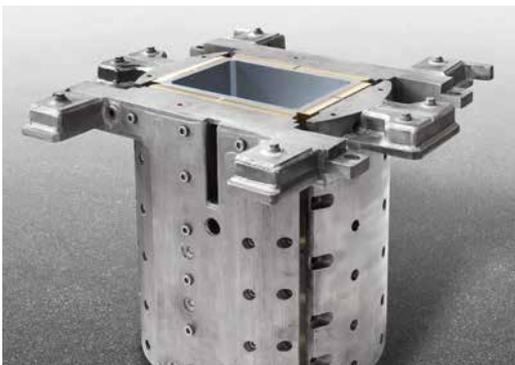


Textured tubes

KME has developed a new method for controlling the heat removal in a mould tube. Using a specially developed manufacturing process, a texture can be applied to the casting surface of the mould tubes. This allows the heat transfer to be moderated in specific areas of the mould.

ATM tubes

The ATM design optimizes the mould cooling over the entire surface area of the mould, while reducing the internal stress in the copper due to the special bolting arrangement.



Mould plates for blooms and slabs

The design and manufacture of mould plates for bloom and slab casting machines, whether furnished with cooling slots or deep-hole drills, is a major part of KME's product range. For these applications, KME delivers a comprehensive selection of mould materials and coatings.

KME has developed various technology packages for the continued development of the moulds used in the casting of bloom and slab shapes.

Based on a precise analysis of the cooling water flow and the load on the moulds arising from the process, an improvement in the service life can often be achieved through local optimisation of the cooling geometry.

ASM – mould plates

KME engineers have developed ASM (Advanced Slab Mould) technology to optimise the cooling of standard mould plates.

By using filler- or adapter plates in conjunction with the patented AFM® mounting, it is possible to reduce the working load on the moulds and to improve casting efficiency and strand quality with adjusted cooling water flow.

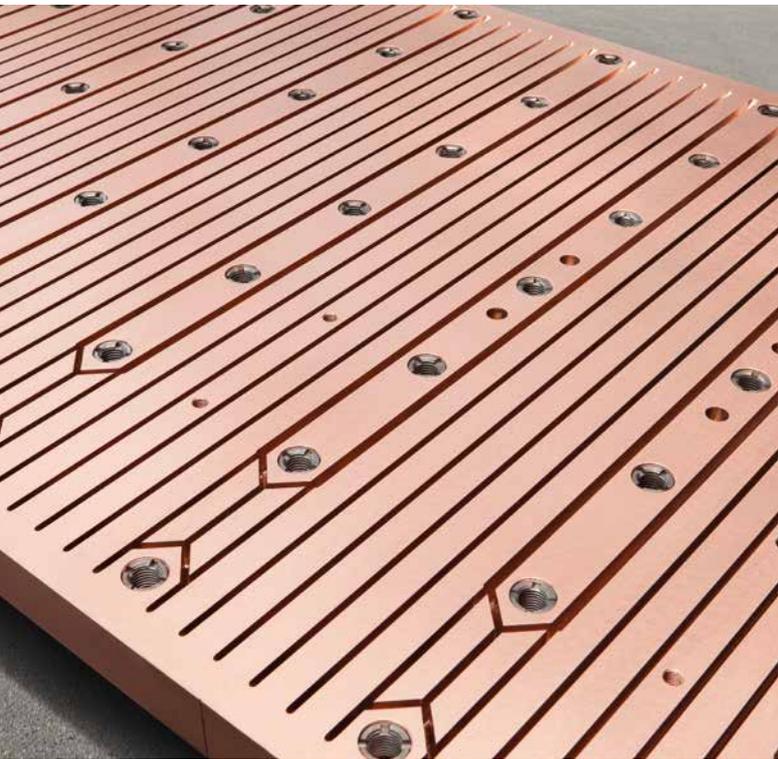
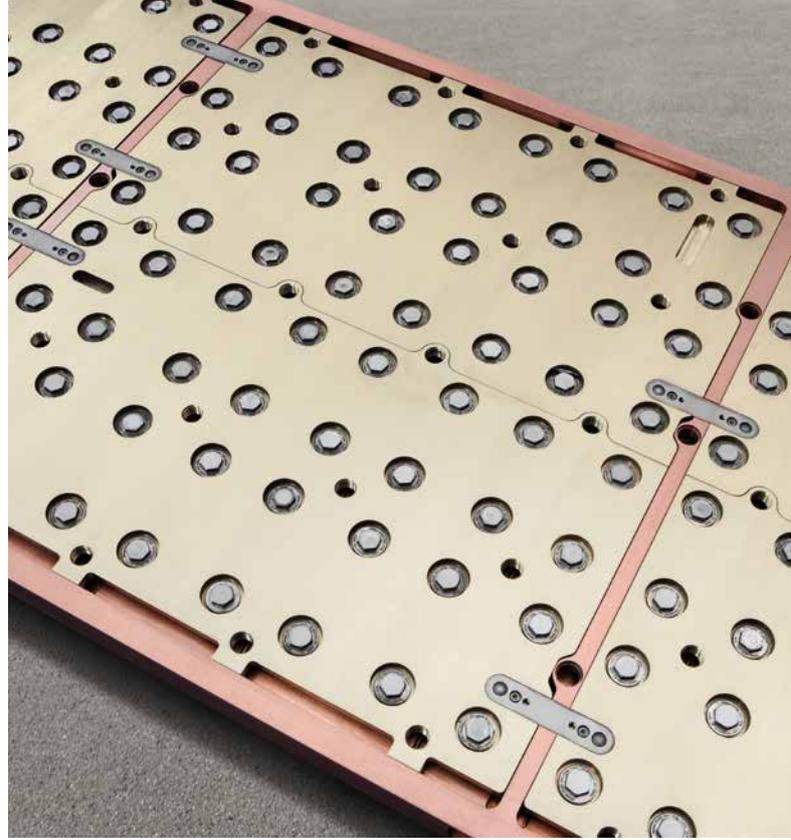
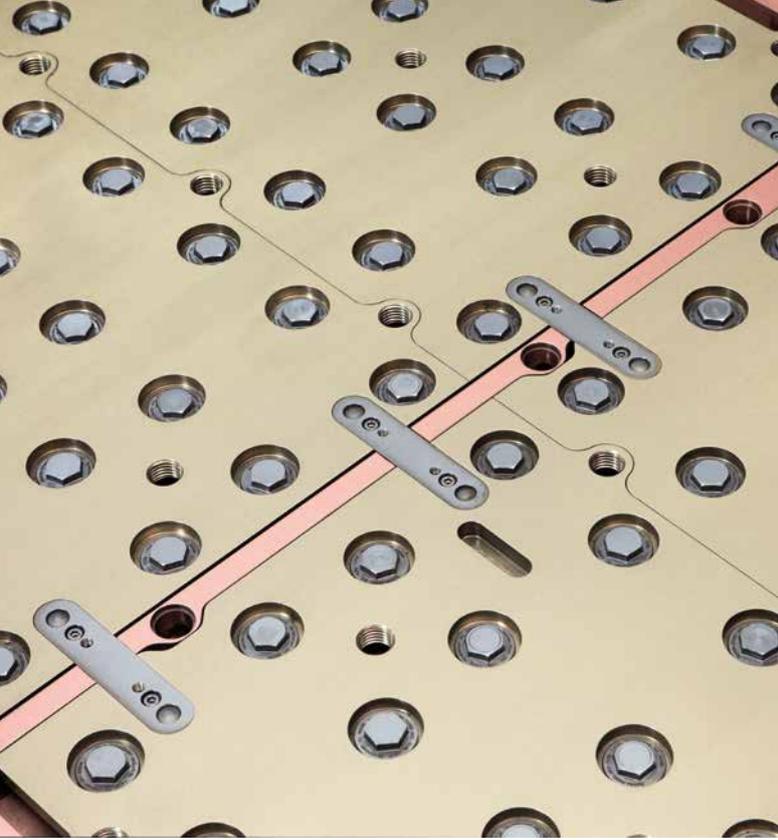
A significant advantage of the ASM technology is that existing moulds can be converted without requiring high investment.

Reduced heat dissipation

For the casting of steel grades that are prone to cracking, KME offers materials with reduced thermal conductivity for mould plates to achieve a reduced heat transfer in the mould.

KME's strength in technical design together with our available materials and coatings, enables us to develop tailor-made solutions for each customer as required.





Manufacturing range for mould plates

Materials	CuAg-GS/NS, ELBRODUR® G/GP/GP-NS/GD-NS/GR, ELBRODUR® NIB
Plate design	<ul style="list-style-type: none"> - Cooling slots or cooling drills - Casting surfaces straight or machined to casting radius
Coatings	<ul style="list-style-type: none"> - Nickel - Nickel + chrome - Nickel alloy + chrome - Metal-Ceramic
Sizes	- Practically no limits



Moulds for near-net-shape-casting

Tubes, plates and rolls

New continuous casting systems must guarantee high productivity, ensure good product quality and drastically reduce the energy outlay from raw material to finished product. These goals are being pursued with the development and introduction of near-net-shape-casting processes. KME played a decisive role in the development of these technologies by developing materials, optimising geometry and adapting the coating for the moulds. By engineering new mould concepts such as the Advanced Funnel Mould (AFM[®]) and the Advanced Beam Blank Mould (ABBM), KME continues to set milestones in the development of moulds for near-net-shape casting technology.

Moulds for beam blank casting

A multi-part mould plate or a mould tube can be chosen for beam blank casting. Plate constructions give a greater degree of freedom when specifying the mould taper, whereas tubes make it possible to use casting oils. Repair techniques for both types of moulds are available at KME.

ABBM – Advanced Beam Blank Mould

The KME Advanced Beam Blank Mould is an innovative new development in mould technology for beam blanks. The combination of a thin-walled mould and a support plate permits the separation of functions in this mould type. For the first time, it is now possible to use thin-walled copper plates for optimised heat dissipation at high casting speeds without losing any of the maintenance-friendly qualities of plate construction.

Mould plates for thin slabs casting

The casting of thin slabs is the most common method of near-net-shape technology used today. The mould takes on particular importance for the performance of the system. Due to the changed surface/volume ratio in this method, about 50% of the slab thickness solidifies in the mould, compared with 10% in conventional slabs. This means that large amounts of heat have to be removed by the mould and the copper is subject to extreme thermal stresses. KME's development of new materials and the in-house production are decisive advantages that can be utilised here. Today, KME manufactures CSP[®], ISP[®] and ftSC[®] mould plates for thin slab casting.

AFM[®] – Advanced Funnel Mould

As the efficiency of thin-slab casters continues to increase, a solution is needed to give the moulds the required level of stability and good heat removal.

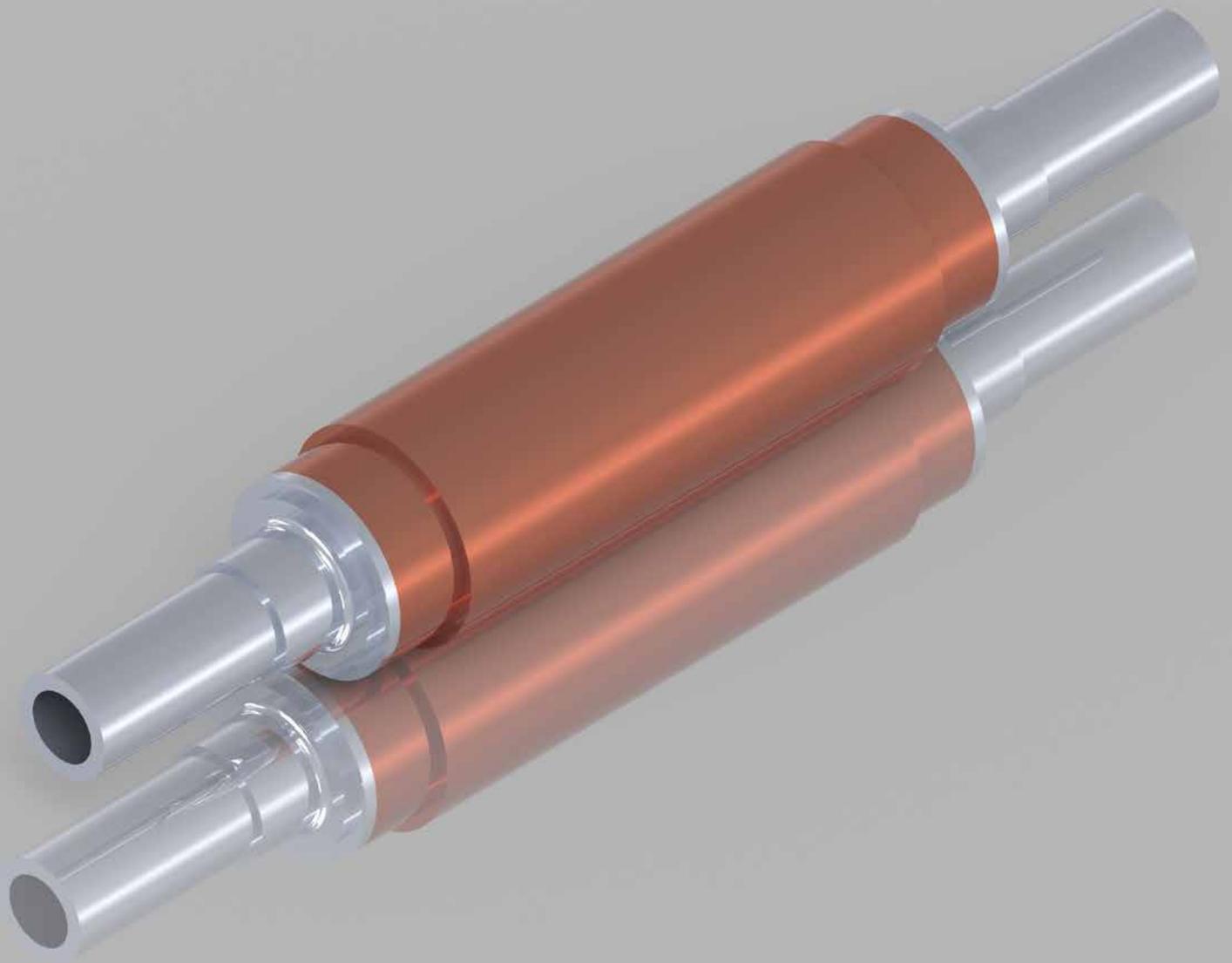
Targeting this, KME has designed and developed the innovative Advanced Funnel Mould (AFM[®]). The AFM[®] comprises an adapter plate which makes it possible to fit the mould to an existing water box. This patented connection allows a controlled heat expansion of the mould during casting, in order to reduce the operating stresses in the copper.

The thin mould plate also allows high heat transfer rates, which is a basic requirement for improved casting efficiency. In addition, the thickness of the mould plate is adapted to the specific heat load in different areas of the mould. This results in homogeneous surface temperatures for uniform melting of the casting flux, and thus improved slab surface quality.



Manufacturing range for near-net-shape moulds

Type of mould	Form	Materials	Design	Sizes	Coatings
Thin slab	Plates	CuAg-NS ELBRODUR® G/GP/ GP-NS/GD-NS/GR ELBRODUR® NIB	<ul style="list-style-type: none"> - With cooling slots or drilled cooling channels - Casting surfaces with special contours for casting thin slabs - Straight or machined in accordance with casting radius CSP®, ISP®, fTSC®, AFM®	Practically no limits	Nickel Nickel + chrome Nickel alloy + chrome Metal-Ceramic
Beam blank	Tubes	CuAg-GS ELBRODUR® G	<ul style="list-style-type: none"> - External contour parallel - Internal geometries: parallel, part-tapered, multi-tapered, or parabolic, and with special internal contours for casting beam blanks with additional cooling channels 	Up to 450 mm square; Larger sizes upon request	Chrome TOPOCROM®
	Plates	CuAg-GS/NS ELBRODUR® G/GP/ GP-NS/GD-NS/GR	<ul style="list-style-type: none"> - With cooling slots or drilled cooling channels ABBM	Practically no limits	Nickel Nickel + chrome Nickel alloy + chrome Metal-Ceramic
Thin strip	Casting rolls	ELBRODUR® G ELBRODUR® NIB ELBRODUR® B 95	<ul style="list-style-type: none"> - Cooling system in the shape of slots or drilled channels, depending on overall design 	Practically no limits	Upon request



Moulds for thin strip casting

As early as 1891, Sir Henry Bessemer drafted the principle of a casting machine in which the molten steel was supposed to solidify directly into steel strips between two casting rolls. Just over a hundred years later, his idea is now starting to take shape in reality.

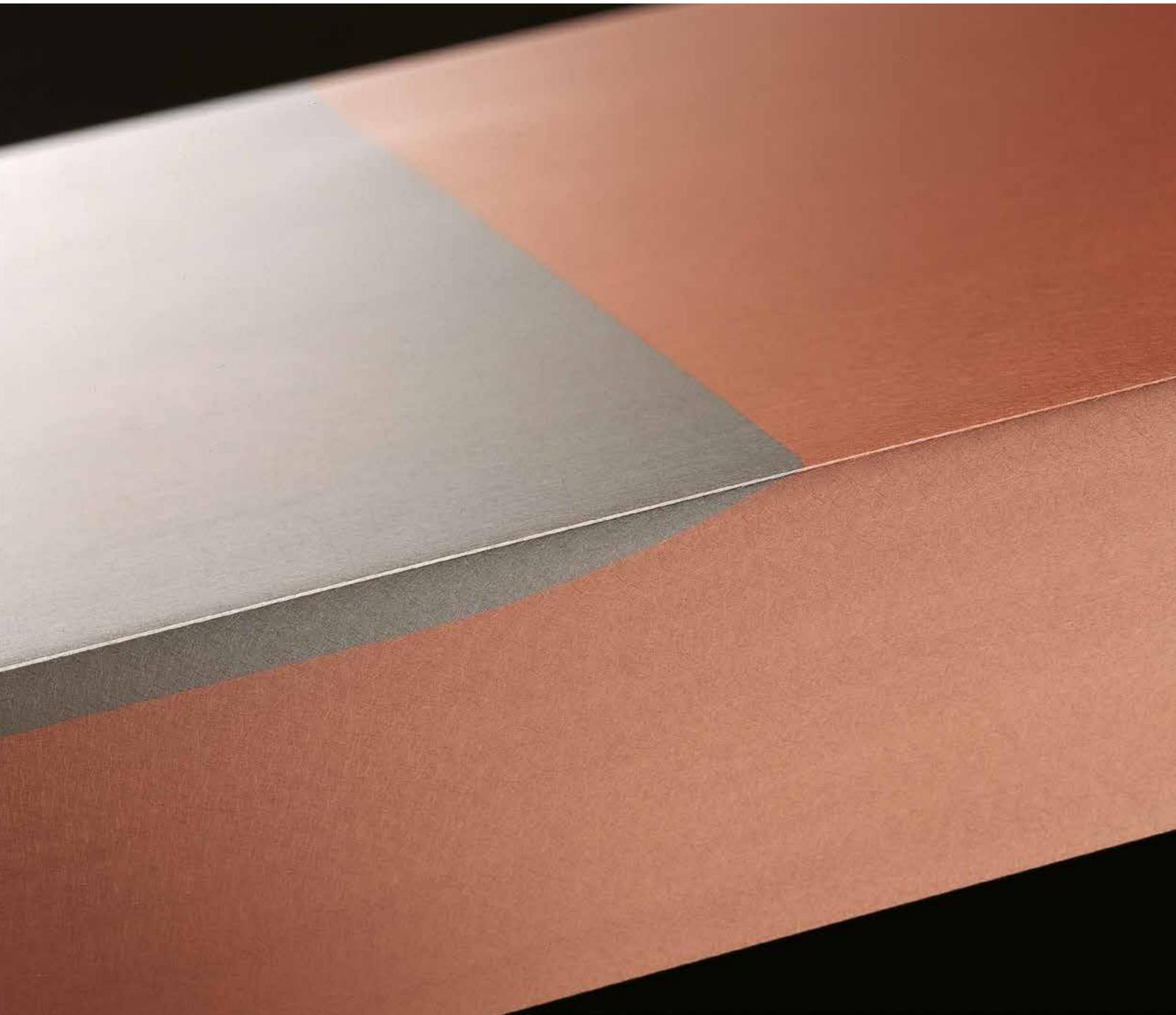
As a result of the unusually high surface/volume fractions that prevail in strip casting, great amounts of heat have to be conducted away by the casting rolls. KME can meet the extremely

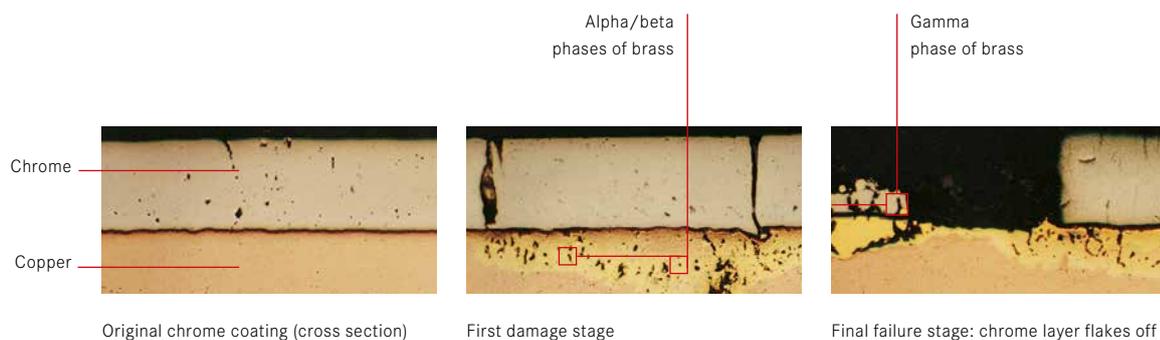
high demands on materials and the manufacturing precision required for all the various strip casting machines in use around the world. Customer-specific adaptations of the material characteristics to the cooling conditions and to the load situation are an important key to the successful development of the technology.

Since KME controls all stages along the entire process chain, it is possible for us to deliver specific solutions for each individual customer.

AMC[®] – Advanced Mould Coatings

Copper materials have a relatively low hardness and thus low resistance to abrasive wear. For this reason, a high degree of wear can occur in the lower part of the mould where the strand shell has hardened. To counteract and improve the service life of moulds, KME has developed advanced mould coatings.





Coating damage from zinc

Excessive wear of the moulds is accelerated by an incorrectly adjusted strand guidance system and casting parameters. Common causes are that the taper of the mould is not consistent with the shrinkage behaviour of the steel, poor alignment of the casting machine (oscillation/strand guidance), or a casting speed that is not adapted to the mould geometry. These are all possible causes of a high degree of wear, which ultimately leads to a change in the mould geometry.

In order to improve the service life of mould tubes, KME decided at a very early stage to apply a coating of hard chrome to the inner surface. A considerable increase in the service life of mould tubes can be achieved in this way. The casting surfaces of mould plates are often partially or completely coated with nickel or nickel alloys, or special ceramic coatings.

The object of coating mould tubes and plates is to increase the service life of the mould, as well as an improvement in product quality. KME has come up with future-oriented solutions by further developing hard-chrome plating and by using new coatings and coating systems for special thicknesses. New wear-protection layers and coating techniques are also being investigated in our laboratories.

Coating of mould tubes

The small size billet moulds, which are mostly operated without any rigid strand guidance downstream of the mould, are particularly susceptible to wear. A hard chrome coating of 650 – 1000 HV, depending on the type of chrome, on the inside mould surfaces provides effective anti-wear protection which results in a substantial gain in mould liner working life. KME recommends AMC®-HC 90 chrome coating for mould tubes having thicknesses of 0.08 – 0.12 mm.

TOPOCROM® coatings

In addition to the well proven AMC®-HC 90 chrome coating, KME can also furnish mould tubes with TOPOCROM® coatings. The textured surface of this type of coating makes it possible for the frictional forces between the strand shell and mould wall to be reduced.

TOPOCROM® coatings have shown less wear under abrasive test loads. This effect can be used to improve the lifetime of mould tubes.

Coating damage from zinc

Zinc from the steel melt can initiate a specific failure mechanism in connection with chrome coatings. Vaporising zinc mainly from automotive scrap makes its way to the copper surface by diffusing into the micro cracks which are always present in hard chrome. High mould temperatures tend to encourage the diffusion, so that the problem mainly occurs in the mould meniscus area. The copper reacts with the zinc forming brittle, and “bulky”, intermetallic alpha, beta and gamma phases of brass which lift the chrome off the copper. The result is premature chrome chipping. Mechanical stresses from the steel strand enhance the process. Where this kind of attack is highly localised, i. e. confined to very small areas, stress raisers in the form of such brittle phases can combine with alternating thermal stresses experienced in the mould wall to initiate fatigue cracks.

This form of damage is especially prevalent in cases where cooling conditions are unfavourable and where mould tubes are exposed to undue temperature levels, i. e. 300 – 350 °C and zinc levels above 30 ppm in the steel melt, over an extended period.



Effect of nickel thickness on heat transfer and wall temperature

Calculation based on constant coefficients of heat transfer; heat flux approx. 1.8 MW/m².

Material: CuAg (DPS-Cu)	Ni coating mm	Δ T wall °C	Δ heat transfer %
Wall thickness: 35 mm	0.7	+ 11	- 0.9
	1	+ 15	- 1.3
	2	+ 30	- 2.6
	3	+ 45	- 3.8

Coating of mould plates

When it comes to coatings for mould plates, a distinction has to be drawn between

- coatings for metallurgical protection to improve the surface quality of the cast strand (e. g. prevention of star cracks), and
- anti-wear coatings to improve resistance to abrasion.

Coatings for slab protection

When casting certain steel grades, in particular shipbuilding qualities, the surface quality of the cast strand can become impaired by copper particles picked up from the mould wall (especially in the lower part of a mould) which can lead to the development of star cracks. To avoid this defect, the mould plates of slab casters used for the production of these sensitive steel grades are protected with a nickel or nickel-alloy coating.

Since the steel grades which tend to develop star cracks are almost exclusively cast through slab moulds, coatings for slab protection are not found with any other mould type.

Anti-wear coatings

In general a distinction is made between thick and thin nickel platings. About 0.7 mm is the thickness limit for a cost-effective thin nickel/nickel-alloy coating.

As a result of the associated reduction in mould heat transfer, and because of the resultant higher wall temperatures which affect nickel adherence to the copper, thick nickel coatings have a major impact on the operational handling and relevant casting parameters. This puts definite limits on the maximum allowable nickel thickness in the meniscus area.

The table shows the effect of nickel plating thickness on heat transfer and wall temperature.

From the point of view of caster operation, a reduction of approx. 3.8 % in heat transfer with 3 mm nickel on the copper is not significant, but the accompanying 45 °C increase in wall temperature causes considerable stresses in the nickel due to the difference in coefficients of thermal expansion of the two metals.

In the course of prolonged service, hairline cracks develop in the nickel at the mould meniscus due to the metal's lower plasticity. While not normally impairing mould performance, such cracks could propagate into the copper if the temperatures reached in the mould wall are higher than normal, or where the plates have undergone repeated remachining and recoating. Undue coating thickness should therefore be avoided, especially in the meniscus area.

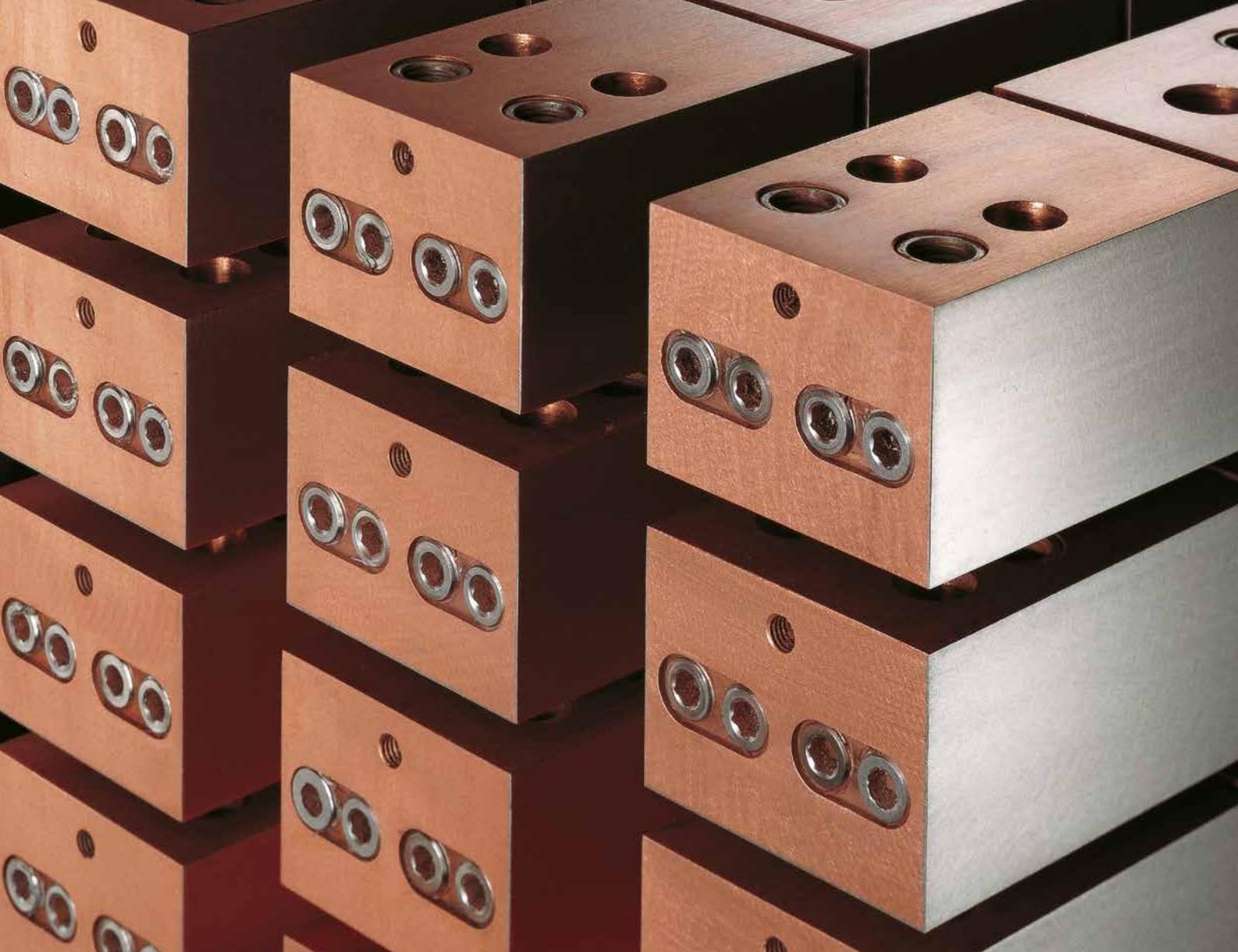
Nickel alloys are an interesting alternative to pure nickel layers. As a result of their greater hardness, they have good anti-wear properties. At the same time, they have a lower heat conductivity than pure nickel, so that the relationship described above between layer thickness and temperature development in the mould is becoming an increasingly important factor.

For the reasons outlined above, tapered nickel coatings that are approx. 1.0 mm thick at the top and approximately 3.0 mm thick at the bottom end, or 2–6 mm thick partial coatings on the lower half of mould plates, represent the optimal solutions with respect to both metallurgical and cost requirements.

As an additional safeguard against wear, one might consider applying a 0.025 – 0.050 mm chrome plate on top of the nickel. However, in most cases this will not be regarded as an economically viable approach on account of the high cost involved.

In certain cases chrome coatings can be an economical means of improving the working life of mould plates for bloom casting.

For adjustable slab and bloom moulds, friction between the surfaces of the wide-face coppers and the edges of the narrow-face coppers leads to wear and the localised development of deep scores and scratches. Any mould powder or steel particles getting into the resultant gap between the sliding surfaces further compound the situation.

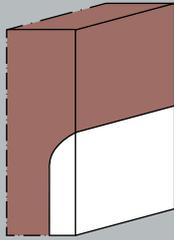


Here, the rate of wear can be reduced considerably by coating the edges of the adjustable narrow-face plates, which slide on the inside (hot face) of the wide-face coppers, with a material that has greater hardness.

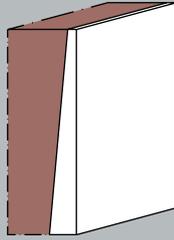
The nickel coatings (AMC®-HN) are preferably used for the narrow-face and wide-face plates of moulds. A narrow-face nickel coating with HN 20 offers much better wear resistance than a plate without a coating.

The HN 40 nickel alloy has twice the hardness of HN 20, which leads to quite a considerable improvement in mould life. Both types of coating can be applied in greater thickness so that they can be remachined.

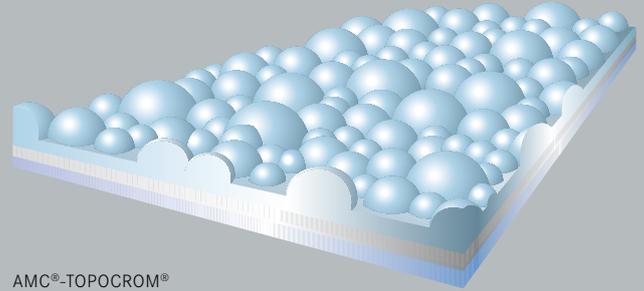
Additionally, KME can supply metal-ceramic coatings (AMC®-HF). The high hardness of such coatings makes it possible to achieve considerable improvements in the lifetime of narrow-face plates, several times that achievable with nickel coatings. KME's recommendation for the narrow faces is an AMC®-HF 120 coating on the hot face surface.



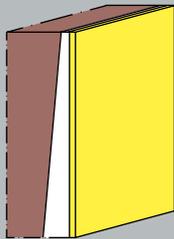
2.0-6.0 mm HN 20
or 2.0-3.0 mm HN 40



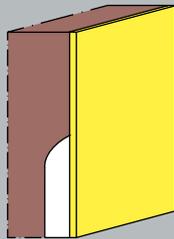
1.0-3.0 mm HN 20
or 1.0-2.0 mm HN 40



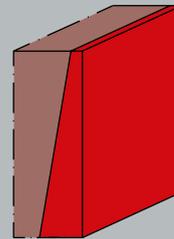
AMC®-TOPOCROM®



1.0-3.0 mm HN 20/40
+ 0.025-0.05 mm HC 90



2.0-6.0 mm HN 20
+ 0.025-0.05 mm HC 90



0.1-0.6 mm HF 120

It can be seen that very complex interrelationships have to be taken into account when selecting a suitable coating and layer thickness. Recommendations can therefore only ever be made in relation to specific system and casting parameters. Close consultation between the system operator and the mould supplier is necessary to ensure that the appropriate coating systems are selected. The selection of coating may furthermore depend on what possibilities exist in terms of mould maintenance.

AMC® - Advanced Mould Coatings – hardness and thermal conductivity

Material	Hardness HV	Thermal conductivity W/(m·K)
 AMC® HN 20	220	90
 AMC®-HN 40	400	80
 AMC®-HC 90	900	70
 AMC®-TOPOCROM®	900	70
 AMC® HF 120	1200	30

AMM[®] – Advanced Mould Materials

Material sciences and the development of copper alloy systems have for many years represented an important area for KME as the leading manufacturer of copper products. A major part of KME's efforts in these fields is dedicated to the development of copper alloy systems for continuous casting moulds. Therefore, depending on the application and the range of properties required, the mould material can be adjusted using specially tailored alloys.



Cu-GS

DHP copper was developed as a standard material for mould tubes under normal service conditions at temperatures in the meniscus area of up to about 300 °C. The material displays excellent heat and creep resistance at high temperatures and its workability is good.

CuAg-GS/NS

Copper-silver alloys (CuAg) are used in applications in which higher thermal stresses and wall temperatures occur. CuAg alloys have a higher thermal conductivity, which means that the temperatures in the mould can be kept on lower levels. In addition, they have higher temperature resistance to softening than DHP-Cu.

ELBRODUR[®] G

ELBRODUR[®] G is an age hardenable CuCrZr alloy which has excellent mechanical properties, both at room and higher temperatures. High heat conductivity, a very high softening temperature, high creep resistance and high resistance to alternating thermal stresses are exceptional properties that set this alloy apart from the copper alloys previously presented. The good combination of properties achieved in this material is made possible by the use of alloying elements and a special thermomechanical treatment (see Fig. 4).

ELBRODUR[®] GP

ELBRODUR[®] GP is an advanced material developed on the basis of the tried and tested ELBRODUR[®] G. It has been possible to further improve this material's properties through careful tuning of the chemistry and process control during manufacture.

ELBRODUR[®] GP-NS

ELBRODUR[®] GP-NS is an advanced material developed on the basis of the tried and tested ELBRODUR[®] GP, but with a higher strength level. It was developed for near-net-shape-casting applications, such as beam-blank and thin slab moulds.

ELBRODUR[®] GD-NS

ELBRODUR[®] GD-NS is an advanced material developed on the basis of the tried and tested ELBRODUR[®] GP-NS. This new material is used for the AFM[®], ABBM and ASM applications. ELBRODUR[®] GD-NS is characterized by improved fatigue and creep strength behavior.

ELBRODUR[®] GR

The ELBRODUR[®] GR alloy is based on the material ELBRODUR[®] G and has been specially developed for moulds that work with electromagnetic stirring coils. The precisely controlled reduction of the electrical conductivity of this alloy, while maintaining the mechanical properties, ensures that the electromagnetic losses in the mould wall are kept to a minimum and no additional output is required from the coils. As a result of these special properties, there is no need to reduce the mould wall thickness. At the same time, sufficient strength of the mould is achieved.

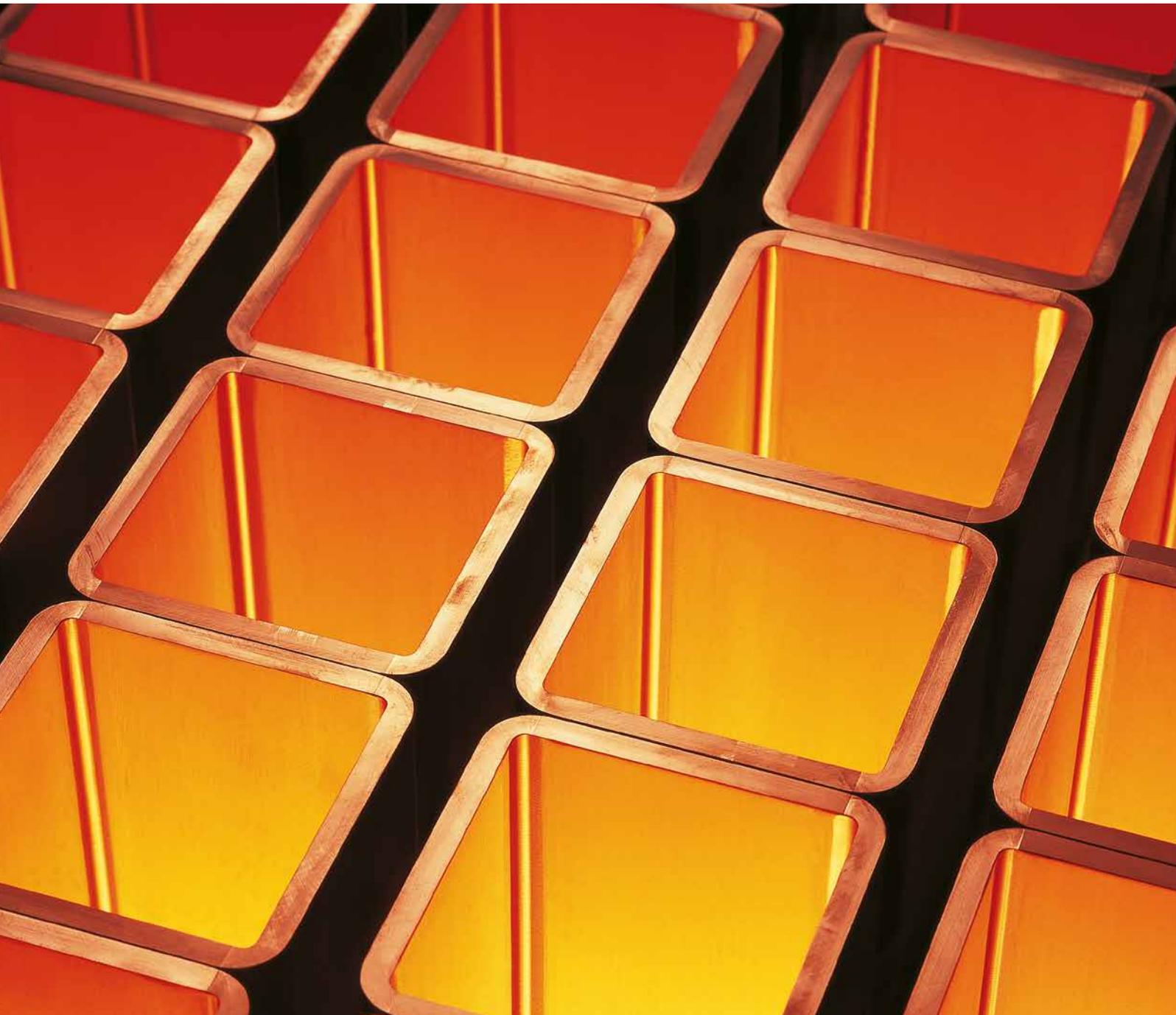
ELBRODUR® B 95

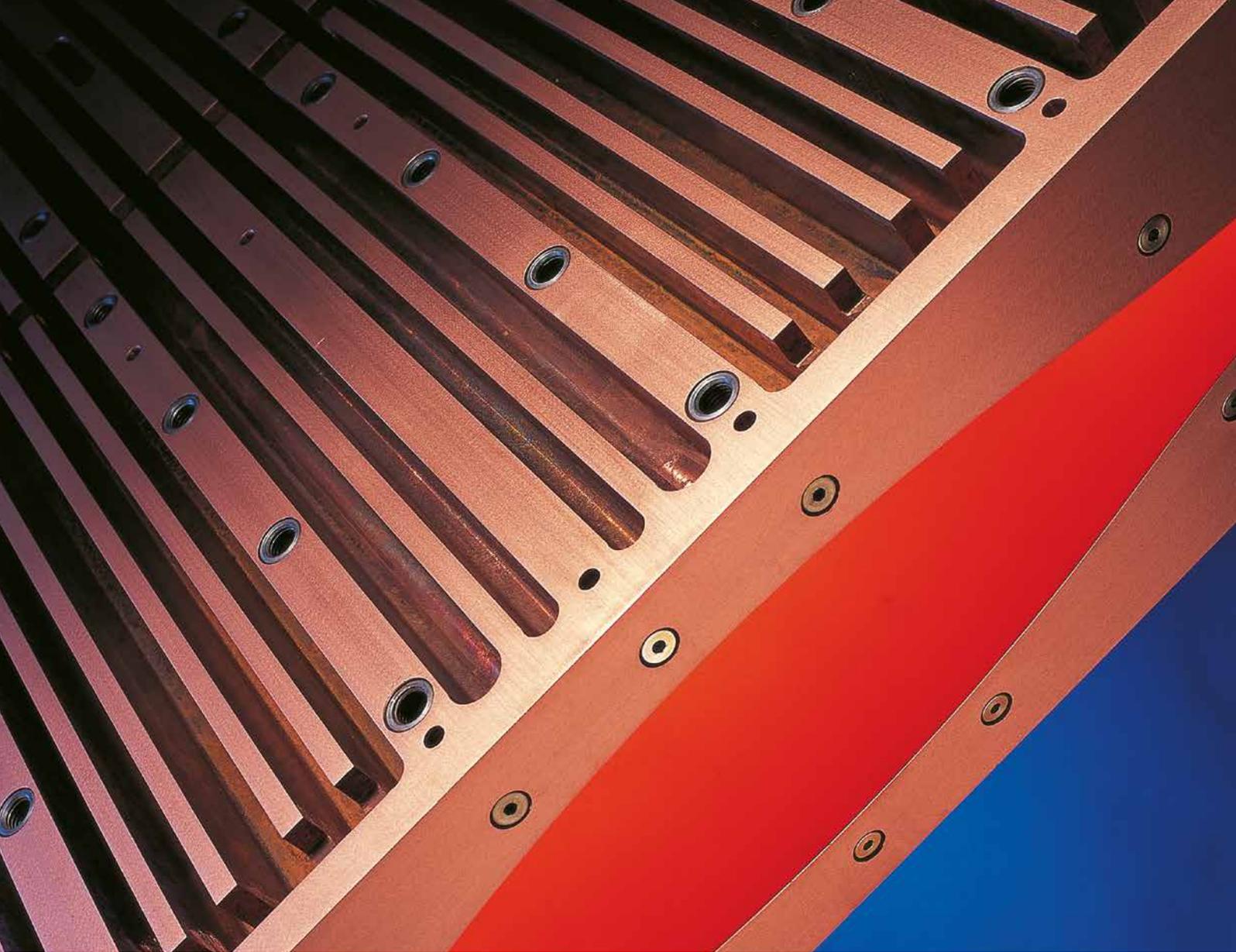
This is a high-alloyed age hardenable CuCoBe based material which has medium conductivity, along with very good elevated temperature strength. This material is suitable for very special applications requiring reduced cooling, such as casting rolls.

ELBRODUR® NIB

This is a newly developed material based on CuNiBe. It has been developed specifically for use in moulds for near-net-shape-casting and other moulds that need to withstand particularly high stresses.

Its outstanding characteristics are high strength along with medium conductivity. Importantly, it has a special resistance to cracking when exposed to thermal stresses caused by large temperature fluctuations in the mould wall.





Properties and applications of mould alloys (See page 30/31, Table 1 and Table 2)

Material	Cu-GS	CuAg-GS/NS	ELBRODUR® G/GP	ELBRODUR® GP-NS/GD-NS	ELBRODUR® GR	ELBRODUR® B 95	ELBRODUR® NIB
Thermal conductivity	High	Very high	High	High	Medium	Medium	Medium
Softening/Recryst. temp.	Medium	Medium	Very high	Very high	Very high	Very high	Very high
Strength/Hardness	Medium	Medium	High	High	High	Very high	Very high
Application	Mould tubes	Wide-face and narrow-face plates for slab moulds/ thin slab moulds; mould tubes	Mould tubes; Plates for slab moulds; bloom moulds; (casting rolls)	AFM®, ABBM, ASM	Tubes for billet and bloom moulds with electromagnetic stirring systems	Moulds for special purposes; casting rolls	Wide-face and narrow-face plates for slab moulds/ thin slab moulds; casting rolls

Fig. 1
Recrystallisation/softening behaviour of KME
mould materials versus standard copper (ETP Cu)

— E-Cu (ETP Cu)
— Cu-GS
— CuAg-GS/NS
— ELBRODUR® G/GP/GP-NS/GD-NS
— ELBRODUR® B 95/NIB

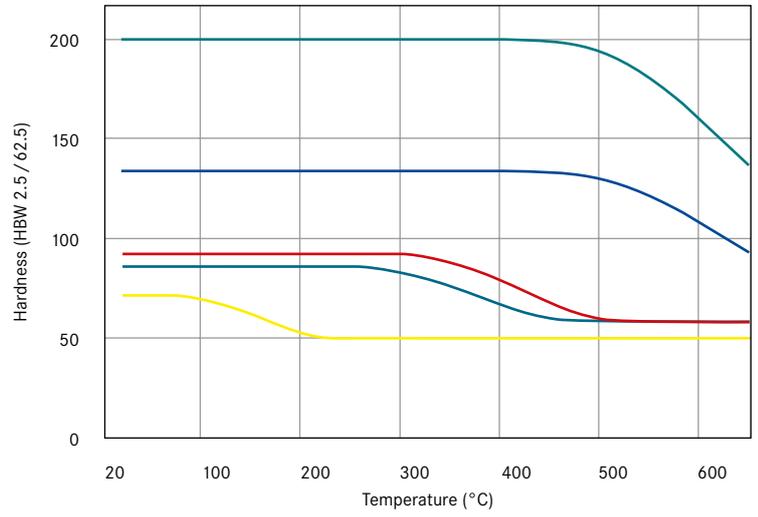


Fig. 2
Creep characteristics of mould materials
(temperature 200 °C/392 °F, stress 150 MPa)

— CuAg-GS/NS
— ELBRODUR® G/GP/GP-NS/GD-NS
— Cu-GS

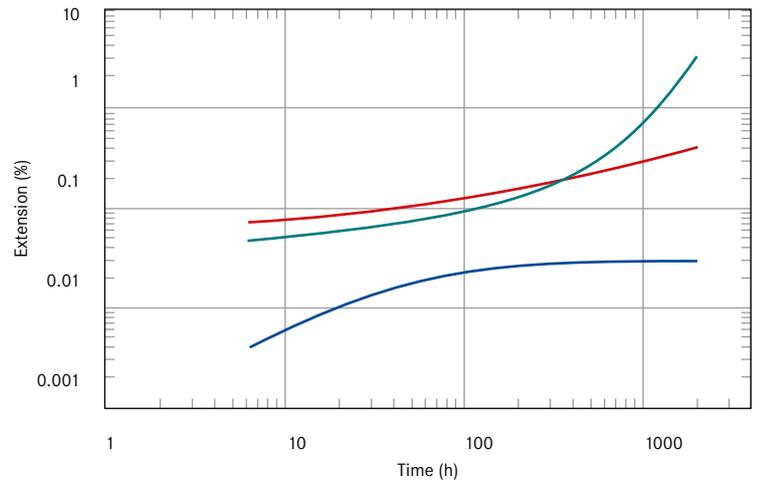


Fig. 3
Hardness and electrical conductivity of
KME mould materials

■ Brinell hardness
 HBW 2.5/62.5
■ Electrical conductivity
 % IACS

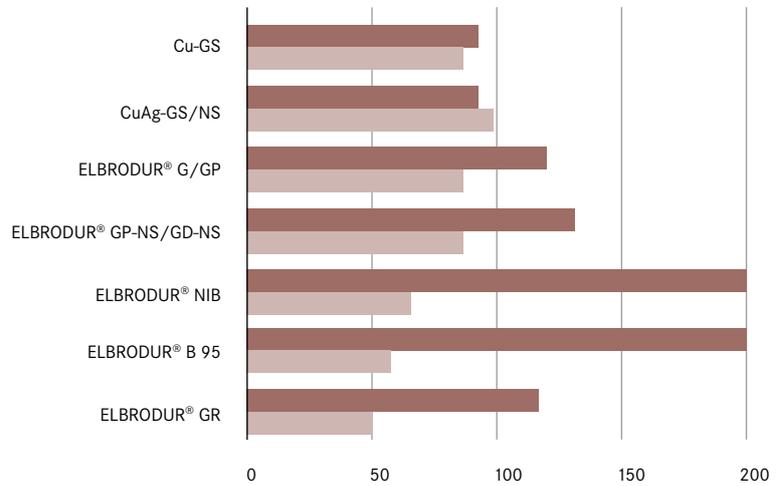
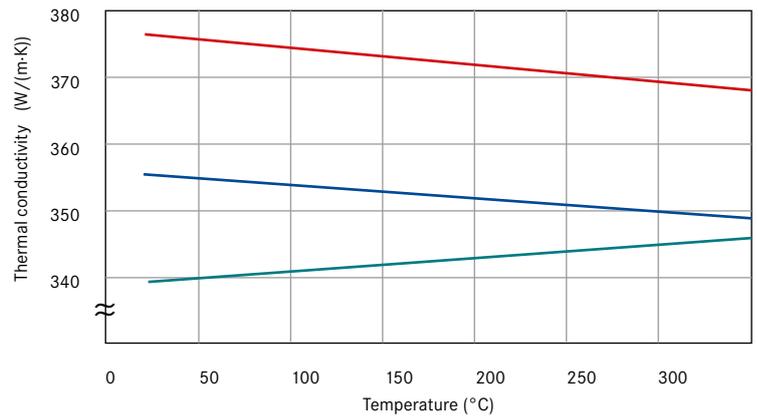


Fig. 4
Effect of temperature on thermal
conductivity of KME mould materials

— CuAg-GS/NS
— ELBRODUR® G/GP/GP-NS/GD-NS
— Cu-GS



AMM® – Advanced Mould Materials

Table 1 **KME materials for mould tubes**

Material Properties*	Temperature		Units	Cu-GS	CuAg-GS	ELBRODUR® G	ELBRODUR® GR** 40/50/60
	°C	°F					
Chemical composition (without copper)				0.03 P	0.09 Ag	0.65 Cr	0.65 Cr
					0.006 P	0.1 Zr	0.1 Zr
							1.5 others
Physical Properties	°C	°F					
Electrical conductivity	20	68	S·m/mm ²	48	55	50	23/29/35
				% IACS	83	95	86
Thermal conductivity	20	68	W/(m·K)	340	377	355	160/205/250
Coefficient of thermal expansion	20–300	68–572	10 ⁻⁶ /K	17.7	17.7	18	18
Recrystallisation temperature	-	-	°C	350	370	(800)	(800)
Softening temperature***	-	-	°C			580	580
Modulus of elasticity	20	68	10 ³ MPa	120	125	128	128
Mechanical Properties	°C	°F					
0.2 % Proof stress R _{p0.2}	20	68	MPa	290	290	360	350
	200	392		260	260	335	330
	350	662		(215)	(215)	295	300
	500	932		(20)	(20)	(185)	(210)
Tensile strength R _m	20	68	MPa	310	310	430	420
	200	392		265	265	400	390
	350	662		(220)	(220)	340	330
	500	932		(80)	(80)	(210)	(230)
Elongation A ₅	20	68	%	16	16	19	20
	200	392		14	14	18	18
	350	662		(12)	(12)	19	16
	500	932		(70)	(70)	(20)	(17)
Hardness HBW 2.5/62.5	20	68		95	95	130	130

Units: 1 MPa=1 N/mm²=0.102 kgf/mm²=0.145 ksi; 1 W/(m·K)=2.388 · 10³ cal/(cm·s·°C)

* Values may change with varying thermal and mechanical treatment due to geometry and manufacturing procedure

** Values can be modified to customer's demands

*** Measurement according to DIN ISO 5182

() Values may change due to restricted reproducibility of measurement



Table 2 KME materials for mould plates, block moulds and casting rolls

Material Properties*	Temperature		Units	CuAg-GS	CuAg-NS	ELBRODUR® G/GP	ELBRODUR® GP-NS/ GD-NS	ELBRODUR® GR** 40/50/60	ELBRODUR® B95	ELBRODUR® B95S	ELBRODUR® NIB
	°C	°F									
Chemical composition (without copper)				0.09 Ag	0.1 Ag	0.65 Cr	0.65 Cr	0.65 Cr	1.0 Co	1.4 Co	1.5 Ni
				0.006 P	0.004 P	0.1 Zr	0.1 Zr	0.1 Zr < 1.5 others	0.1 Be	0.3 Be	0.2 Be
Physical Properties	°C	°F									
Electrical conductivity	20	68	S-m/mm ²	54	57	48	49	23/29/35	35	31	40
				% IACS	93	98	83	84	40/50/60	60	54
Thermal conductivity	20	68	W/(m-K)	377	385	350	350	160/205/250	240	220	290
Coefficient of thermal expansion	20-300	68-572	10 ⁻⁶ /K	17.7	17.7	18	18	18	18	18	18
Recrystallisation temperature	-	-	°C	370	350	(800)	(800)	(800)	(800)	(800)	(800)
Softening temperature***	-	-	°C			580	580	580	590	590	590
Modulus of elasticity	20	68	10 ⁵ MPa	125	125	128	128	128	128	128	128
Mechanical Properties	°C	°F									
0.2 % Proof stress R _{p0.2}	20	68	MPa	275	285	285/330	370/380	275	490	610	510
	200	392		245	255	260/290	330/335	250	450	580	500
	350	662		(200)	(200)	230/255	300/305	220	430	540	470
	500	932		(20)	(20)	(200/220)	(245/250)	(180)	(400)	(450)	(420)
Tensile strength R _m	20	68	MPa	280	290	410/420	430/440	400	630	720	630
	200	392		250	250	350/365	370/375	340	570	670	570
	350	662		(210)	(210)	295/310	325/330	290	500	600	510
	500	932		(80)	(80)	(230/250)	(255/260)	(215)	(440)	(500)	(430)
Elongation A ₅	20	68	%	16	17	25/22	19	26	13	10	12
	200	392		14	15	24/20	16	23	11	7	10
	350	662		(12)	(12)	22/19	16	21	(5)	(3)	(4)
	500	932		(70)	(70)	(22/19)	(16)	(21)	(3)	(2)	(3)
Hardness HBW 2.5/62.5 ¹⁾	20	68		90	90	120/130	135	120	200	235	200

Units: 1 MPa = 1 N/mm² = 0.102 kgf/mm² = 0.145 ksi; 1 W/(m-K) = 2.388 · 10³ cal/(cm-s · °C)

* Values may change with varying thermal and mechanical treatment due to geometry and manufacturing procedure

** Values can be modified to customer's demands

*** Measurement according to DIN ISO 5182

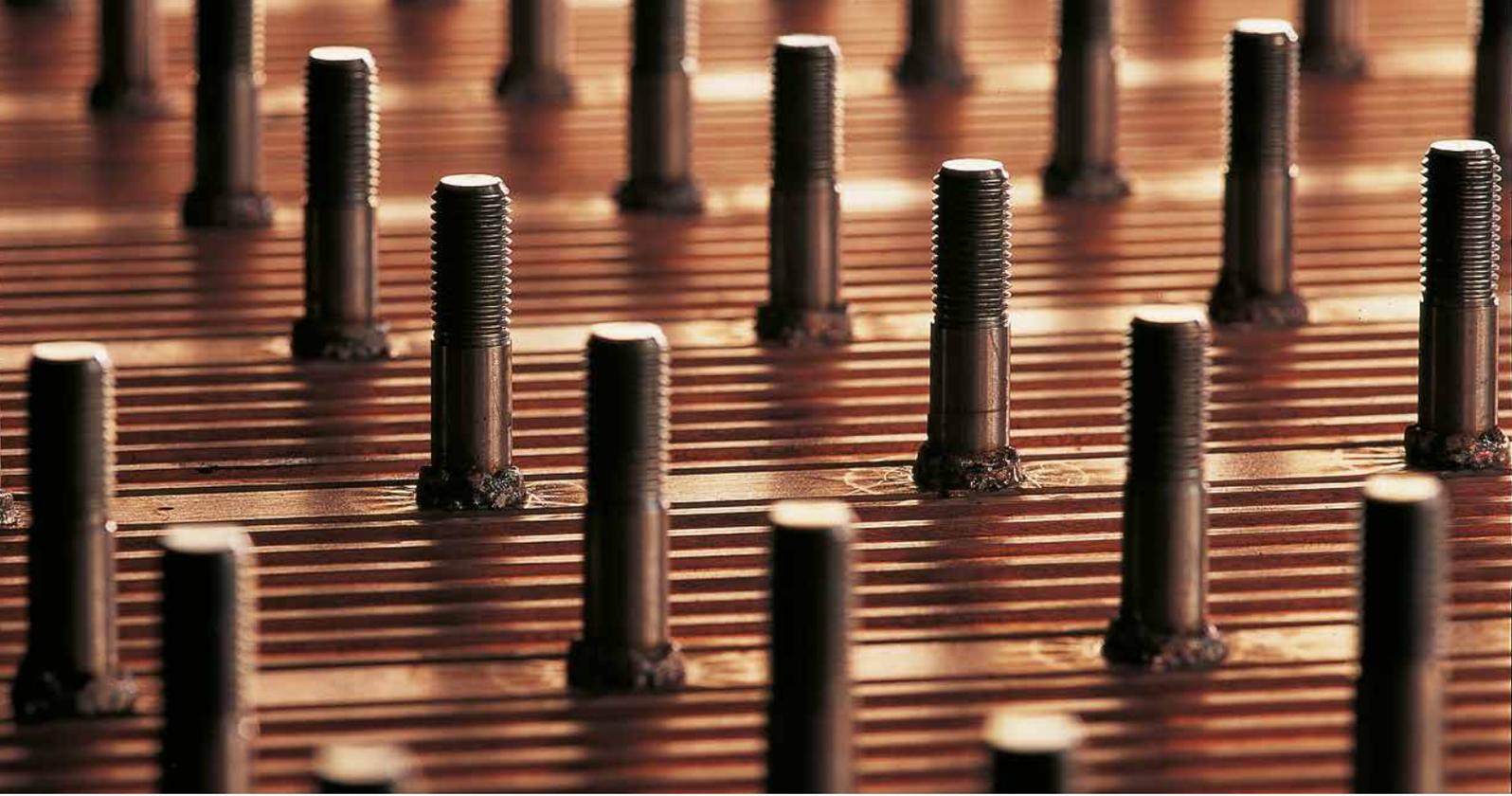
() Values may change due to restricted reproducibility of measurement

¹⁾ Hardness HBW: 2.5 /187.5 for ELBRODUR® B95, ELBRODUR® B95S and ELBRODUR® NIB

Research and Development

The goal of our work is to constantly improve our products for the benefit of our customers. To this end, KME is continually working on new materials and materials processing techniques. For the development of moulds, we can use the core expertise and knowledge of the entire group. The R&D departments of the group have been set up in such a way that they can deal with the complete range of assignments, from developing new mould materials right through to supporting the application of the new products.





The development of new materials involves testing new compounds as well as further developing known ones. The R&D department for material development solves both tasks. Here, mould materials used throughout the world today were developed at the beginning of the 1960s – such as ELBRODUR® G/CuCrZr and others.



KME's laboratory's melting and casting facilities are capable of casting blocks weighing 3,500 kg which can be further processed at the production facilities. This means that optimal production parameters can be determined in advance. A rolling mill and a press, together with annealing and salt-bath furnaces, are used for thermo-mechanical treatments within the department.



The development of materials is supported by the full range of chemical analysis (S-OES, XRS, ICP, GF-AAS, etc.), including metallography, and by SEM/TEM electron microscopes, including EDX/WDX analysis systems. In the area of coatings, a galvanic laboratory was set up to facilitate their development. The technological laboratories for physics and mechanics are equipped with all of the necessary devices for testing and measuring. This includes tests on creep, relaxation, softening, fatigue resistance, etc.



Destructive tests provide additional data, making it possible to investigate customer-specific information on particular stresses such as thermal/chemical problems in the meniscus area with softening and brass formation, deformation due to insufficient cooling, wear in the bottom/edge area, etc.



Today, basic laboratory research is supplemented by development work for the customer, focussing on improved productivity together with high reliability and service life in specific industrial applications. Thus, the primary goal of all development activities carried out by KME is to provide technical support to customers on how to optimise their facilities, processes and products.



Advanced Mould Manufacturing

Another major element of integrated mould technology is KME's comprehensive production knowledge. Starting with material development, through the entire process chain from melting to coating and all the way up to final quality control, KME uses its vast experience to supply superior manufactured mould products.



Melting and casting

In KME's melting and casting facilities, copper and copper alloys are produced on state-of-the-art systems. High purity cathodic copper is mainly used for producing the mould materials and the composition of the melt is monitored by an appropriate analysis system. Billets and slabs can be cast on different casting machines in different geometries so that the dimensions of the starting material offer favourable conditions for the downstream production stages, for example, if sufficient degrees of formability have to be ensured for subsequent forging operations.

Forming

Close coordination between the casting process and the subsequent forming process is crucial to ensure optimal material properties in the production of moulds.

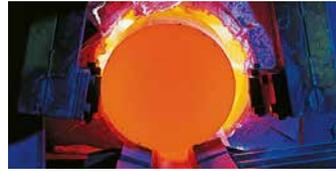
KME has both hot and cold rolling mills for forming the materials. In addition, we have systems for extruding, forging and annular rolling as well as for the heat treatment of our mould materials.

Special procedures and process sequences developed by KME make it possible for us to produce complex geometries and dimensions, while maintaining the highest levels of quality.

Machining

Modern, precise CNC machine tools are available for final machining of the moulds. Construction data for producing the desired workpiece geometry are transmitted via integrated CAD/CAM systems. This makes it possible for KME to produce complex workpiece surfaces – like those found in the funnel area of mould plates for thin slab casting or on beam blank liners – together with extremely tight tolerances.

In addition to its comprehensive expertise in milling and drilling copper, KME can boast many years of experience in the field of deep-hole drilling. This technique makes it possible to ensure optimum cooling conditions, even for complex geometries. Our production facilities are also set up for the finishing of tough and hard anti-wear coatings.



Research & Development

Engineering

Melting

Casting



Hot extrusion

Drawing

Cold forming

Machining

Plating

Quality control

Final product – Tube –

Hot rolling

Cold rolling

Machining

Plating

Quality control

Final product – Plate –



KME

Osnabrück Germany

Dept. Engineered Products

Quality Assurance

The use of high-quality products is absolutely imperative for the safe operation of continuous casting facilities. In order to ensure this, KME has all production and business processes certified to DIN ISO 9001.

This total in-house capability gives KME the start-to-finish control needed to pursue its business philosophy on all levels involved and through all stages of production.



Copper material performance requirements

Mould function, type of exposure	Properties required
Handling; assembly/ disassembly	High basic hardness and strength
Transfer of superheat and heat loss of solidification	High thermal conductivity
High wall temperatures	Retention of high strength at the relevant operating temperatures
Mechanical stresses at high temperatures	High resistance to creep
Heavily fluctuating thermal stresses (fluctuating meniscus level)	High resistance to fatigue and cracking
Strand/mould friction	High hardness and resistance to wear
Screening in electromagnetic stirring systems	Reduced electrical conductivity

Service for Maintenance and Recoating

Mould assemblies

From the smallest size billet mould to remotely adjustable slab moulds – KME builds and assembles all types of casting moulds complete with their complex drive and control systems.

Here, too, the uncompromising quality standards of KME are ensured through in-process quality control at all stages of a project, no matter whether it is an one-off job or the manufacture and assembly of a whole series of moulds. These services for maintenance and recoating are for customers requirements on a worldwide basis.

Repair of mould tubes

As a matter of basic principle, mould tubes are designed as expendable items. Yet, in certain cases it may be economically worthwhile for a client to have his large-section mould tubes reworked.

Repair of mould plates

KME's maintenance and repair services for mould plates include the proper remachining as well as repair of stud-welded moulds and possible recoating of the copper, plus a complete overhaul of the entire mould assembly, if needed.

In the case of a complete mould overhaul, the mould will be dismantled and all its mechanical and supporting parts will be inspected and, if necessary, renewed. Like KME's newly built moulds, the reassembled unit complete with the remachined copper – or with new copper, if necessary – will undergo a complete operational check.

KME provides the following services for customers wanting to do the remachining of mould plates in their own workshop:

- assistance with the selection/supply of appropriate machine tools;
- transfer of the necessary expertise;
- installation and startup of the machining centre;
as well as
- detailed training of the customer's operating personnel.

The whole package can, of course, be tailored to individual local requirements and a customer's existing facilities.



KME Service Stations Worldwide



KME developments on mould tubes

1960

Manufacture of the first copper mould tubes for continuous casting of steel
Size range 80-120 mm



Straight



Inside parallel uncoated

1963-1965

Development of a special manufacturing process to ensure a reproducible quality regarding

- high dimensional stability
- close tolerances



Curved



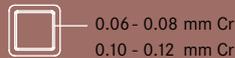
Inside tapered

- Broadened size range
- All shapes



1965/66

Development and use of Cr-plated mould tubes



From 1980

Improvement of mould tube geometry to meet high-standard market requirements

- set up individual taper
- modification of corner radii
- modification of wall thicknesses
- closer tolerances



Double/
triple taper



Parabolic
taper

1982

Supply of first mould tubes with beam blank moulds



Curved tapered Cr-plated

1986/95

Supply of world's largest mould tubes

Square
Round



Size
360 x 320 mm



ø 600 mm

1994/95

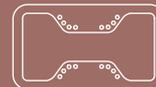
Supply of mould tubes with special geometries for high speed billet casting

- CCT®-Mould
- AMT®-Mould
- DIAMOLD®



1998/2001/2002

Gun-drilled beam blank moulds



2001

Development of improved chrome coating



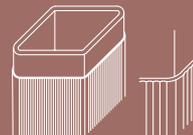
2006

Development of homogenous cooling mould tubes



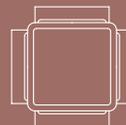
2008

Development of the AHE Advanced High Efficiency Mould Tube



2009

Development of the ATM Advanced Tube Mould



2010

Development of the Textured Mould Tube



KME developments on mould plates

1964

Start of manufacture and reconditioning of complete non-adjustable slab moulds



Size 200 x 1700 mm

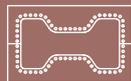
1966/70

Development and use of the special alloys of CuAg and ELBRODUR® G

Extreme dimensional stability i.e. resistance to deformations through
 – high thermal conductivity
 – excellent high temperature strength
 – high creep resistance

1968

Supply of the first beam blank moulds
 2-piece design



Size 560 x 265/100 mm

1969/70

Supply of adjustable slab moulds



Various sizes

1975

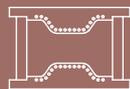
Continued development of electro-deposited nickel coatings



CrNi Ni Ni Ni Ni+Cr

1986

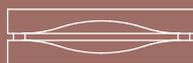
Supply of the first beam blank moulds, 4-piece design



Size 685 x 225/50 mm

1988

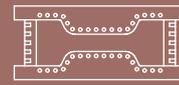
Supply of the first thin slab moulds



40 - 50 mm thickness
 x 900 - 1100 mm

1990

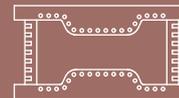
Supply of wide flange beam blank moulds
 4-piece design



Size 500 x 410/123 mm

1994

Supply of wide flange beam blank moulds
 4-piece design



Size 1120 x 500/130 mm

1998

Gun-drilled funnel mould with optimised cooling design by KME



2003

Development of the KME AFM® mould



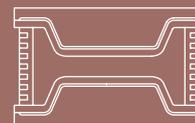
2006

AFM® mould running in industrial-scale production



2007

Development of the KME ABBM beam blank mould



2009

Development of the ASM Advanced Slab Mould



2012/2013

Development and use of the special alloy ELBRODUR® GD-NS

ELBRODUR® GP-NS
 – fatigue behavior
 – creep strength

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